EXPLOSIONS IN SODA RECOVERY

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Introduction :

This article does not pretend to present anything original but is only a review of the literature available. Because of the frequent explosion of the Recovery Boiler and Dissolver, it has become necessary to collect as much data and information as is available. So far as our knowledge goes, there has not been any Recovery Boiler explosion in India, nevertheless the potential danger exists. But Dissolver explosions have occurred practically in Recovery Units, at the stage of commissioning the Recovery Units.

We experienced Dissolver explosions twice in the past five years, once during the commissioning of the Unit and second time in October, 1962. The first explosion can be partially attributed to inexperience. Of the 35 Recovery Boiler explosions reported in the North America, 17 were said to be failures of auxiliary fuel and 14 were due to mysterious smelt water reaction. (7) The explosion results in loss of life, loss of production and of great cost of rehabilitation. The rehabilitation alone is estimated to cost 35% of the original cost of the Boiler.

In view of this, it is necessary to form a Committee under the auspices of the Indian Pulp and Paper Technical Association (IPPTA) to study, collect and analyse the information regarding Dissolver explosions, Recovery Boiler explosions and suggest safety methods and precautions to be followed by the Recovery Staff of the Paper Mills.

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In this report, it is intended to review the available literature on (1) Dissolver Explosions and (2) Recovery Boiler Explosions.

Dissolver Explosions :

As regards explosion in the Soda smelt dissolving operation, some work has been carried out by John A. Sallack (4) and C. R. P. Cash (5) in the past. Various theories have been presented to explain the causes of explosion resulting due to violent reaction of molten smelt with green liquor or water. We can consider that the dissolving of smelt in green liquor always results in miniature explosions of harmless nature. There has been general agreement that the majority of explosions have occurred during periods of heavy smelt flow. Usually explosions occur during the start up or shut down of Recovery Units, when it is difficult to control the formation of initial char bed in the hearth or control the temperature of hearth zone resulting in excess formation of smelt. The smelt pools are generally caused by plugging of spout partially or completely thereby entrapping the molten smelt in the Furnace. The heavy smelt accumulation later on gets released after the removal of obstruction by changed conditions in the Furnace. The simple explanation that could be presented for explosions due to heavy smelt flow is that the molten smelt penetrates a dissolving medium to a considerable depth and suddenly shatters a large surface of very hot material, suddenly comes in contact with the dissolving medium with formation of vapours at much faster rate than it can escape. This naturally builds up enormous pressure and explosion occurs. John A. Sallack (4) after a series of tests has come to some interesting conclusions as regards causes which increase the intensity of explosions.

The explosions occur due to accumulation of combustible gases at the top of the dissolving tank which possibly are formed due to reaction of steam with carbon present in the smelt or by the reaction of metallic sodium with water. The elemental sodium might be formed due to extreme reducing conditions present in the Recovery Furnace hearth. The following reactions were given by Malcolm N. Ray (2).

Na_2S plus H_2O plus CO	— Na_2 plus H_2S plus CO_2
Na_2S plus H_2O plus C	— Na_2 plus H_2S plus CO
Na_2CO_3 plus CO	— Na_2 plus $2CO_2$
Na_2CO_3 plus C	— Na_2 plus CO_2 plus CO
Na_2SO_4 plus C	— Na_2 plus CO_2 plus SO_2
Na_2O plus C	— Na_2 plus CO
Na_2O plus CO_2	— Na_2 plus CO_2
$2NaOH$ plus C	— Na_2 plus CO plus HO_2
$2NaOH$ plus CO	— Na_2 plus CO_2 plus HO_2

But the analysis of vapours at the top of the tank failed to show the presence of combustible gases.

The usual contamination in the smelt will be carbon, sodium chloride and silica (in the Bamboo liquor).

John Sallack (4) found out (1) that no explosions were produced until the salt content was greater than by 5% by weight of smelt. The critical explosive composition appeared to be about 6% by weight of salt. The heaviest explosions were produced with smelt containing 8 to 20% salt. (2) Smelt composed of sodium carbonate and sodium hydroxide show that this mixture will explode when sodium hydroxide content is above 10% by weight. But generally sodium hydroxide content in the kraft liquor smelt do not exceed 2 %. (3) The temperature of smelt appeared to have no effect on the explosion. (4) The temperature of dissolving liquor had slight effect, frequency and intensity of explosion decreasing with increase in temperature. (5) The presence of carbon had no effect. (6) The concentration of dissolving liquor had some effect. When water was used, the number of explosions were less, possibly due to better heat dissipation.

As a practical solution, the two important steps are followed. The stream of smelt leaving the spout is shattered to small particles of smelt thus providing large surface area for the dissolution. The kinetic energy of the jet would break up the stream. In the case of liquid jet, the contact of the liquid with the molten smelt would create continuous minor explosions in mid air. Secondly, proper vents are to be provided for the dissolver to prevent any build up of vapour in the tank. A good agitation of the dissolving liquor will facilitate good distribution of heat thus preventing localisation of heat.

In our Recovery Unit here, we have a peculiar problem which increases the chances of explosion. Due to severe fouling of super-heater and screen tubes of our 85 ton (B & W Heat ton) Tomlinson Recovery Boiler, we have to stop liquor firing weekly and clean super-heater and screen tube area from outside using rods. The usual procedure is to stop liquor firing, melt down the hearth, and then start cleaning the super-heater and screen tube area. The Boiler is kept on oil firing during this period. The knocked down stuff is melted and removed by using burners at the primary air-port zone. This operation is continued for about 8 to 10 hours. The stuff deposited at the superheater and screen tubes generally contain higher Na_2SO_4 content and therefore, the resulting molten smelt is very viscous. The temperature of the hearth zone is much less than normal. It requires great care during this period, to prevent accumulation of smelt in the hearth due to partial or complete plugging of spout, or smelt passages in the hearth, by the loose stuff that is knocked down from the super-heater area. It was on one such occasion, that we experienced an explosion of dissolver (October 1962). This explosion resulted in damage of machinery and loss of production for two days.

Dissolver cover, vent pipes and spout were badly damaged. Dissolver had shifted by about 3 to 4 inches, damaging pumps and agitators. Apart from loss of production for two days, cost of rehabilitation amounted to 15,000 to 20,000 rupees. Fortunately there was no loss of life in either of these explosions.

Boiler Explosions :

The principal cause of explosions of earlier Sulfate Recovery Smelters was the use of water cooled blow pipes or tuyers. The use of unconditioned river water inside blow pipes resulted in scaling, rusting and corrosion. Leakage of water accumulated in the Furnace resulted in explosion. Fortunately, due to small size of these Units, some warning usually occurred and damage was not very serious. With the development of water walled Furnace, the frequency of explosion has reduced, nevertheless, intensity of explosion could be very serious.

Statistical data have been collected by the "BLACK LIQUOR RECOVERY BOILER ADVISORY COMMITTEE" sponsored by TAPPI (7), regarding the explosion of Recovery Boiler in the United States.

Of the 223 Units in the United States, 38 have exploded, 40% of which is attributed to auxiliary fuel failures, 40% due to the smelt water reaction. This problem and recommendations for preventing these explosions can be studied under two categories.

(1) Explosions resulting due to the failure of auxiliary fuel.

(2) Explosions due to the smelt water reaction as a result of tube failure in the Furnace hearth.

(1) Explosion resulting due to failure of auxiliary fuel :

The probable reason for this is attributed to the accumulation of inflammable gases inside the Furnace due to a breakdown of the auxiliary oil burners. A small flame is sufficient to ignite and explode this gaseous explosive mixture.

British Columbia Research Council contends that at 1000°F, the thermal cracking of oil fuel injected by extinguished burners and the decomposition of the organic material in the black liquor will produce a flammable mixture.

Recent statistics indicate that approximately half the explosions in the Recovery Furnace are caused by delayed ignitions of liquid or gaseous auxiliary fuel. It is not precisely known as yet as to how this type of explosion can be prevented.

There is no doubt that the ease of using gas or oil as an auxiliary fuel has contributed to less careful operation. There is no record of a Recovery Boiler explosion where wood was used as an auxiliary fuel.

The Furnace manufacturers have done some excellent work in developing flame-out protection for gas and oil used in Recovery Furnaces as an auxiliary fuel. Yet, these instruments cannot be relied upon completely without personal monitoring.

Recently there have been suggestions to use a solid auxiliary fuel, in place of gaseous or liquid fuels, having the following properties :

(a) The fuel must be easy to ignite and when ignited must continue to burn until consumed.

(b) The fuel must be convenient and easy to feed mechanically.

(c) The fuel must have a very low ash content.

(d) The fuel must be economical.

Petrolium coke in the form of briquettes has been suggested as a solid auxiliary fuel having all these properties.

(2) Boiler explosions due to Smelt Water Reaction :

This type of explosion is caused due to leakages of the tubes of the Furnace resulting in water coming in contact with the smelt.

A typical example of such a case is the explosion which took place at Elk Falls, Canada. Due to a small leak at a tube fin weld, water started entering the side wall of the Boiler. A few hours later there was another leak and the initial leak suddenly increased. Oil fires could not be maintained and shut down procedures were under way when there was a big blast. As a result, the front of the floor was pushed down by about three feet while the front tubes became disengaged and a ruptured oil circulating header burst into an external oil fire.

A lot of research has yet to be carried out on this mysterious smelt-water reaction. As per Mr. Donold Denham (3), the Chief Boiler Inspector of Vancouver Province. "Chemists and Engineers are not yet completely aware of what goes on within the smelt. There have been many cases wherein explosions occurred two hours after everything had been closed down. Possibly temperature and an unknown chemical action causes the smelt to explode. Possibly there is a critical point in temperature which may be the explosive point".

The recommendations made by the Standing Commitee formed under the sponsorship of British Columbia's Boiler Inspection Service to off-set a recurrence of explosion due to water-smelt reaction are (7) :

(1) Any leak in either the Furnace or Boiler Section, is reason to adopt shut down procedure.

(2) Provision of an explosion proof control room with shatter-proof glass and quick escape routes.

(3) Manually controlled alarm signal evacuate personnel.

(4) Use superheated steam in soot-blower.

(5) Establish a shut-down drill for Recovery crew and keep them alert by repetitive instructions.

(6) Provide more access doors for inspection in soot-blower areas.

(7) Give consideration to motor drive for induced draft fan.

The Black liquor Recovery Boiler Advisory Committee (7) formed a special Sub-Committee to study development of emergency shut down procedures. It has outlined practices to upgrade operating and maintenance procedures. Therefore, even in case of minor leaks, Boiler should be shut down by burning the bed. But when water enters char bed or smelt pool, the emergency procedure outlined below should be followed :

(1) Discontinue firing the auxiliary fuel.

(2) Shut down air supply immediately by tripping forced draft fan and close its damper and regulate the induced draft fan damper to about 0.2 or 0.3 inch draft in Furnace.

(3) Quench flame or bed with heavy black liquor but do not use liquor to excess.

(4) Shut off feed water supply to Boiler,

(5) Open inspection and access doors to allow air in and purge gases from upper furnace.

(6) Check furnace periodically to assume a quenched bed.

The induced draft fan should never be shut down when there is heat or possibility of gases accumulating in Furnace. An alarm should be used to clear out unnecessary personnel.

In our Recovery Unit, we were very fortunate to escape from the hazards of the explosion. Possibly due to inherent defect of the furnace design, we are facing two problems. (1) Severe fouling of superheater and screen tubes and (2) Ledge formation on the rear wall and front corners of the furnace wall. These troubles have limited the running of our unit to one month, with three intermediate cleanings. Liquor firing is stopped at the end of sixth or seventh day for a period of 12 hours. The superheater tubes and screen tubes are partially cleaned by using long rods from outside. The ledges on the furnace walls are removed by using crow bar and hammer. During this entire operation the Boiler is kept on oil firing. The knocked down ledge pieces, cleaned loose stuff from the superheater and screen tubes area, are melted on the hearth by using burners at the primary airport.

Quite often the fins from the nose baffle have been knocked down while cleaning superheater and screen tube area. In the process of removing of ledges from the furnace walls, on two occasions, the furnace wall tubes were punctured, once at the liquor spray level and on second occasion at the secondary airport level. Of course, on both occasions emergency shut down was taken; nevertheless we were very near the explosion danger. Since then great precautions have been taken in cleaning and removal of ledge.

Due to changed conditions of pulping technique in our Pulp Mill, black liquor characteristics have changed. As a result, ledge formation and fouling have considerably decreased, reducing the chances of danger.

The use of burners at the primary airport during intermediate cleaning is an undesirable practice but it is unavoidable. There is always possibility of some obstruction for the burning of fuel oil, resulting in accumulation of unburnt oil in the hearth. It is reported that there was a similar tube failure in the Nepa Mill Recovery Unit while dislodging smelt deposits. It is quite possible that other paper mills in India too have experienced similar 'near danger' occasions. The continual danger has made it imminent for both the technicians and Management of Paper Industry to come together to study this problem.

CONCLUSIONS

In view of the damage caused due to these explosions, apart from the human factors involved in it, it is necessary to form a Safety Committee under the auspices of IPPTA with the following objectives :

(1) To collect statistics regarding the explosions occurring in the different mills.

(2) To enquire into the causes of such explosions.

(3) To make a comparative study of the causes of the different explosions.

(4) To recommend safety methods and procedure for running the Units.

(5) To provide training facilities in the prevention of explosions to the Recovery personnel.

(6) To keep in touch with the other International Committees in regard to their activities in this direction.

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