Scientists for People

Critique of Final Enquiry Report

on

Fire and Explosion at VNAI, Chandrapadia

All management systems and all safety techniques are useless unless the people using them have knowledge, experience and ability.

Trevor Kletz, "By Accident… A Life Preventing Them In Industry"

Recent toxic gas release tragedy (11 May 2021) killing four employees at Venkata Narayana Active Ingredients Pvt Ltd (VNAI), Chandrapadia, SPSR Nellore district brought media focus on the safety at their plant. Last July 29, 2020 early hours witnessed a fire and explosion at the same plant killing three persons and permanently disabling one. District Collector formed a committee of state officials to inquire into these accidents. Having studied a few Joint Committee reports into recent spate of accidents in AP killing several workers and public, we are aware of the poor quality of such reports. These reports were accessible due to the order of NGT to display them on the websites of CPCB and APPCB. Otherwise accident investigation reports are not made public.

We offered to help the committee in the investigation of gas release in a letter to district collector, but there was no response. NGT, New Delhi took up a suo motu case on this incident and included it in OA No 144/2020 before it and appointed a joint committee to investigate and report to it. We learnt that the committee submitted its report to the Collector but it is not made public as is the practice. Nowhere in the world are accident investigation reports kept secret. We regularly access and read reports of Chemical Safety Board, USA.

We received a copy each of the preliminary and final enquiry reports of the July 2020 explosion accident from an anonymous sender. It is bare report without any annexures mentioned in it. We have read and discussed that report and felt it necessary to critique it as the report was an attempt to explain away the accident within the knowledge constraints of the committee members. There is no trace of having done any serious study and asking right questions. No pictures of the accident scene are included in the report.

At the time of the explosion the process in progress was a physical operation to dissolve AIPAU in methanol at ambient temperature in preparation for recrystallization of AIPAU. No chemical reactions are involved.

There were three possibilities for fire and explosion at VNAI on that day
1. Methanol explosion
2. AIPAU dust explosion and
3. Hybrid explosion.

We confine our critique to the main conclusion of the report on the cause of the fire and explosion and then give our understanding of what could have happened.

1. Methanol Explosion:

We quote here the premises considered for the cause of fire and explosion from the final and preliminary enquiry reports.

".. at about 02:10 AM (early hours of 29-07-2020), **static electricity was generated and developed spark and hence caught fire with the methanol vapors accumulated in that room and caused the fire accident resulting which the walls of the room got damaged and all the four workers working in that room sustained severe burn injuries.**" [Preliminary Report]

"It is learnt during the course of preliminary enquiry that at about 2:10 AM on 29.07.2020, **methanol vapours accumulated in the clean room -2 caught fire**, **presumed to be due to static electricity generation in the SSR/120 Reactor** and developed spark while charging the chemical powder of ALLYL ISO PROPYL ACETYL UREA (AIPAU) into the reaction vessel through its manhole" [Final Report, Pages 1 & 2]

"Since the management adopted the procedure for charging of chemical powder into the Reactor through its manhole, it had given a **scope to escape large quantity of methanol vapours and powder dust into clean room**, which were generated inside the vessel during the process and thus caused to accumulate and form vapour & dust cloud in the room, which is an un-safe practice" [Final Report, Page 9]

Committee assumed that large quantities of methanol vapour and AIPAU dust accumulated in the clean room due to practice of charging methanol and AIPAU followed. All the operations of charging methanol and AIPAU before the accident were at room temperature. The vapour pressure of methanol at 30 C is about 20 mm Hg. As AIPAU is dissolved in methanol there would be depression in vapour pressure of methanol solution. At such low vapour pressure methanol vapours accumulating in the clean room is not probable. Heat of vapourization of methanol at 25 C is 279 kCal/kg.

For significant quantity of methanol vapours to accumulate in the room what is the source of heat?

There is no evidence for the accumulation of methanol vapours in the room. Lower explosive limit for methanol is 6.0% by volume or 78527.61 mg/m^3 in air. Methanol in air is irritating at a concentration of 22875 mg/m^3. [Ruth (1986)] Short Term exposure limit for methanol is only 250 ppm. If there was indeed such high level of

methanol in the air in the clean room, the workers in the room could not have tolerated the irritation odour of methanol. Accumulation of methanol vapours in the room is merely an assumption not borne out by factual data. Also there is no data available or observations made in the plant on the heat of solution of AIPAU in methanol to check the possibility of methanol temperature increase. Past operating data of this physical dissolution process is not checked before making the assumption of methanol vapour generation and spread. Assumption of methanol vapour accumulation in the clean room is not realistic or credible.

The thrust of the committee was to show that methanol vapours were released from the reactor and caught fire due to static electricity discharge. Report was framed around this conclusion. Minimum Ignition Energy required for methanol is 0.14 mJ.

Methanol Safe Handling Manual 5th Edition considers that methanol storage is not expected to accumulate static charge enough to cause ignition.

"Grounding is especially important in protecting methanol from accidental ignition resulting from static discharge. Methanol is an electrically conductive, polar compound. In general, methanol storage is not expected to accumulate static charge." [Page 46}

"Hoses must be grounded. In methanol loading and unloading situations, the possibility of spark generation due to accumulation of static electricity is less than with materials such as low sulfur diesel. Methanol is not a static accumulator. Electrical conductivity of methanol is relatively high when compared to that of most fuel materials." [Page 47]

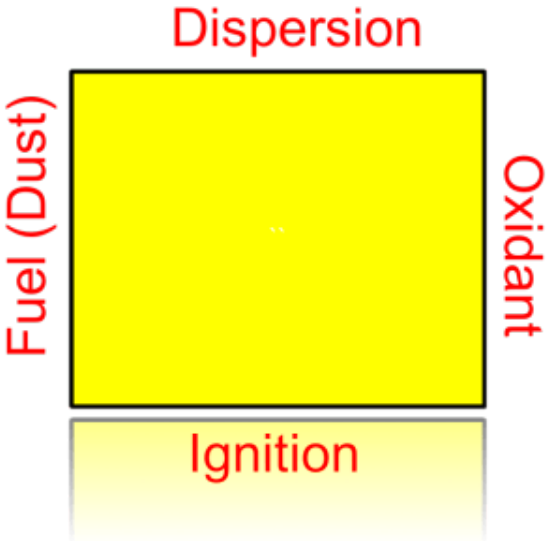
"Methanol is not a static accumulator. This is recognized by the American Petroleum Institute (API) in recommended Practice 2003 (API-RP-2003) Protection Against Ignitions Arising out of Static, Lightning and Stray Currents which states in part that in most situations when water-soluble liquids (such as alcohols) are handled in grounded conductive equipment they "do not accumulate electrostatic charges because of their relatively high electrical conductivity (greater than 50 picosiemens per meter)". API-RP-2003 also states that the necessary precautions for prevent build-up of static charge "do not apply to the loading of water-soluble products such as alcohols. These materials do not accumulate hazardous static charge." The APRP-2003 stipulates that the accumulation of electric charge is likely if the electrical conductivity of the liquid is below 50 picosiemens per meter. However, the electrical conductivity of methanol is considerably greater than 50 picosiemens per meter. A value for pure methanol has been reported as 150,000 picosiemens per meter (Commercial Solvents Corporation). Values measured for commercial grade methanol have been in the range of 2 X 10^6 to 2 X 10^7 picosiemens per meter (Methanex Corporation). [Methanol Safe Handling Technical Bulletin, Precautions for Loading, Unloading, Transport and Storage of Methanol Page 4]

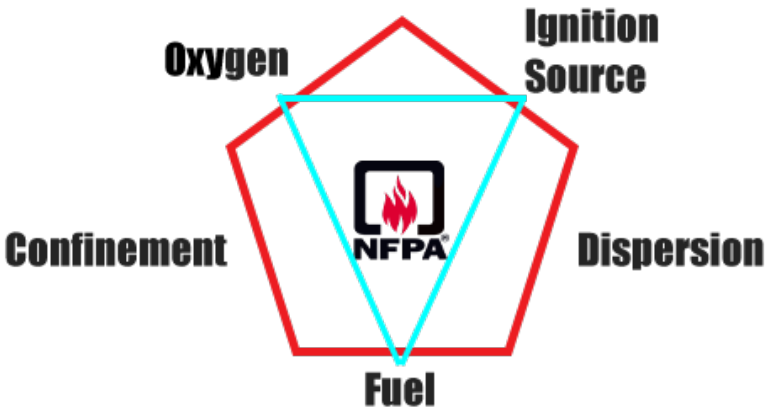
So the probability of the fire and explosion being caused by methanol vapours ignited by static discharge is unlikely.

2. AIPAU Dust Explosion:

AIPAU is a combustible material in powder form. Dust explosions are common in industry. “Among the earliest records of the cause of an industrial accident being attributed to a dust explosion was the account of an explosion in a flour warehouse in Turin, Italy in 1785.” [Worsfold et al (2012)] Dust explosions received attention as early as 1925 and a book on “Dust Explosion” was written in German by Beyersdorfer. “A CSB study released in November 2006 found 281 similar dust explosions between 1980 and 2005 that collectively killed 119 U.S. workers and injured 718.” [Johnson (2018)] Dust fires and explosions reported in USA alone in 2019 were 200. In countries outside the US over 100 such incidents were reported in that year [Angela (2021)]

Fire triangle representing fuel, oxygen and ignition source gives the necessary condition for a fire to occur. For a dust flash fire to occur dispersion of the dust is an additional fourth requirement in a fire square. If the combustible dust is dispersed in a confinement such a vessel or a room explosion can occur. For dust explosion, a fire pentagon with fuel, oxygen, igition source, dispersion and confinement are all required.





This video by National Fire Protection Association, USA explains the dust fire and explosion. https://www.youtube.com/watch?v=Za1yhKc0Xr8&t=56s

There is hardly any property data available on AIPAU. Some MSDS of this chemical do not even contain the melting point data. To obtain melting point and boiling point temperatures we had to do a great deal of searching on the Internet. We are giving that data here as it is useful. Melting point: 194°C, Boiling point: 318.19°C (rough estimate). It is noteworthy that the MSDS for AIPAU do not warn of dust hazard. "A CSB survey found that that nearly half of MSDSs for known combustible particulate materials contain no dust explosion warnings, only seven reference NFPA standards, and few contain practical information about preventing explosions." [CSB (2006)]

Committee has not examined the possibility of AIPAU dust explosion. Minimum Explosible Concentration (MEC) for a dust is the lowest concentration of a combustible dust in air, expressed in grams per cubic meter that will propagate a flame. [CCPS, AIChE]. Typical data for MEC of several materials is given here.

MEC test results table

Material	MEC
Grain dust	125 g/m^3
Coal dust	30 g/m^3
Flour	60 g/m^3
Sugar	125 g/m^3
Aluminium dust	100 g/m^3
Sewage sludge	250 gm/m^3

Source:
https://www.explosiontesting.co.uk/lel_and_mec_14.html#:~:text=The%20lower%20explosible%20limit%20%2D%20also,the%2020%20litre%20sphere%20apparatus
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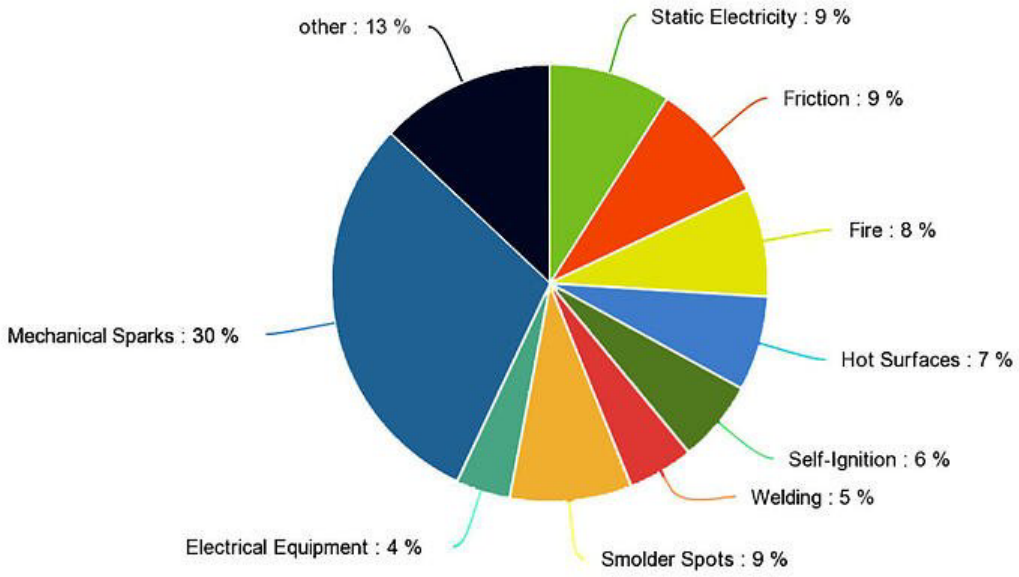
Minimum Ignition Temperature (MIT) of the dust cloud is also an important parameter. The minimum ignition temperature (MIT) is the lowest temperature of a hot surface that will cause a dust cloud, rather than a dust layer, to ignite and propagate flame. Typical data are presented below.

MIT test results table

Material	MIT
Grain dust	490^oC
Coal dust	no ignition up to 850^oC
Flour	400^oC
Sugar	480^oC
Aluminium dust	650^oC
Sewage sludge	430^oC

Source:
https://www.explosiontesting.co.uk/ignition_temp_9.html#:~:text=Minimum%20ignition%20temperature%20of%20a,to%20ignite%20and%20propagate%20flame.
Static electricity is not a major ignition source in dust explosions as the chart below indicates it as a source for just 9% of cases. Table 1-7 in Eckhoff (2003) gives static electricity as an ignition source in 8.7% of the dust explosions.



Source:
https://info.hughesenv.com/surprising-sources-industrial-dust-explosions

There is hardly any information in the literature on this material. This data could have been generated at an experimental facility such at CSIR-CBRI, Roorkee. An accident investigation should exhaust all possibilities. There is no evidence in the reports that the committee looked for related published studies and similar accident investigations done.

3. Hybrid Explosion:

We did literature search and found a number of studies dealing with pure solvent explosions, pure dust explosions and hybrid dust/vapour explosions of combustible dust wetted with flammable gas or vapour.

It is experimentally observed that with addition of a solvent to a dust mixture, ignition can occur at a lower dust concentration compared to dust alone. Addition of a solvent effectively reduces the minimum explosible concentration. [Dufaud (2009), Pilao et al (2006)] Similarly, addition of a small quantity of dust lowers the lower flammable limit of a solvent. “For example, the MEC of an antibiotic powder was found to be 500 g/m^3, but when a small amount of solvent was introduced, the dust was now able to explode at a concentration of 200 g/m^3. Additionally, the lower

explosive limit of toluene is 8%, but it can explode at a concentration of 4% with the addition of combustible dust." [Dufaud (2009)]

"Hybrid mixtures of a combustible dust and a flammable gas/vapor display a higher explosion severity and a lower minimum explosible concentration than that of the dust alone. Violent hybrid explosions may occur even if the dust and the gas/vapor are below their respective lean limit concentrations." [Worsfold et al (2012), Dufaud (2009)]

From literature we gather that

- Hybrid mixtures of dust and solvent produce explosions of higher severity over that of the dust alone.
- The MEC and MIT of dust is reduced for hybrid mixtures.
- The MIT and LEL of gases decreases for hybrid mixtures
- Violent explosions can occur for hybrid mixtures even if both the dust and gas are below their minimum explosible concentration/lower flammable limit.

All these conditions favouring an explosion possibly existed at that time of fire and explosion at VNAI. It is also widely reported that dust explosions occur as primary and secondary explosions in series. In a grain dust explosion at Corpus Christi, Texas, USA investigators listed 12 explosions happening in a matter of 2 minutes. Saunders, a federal inspector for the United States Department of Agriculture at the time of the accident in April 1981 recalling the incident 40 years later said "Every explosion got bigger… Before I could even take another breath, that 12th and biggest explosion exploded where we were at — completely destroyed the building we were in — left nothing but the concrete foundation." He also recalled being blown through the roof of a two-story building and landing on concrete and presumed dead with skull crushed but for a faint pulse.

[https://www.kristv.com/news/local-news/40-years-later-saunders-reflects-on-1981-grain-dust-explosion]

OSHA factsheet on combustible dust explosions clearly describes the possible occurrence of secondary explosions. "An initial (primary) explosion in processing equipment or in an area where fugitive dust has accumulated may dislodge more accumulated dust into the air, or damage a containment system (such as a duct, vessel, or collector). As a result, if ignited, the additional dust dispersed into the air may cause one or more secondary explosions. These can be far more destructive than a primary explosion due to the increased quantity and concentration of dispersed combustible dust. Many deaths in past incidents, as well as other damage, have been caused by secondary explosions."

We consider that while charging the 9th bag of AIPAU powder mechanical friction between the falling particles was enough to create a flash fire given the hybrid

mixture of dust and solvent vapours present in the vessel. Also the crude AIPAU itself is likely to contain a solvent like xylene from Stage IV of production. Composition of crude AIPAU is not given. With the manhole of about 450 mm in diameter open (No data available on the vessel) the primary explosion/ deflagration caused violent dispersal of AIPAU dust into the clean room through the open manhole and a more severe secondary explosion followed. As per the final enquiry report, supervisors rushing to the clean room – 2 after the explosion found "Mr. Sayyad Hafeez standing at the spot with severe burn injuries and his body covered with chemical powder."

Information filed by the company with Inspector of factories indicates Sri Hafeez died on the spot. Witness accounts say that others ran to the factory gate while burning. No one was taken to a shower as is the expected norm. We understand that there are no safety showers nearby and the employees are not aware of the safety practice of taking showers for chemical and thermal burns. The inspection order and notice issued on 08 November 2020 after inspection by the joint district committee on 08 November 2020 has no word on dust hazard.

Primary explosion likely occurred in the open vessel throwing out AIPAU dust into the room and secondary explosion (s) caused the real damage to property and life. There is no information on the presence of AIPAU or other combustible dust already present on surfaces in the clean room and in the AHU ducts. NFPA warns that a thin layer of dust above 0.8 mm thickness over 5 percent of the surface of the room can lead to explosions due to re-suspension into air from shock waves of primary explosion leading to a secondary explosion [CSB (2006)]. Investigation report has totally missed this aspect and has not gathered and presented any information related to dust in the clean room. The video on "Deadly Dust II" presents the devastation dust explosions cause.
[https://www.youtube.com/watch?v=rJWWmQrAAKU]

All available evidence points to a hybrid dust/vapour explosion and not a methanol explosion.

Conclusion:

It is unfortunate that four decades after the Bhopal disaster our process safety regulation has not improved. Major deficiency is the lack of adequate human resources to mange safety at workplace and neglect of development of skills and knowledge base in process safety and accident investigations.

Since the styrene release accident last year, we have not found any good quality investigation rooted in science on the fatal accidents that occurred at regular intervals in AP. At VNAI, two fatal accidents occurred in a span of 9 months due to complete absence of safety regulation and enforcement.

Valuable lives lost are treated as merely an expense to the company. There is no standard and genuinely compassionate method of compensating for involuntary death at work place.

Accident investigation reports are not made public in total disregard for safety ethics. All the accident investigation reports and accident data must be put on public domain as is done in developed world.

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