Carbide fire in an acetylene gas plant – a case study

Gargi Bhattacharjee[1,2], Gopal Bera[3], Sudip Kumar Das[1], and Biswajit Singha[4*]
[1]*Department of Chemical Engineering, University of Calcutta, 92, A.P.C. Road, Kolkata-700009*
[2]*Department of Human Development, Prasanta Chandra Mahalanobis Mahavidyalaya, 111/3, B.T. Road, Kolkata -700108*
[3]*Geochemical and Environmental Research Group, Texas A&M University, 833 Graham Road, College Station, Texas 77845, USA and*
[4]*Department of Chemistry, Camellia Institute of Technology Madhyamgram, Kolkata-700129*

This study deals with an incidence of small fire breaks in an industrial gas plant, manufacturing acetylene gas. It also explains the probable causes, preventive and corrective measures. What – if analysis and Cause – consequence analysis were used to identify the possible errors and the unsafe activities. Emergency procedures are also discussed. Finally some useful recommendations are listed which has been drawn for industrial facilities storing calcium carbide which is the raw material for acetylene production and preparing acetylene.

I. INTRODUCTION

Calcium carbide primarily is an inert substance at dry atmosphere. But at wet atmosphere it reacts slowly with moisture to form acetylene, a highly inflammable gas and lime as per the reaction cited below, an exothermic reaction in nature, energy liberates about 1795.7 kJ/kg.

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2 \qquad (1)$$

The rate of reaction is quite high in presence of water. Acetylene is a well known fuel gas used almost universally in gas welding. Acetylene is flammable and the National Electric Code (IS – 2148: 2004) has a special designation for using electrical equipment in the acetylene users area. The mixture of air and acetylene is an explosive with explosive limit 2.5 – 82% by volume. Acetylene is approximately 10% heavier than air at 15^o C.

The generation of acetylene from carbide is basically a simple process, but it was hazardous owing to high heat of reaction and explosiveness of acetylene in air. The conditions of Flammability (LEL %) 2.2 and (UEL %) 80 to 85 and the auto ignition temperature is 296^oC. Pure acetylene can ignite by decomposition above 207kPa; therefore, the UEL is 100% if the ignition source is of sufficient intensity. A minor heat source like spark is good enough for catch fire and may cause an explosion from the bad to worse condition. Acetylene is chemically unstable and can decompose and release a large amount of energy, even in the absence of air or oxygen, if the cylinder is heated, struck or dropped. So it is imperative to follow the appropriate procedures for handling acetylene cylinder. Every day thousands of acetylene gas cylinders are used in the workplace. However, if the gas cylinders are not properly handled, the situation involved in a fire or explosion and makes the condition worse.

The accident of the acetylene user are very common particularly acetylene cylinder incidents. From 1^{st} January 2004 to 31^{st} December 2008 London Fire Brigade Headquarters reported 471 cylinder incidents of which 91 involved acetylene cylinders (http://www.bcga.co.ukpreviewpdfs dated 09.03.2012). These accidents were due to either vibration of the cylinder or leakage from the cylinder. The leak from the acetylene cylinder may accumulate the gas prior to fire and explosion. The gas then mixed with ambient air within the room, forming a dangerous concentration of an ignitable mixture and results a high intensity fire (Koshy, 1999).

In general acetylene is not a serious toxic hazard, but it is a serious fire hazard and also an explosion hazard. Inhalation of acetylene is the only route of exposure. The exposure occur in the workplace where it is produced or used in wide range of industrial activities like chemical synthesis, welding etc. [NIOSH, 1976]. The toxic effect of acetylene exposure is asphyxiation as it displaces oxygen from air and causes in hypoxia. Exposure symptoms are dizziness, headache, fatigue, tachycardia, tachypnoea, nausea and vomiting. In severe cases convulsion, loss of consciousness and even death may occur (Williams and Whittington, 2001). Industrial acetylene often associated with toxic impurities like ammonia, arsine, hydrogen sulphide and phosphine and injury or deaths have been reported on exposure of industrial acetylene (NIOSH, 1976, Williams and Whittington, 2001).

The important task is to identify the real causes to minimize the incident. This study deals with a carbide fire incident in an acetylene manufacturing plant, its causes, preventive and corrective measures, emergency preparedness and useful recommendations which has been useful for the plant personnel.

II. EVENT LEADING TO THE OCCURRENCE

The incident took place in an industrial gas plant in West Bengal, India in one night of March 1993. The shift officer was on routine visit in the plant at around 11pm. It was a summer night and there was heavy downpour around for two hours from 8 to 10 pm. There was water logging in the factory roads due to rains. The shift offi-

*e-mail : singhabiswajit@gmail.com

cer was on round by company car after the rain stopped. While passing beside the calcium carbide godown, heavy smoke was seen issuing from the entrance of the main godown. The officer then stopped the car on road and observed that smoke was issuing from a carbide drum. The drum was kept on floor outside the godown beside the covered walkway approaching acetylene gas generator room. No flame was found to come out of the drum. The drum lid was in open condition. The fire was extinguished by fire extinguisher immediately. There was no loss of life and no loss of property.

III. PROCESS OF FIRE IN THE PLANT

Water ingress to the carbide drum occurred during rain. Thus a typical carbide fire occurred as soon as carbide came in contact with water followed by formation of acetylene gas as result of temperature raised to the flash point of acetylene and there was auto ignition of acetylene.

IV. PROBABLE CAUSES OF THE INCIDENT

1. Carbide drum with dust and lump was kept for long time for necessary disposal, 2. Carbide dust was partially exposed to atmospheric air, 3. There was water ingress into exposed drum, 4. Formation of acetylene in the drum, 5. Auto ignition of acetylene inside the drum due to rise of temperature in drum, 6. Safe procedure was not followed for disposal of carbide dust and lump, 7. Strict supervision was lacking.

V. TYPES OF FIRE GENERALLY OCCUR IN ACETYLENE PLANT

There are primarily three types of fire that generally occur in an acetylene plant. They are as follows,

A. Chemical fire

Acetylene is a colourless and pungent gas, fire occurs for its flammable nature and high explosive limit in presence of air and oxygen in gas phase. Acetylene fire can occur at the following places during acetylene generation, i. Acetylene generator, ii. Acetylene gas holder, iii. Acetylene purifier, iv. Acetylene compressor, v. Acetylene cylinder filling manifold, vi. Acetylene cylinder yard. In all the above cases DCP (dry chemical powder) fire extinguisher and water are abundantly used as fire extinguisher.

B. Acetone fire

Acetone is used in the acetylene cylinder where acetone initially absorbed by carbon (spongitype) particle and the filled acetylene in to the cylinder. One volume acetone can absorb 25 volume of acetylene. This measure is taken for safety reason. Acetone is a colourless volatile organic liquid. Acetone fire occurs for its flammable nature in presence of air and oxygen. Acetone fire can occur at the following places in a plant. i. Acetone storage area, ii. Empty acetylene cylinder. In both the cases fire is extinguished by foam (mechanical) fire extinguisher.

C. Calcium carbide fire

Calcium carbide is a solid material. Dry carbide is extremely inert, but carbide with moisture or water produce acetylene to cause carbide fire. This can happen at the following place in an acetylene producing unit- i. Calcium carbide godown, ii. Carbide charging device (skip hoist), iii. Acetylene generator hopper, iv. Acetylene generator water overflow line, v. Lime sludge pit. Carbide fire can only be extinguished by DCP (Dry Chemical Powder) only. Water should never be used for carbide fire since water with carbide produces acetylene that will augment the fire hazard to continue only.

D. Oil fire

Lubricating oil used in acetylene compressor. This is only occurring in acetylene compressor. The oil fire is always extinguished by foam (mechanical) fire extinguisher.

E. Electrical fire

This can happen at the following places in the acetylene plant, i. Carbide warehouse, ii. Electrical installations, e.g., compressor/pump motors, electrical panel, skip hoist motors, sludge water handling pump motor etc. Electrical fire always extinguished by carbon-di-oxide fire extinguisher, sand and also by DCP. Water is certainly not used for extinguishing electrical fire. The basic precaution for electrical hazard is to install flame proof electrical installations (IS 2148: 2004).

VI. ERRORS AND THE ACCIDENT ANALYSIS

The human error, unsafe act committed by the system operator which led to the accident. This unsafe act either involve doing something wrong or failing to do something. The maintenance failure is also a major cause of human errors. Table 1 shows what-if analysis and Fig.1

Sl. No.	What- if questions	Answer	Likely hood	Consequences	Recommendations
1.	If calcium carbide drums are in contact with moisture?	Acetylene formations occur.	Possible	Serious	Use local exhaust ventilation or workers should worn respirators and personal protective equipment (P.P.E.).
2.	If acetylene gas mix with air?	Explosions occur.	Possible	Serious	Establish an emergency response plan for responding in accidental situation.
3.	If workers are illiterate or if operating procedures is not properly follow?	Accidents may occur.	Possible	Serious	General chemical and hazardous information should be displayed to the workers and train them for proper handling calcium carbide.
4.	If the calcium carbide rules, 1987 are not properly maintain?	Typical carbide fires occur.	Possible	Serious	Follow the Calcium carbide Rules, 1987.
5.	If acetylene gas spread off-site?	Severely irritate and burn the eyes, skin, mouth, throat and shortness of breath.	Possible	Serious	On skin contact immediately wash or shower to remove the chemical, use P.P.E and goggles.
6.	If acetylene fire break down?	Explosion occur.	Possible	Serious	Establish an emergency response plan for responding in accidental situation and use explosion proof electrical equipment and fittings.

TABLE I: What-if analysis.

shows cause consequence analysis which reveals that the accident occurred due to maintenance and operating error. The management of the gas plant does not maintain the maintenance procedure of the carbide storage and the plant operators had insufficient knowledge as, i. The carbide drum which was necessary for disposal was kept for long time outside the godown on floor beside the walkway approaching acetylene gas generator room. ii. The lid of the drum was also in open condition. iii. The maintenance of the roof of walkway was very poor, so the water ingress to the carbide drums during rain due to spillage of rain water in the drum.

Thus the plant was running poor supervision. Although there was no loss of life and no loss of property but big incident could occur.

VII. RECOMMENDATIONS FOR CALCIUM CARBIDE STORAGE

Calcium carbide is a very water reactive chemical and it produce acetylene gas from calcium carbide and water reaction, so it should be stored in a proper way. License shall be required for storage of carbide and the following conditions must be followed, i. It shall be stored in a dry and well ventilated storage shed, which may form a part of or attached to a building provided that it is separated. ii. It shall be kept securely closed except while

taking out carbide. iii. Observance of safety distance from the licensed storage shed necessary. iv. Not more than 1000 metric tonnes of carbide shall be stored in any one building, provided that not more than 250 metric tonnes of carbide is stored in any one room or other part of the building. v. A carbide storage shed may also form a part of, or attached to an acetylene plant provided that it is separated from other portions of the plant by substantial partition. vi. Every building storing carbide shall be surrounded by a wall or fence of at least 1.8 meters high to prevent unauthorized persons having access to the shed and are enclosed by such wall or fence shall cover the safety zone required to be kept clear. vii. Construction of storage premises - Every premises for storage of carbide shall be constructed of non-flammable material with cemented floor raised at least 30 centimeters from the surrounding ground level and be well ventilated. (Calcium Carbide Rules, 1987, Chapter V-storage of carbide (http://explosives.nic.in/pdf/calcium-gazette.PDF dated 03.01.09).

VIII. LESSONS LEARNT

1. Calcium carbide dust, sweeping, calcium carbide lump etc. should be disposed as soon as possible, 2. Carbide dust, lump etc. be stored at dry place before disposal, 3. Care must be taken for supervision of carbide handling and storage, 4. Refresher training programme to be in place in close frequency for all concerned, 5. Encourage good performance in maintenance work, 6. Good communications in maintenance team, working conditions (enough light, not very hot or not very cold, well ventilated clean storage area) are maintained by the management.

IX. CORRECTIVE ACTION

1. Training was conducted for all concerned responsible for acetylene plant operation, in regular interval of time, 2. Intense care was taken for carbide dust and lump disposal in the regular frequency, 3. Storing carbide outside carbide godown was bad practice, 4. Management should strictly follow the Calcium Carbide Rules, 1987, Chapter V for storage.

X. DISASTER MANAGEMENT

All the fire in acetylene plant hazards can lead to disaster within a short while in acetylene plant due to inflammable nature of acetylene. The acetylene plant must have a disaster management plan to meet emergency situation. A very short resume of disaster management plan is cited here. The salient features of the plan are as usual the following basic steps of a standard hazard management plan. They are as under, 1. Hazard identification, Safety audit, etc. 2. Hazard analysis / evaluation, HAZOP study etc. 3. Mitigation of hazard 4. On site / off site emergency plan 5. Rescue and evacuation 6. Public information 7. Roles and responsibilities of managerial and worker 8. Testing the plan

XI. RECOMMENDATIONS

1. Management must take the responsibility to train their personnel to be sure that they understand the hazards while handling flammable materials and training should be carried out in regular interval, 2. Carbide must always be stored and handled at dry and moisture free condition, as per calcium carbide rules, 1987, 3. Carbide must be used in the process on FIFO (First in First Out) principle, 4. Handle carbide/dust only with spark proof shovels. Disposal of carbide dust must be done in the open with copious supply of water as soon as possible, 5. System must be in place for periodic audit of operation and safety procedure of the plant by internal and external audit team, 6. At no condition acetylene release, leakage etc. can be allowed in an acetylene producing plants. All leaks to be identified and stopped with immediate effect. No delay is permissible, 7. All maintenance jobs must be done with best care and under permit of work procedure, 8. All operating staff must use Personnel Protective Equipments (PPEs), e.g., Air stream helmet, cotton suits, fire proof hand gloves, safety shoe while charging carbide to acetylene generator and other jobs to be performed with the recommended PPEs, 9. The alarm system should be provided in different work area to operate the plant safety, 10. All do's & don'ts must be displayed at the entrance and also important areas of the plant, 11. An emergency disaster management plan should be formulated the HAZOP study should be conducted to detect the human failure, if any, 12. The management is to manage available tools/equipment, reduce interruptions and distractions, housekeeping and tool control, manage fatigue-work schedules, manage boredom- by task assignment, appropriate rules procedures, reduce action slips, reduce memory lapses, improves task completion, improve attention and memory, reduces complacency and overconfidence, reduce risky decision making.

XII. CONCLUSION

The analysis of the incident has been carried out with respect to human errors (maintenance error). The "What-if analysis" questions were framed according to the working procedure, location, safeguards and "Cause-consequence analysis" was framed according to human error, maintenance error and inadequate atmosphere in the plant. Such methodical analysis helps to identify conditions that can lead to an accident or near miss situations. The carbide drum was for disposal kept for long time outside the godown on the floor beside the walkway

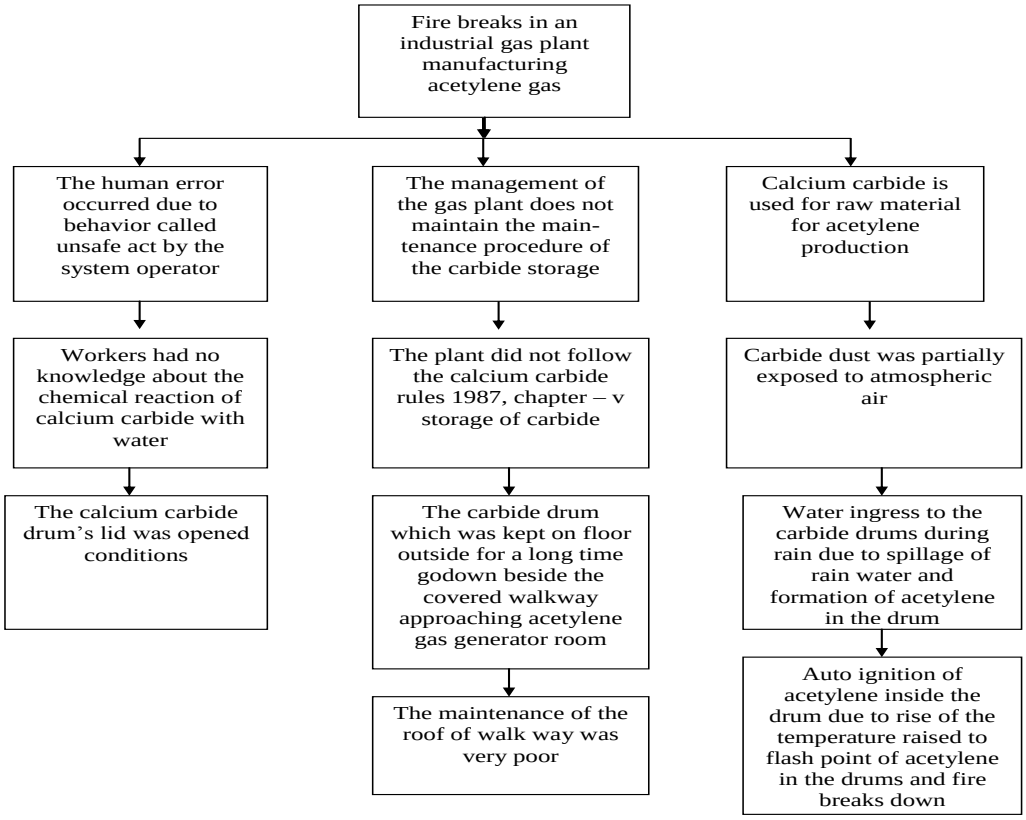

FIG. 1: Cause - consequence analysis.

approaching acetylene gas generator room; there was water ingress in to the drum during rain due to spillage of rain water from roof of walkway. Then a typical carbide fire occurred which came in contact with rain. The management of the gas plant does not maintain the maintenance procedure of the carbide storage according to Calcium Carbide Rules, 1987. The management should understand how to run the plant more safely and follow the suggested corrective actions and recommendations.

[1] http://www.bcga.co.ukpreviewpdfs dated (09.03.2012).
[2] Koshy, A., Incident in a gas storage room aboard a ship a case study, Proceedings of First International Seminar, SAFE99, on Safety & Fire Engineering, Cochin, India, November 24-26, (1999).
[3] National Institute for Occupational Safety and Health, Criteria for a Recommended Standard, Occupational Exposure to Acetylene Washington, DC: U.S. Department of Health, Education and Welfare; Public Health Service; Center for Disease Control (1976).
[4] Williams, N. R. and Whittington, R. M., Death due to inhalation of industrial acetylene, Journal Toxicology - Clinical Toxicology, 39, 69-71, (2001).
[5] IS 2148: 2004 Electrical apparatus for Explosive Gas Atmosphere Flameproof Enclosures d (Third Revision).
[6] http://explosives.nic.in/pdf/calcium-gazette.PDFdated (03-01-2009).

The American Journal of Physical Sciences and Applications (AJPSA)

US: ISSN 2644-0792

Welcome To AJPSA

The American Journal of Physical Sciences and Applications (AJPSA) (US: ISSN 2644-0792) is an international open access, peer-reviewed, biannually Journal published by Society for Makers, Artist, Researchers and Technologists (SMART). It publishes high quality research works in a wide range of fields, not published previously in Journals. The multi-disciplinary research journal includes topic like theoretical and experimental science, engineering, technology, etc. The prime aim of the Journal is to promote research by disseminating original results in the form of full length articles, short communications and review articles.