Risks of bacterial hydrogen generation in white water systems

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ABSTRACT: Between 1969 and 1988, at least eight explosions occurred in paper mills under conditions of limited ventilation. Bacterial hydrogen generation is known to have been responsible for four of these explosions and is suspected in the others. Current trends to convert to alkaline process conditions and further close up white water systems are increasing the danger of exposure to this risk.

KEYWORDS: Bacteria, explosion, hydrogen, hydrogenation, paper mills, storage tanks, white water system.

Despite records of several explosions (*1-7*), the risk of hydrogen generation from bacterial activity in paper mill white water systems is still not widely recognized. Moreover, current trends to convert to alkaline process conditions and to further close up white water systems are increasing the degree of exposure to this risk.

In July 1988, bacterial hydrogen generation was responsible for an explosion of a white water storage tank which claimed the lives of two welders at an Ontario corrugating medium mill (*5*). Subsequent investigation indicated the presence of a very active population of spore-forming *Clostridium* sp. in the mill's white water. During normal mill operation, the activity of these bacteria is greatly curtailed as contact with air at numerous points provides sufficient oxygen transfer to prevent the onset of anaerobic conditions. However, under stagnant conditions, such as during a mill shutdown, the oxygen level in the white water is rapidly depleted. Laboratory and mill studies indicated hydrogen generation rates of 0.01–0.02 L per L of the mill's white water per hour. For the white water storage tank during a typical mill shutdown, this corresponds to a hydrogen generation rate approaching 180 L/min with a total production of over 100 m^3. **Figure 1** illustrates this hydrogen generation.

Initially this explosion was thought to be a unique event in the industry. However, through the catalyst of dissemination and discussion, information has been obtained on seven other explosions of apparently similar origin between 1969 and 1988. An examination of the circumstances involved in the eight explosions identified a number of recurring elements:

- All of the explosions occurred under conditions of very limited ventilation.
- Hot work was identified as the ignition source in six of the explosions.
- Linerboard or corrugating medium mills accounted for six of the eight incidents.
- Six of the explosions occurred in stock tanks or chests, and two occurred in semistagnant white water tanks.
- Half of the explosions occurred during startup operations.

Incubation of white water samples from a number of mills in our laboratory has shown this type of activity to be commonly present to varying degrees in nonacid-based papermaking operations. Samples indicating evidence of hydrogen generation have included several corrugating medium operations using various fiber sources, a recycled fiber supplied linerboard mill, a roofing felt mill, three gypsum board liner mills, and an alkaline fine papers operation. Starting pH of these samples before incubation ranged from 5.3 to 8.7. In contrast, samples from acid-based papermaking operations (pH 4.5–5.0) from fine papers, newsprint, and kraft linerboard mills showed no evidence of such activity.

Laboratory experiments further indicated that adjusting the starting pH of the white water from the Ontario corrugating medium mill involved in the 1988 explosion to 5.5 substantially reduced hydrogen generation. A further decrease to pH 5.0 eliminated the activity. **Figure 2** illustrates the effect of changes in pH on anaerobic activity. Continuing trends toward more tightly closed white water systems,

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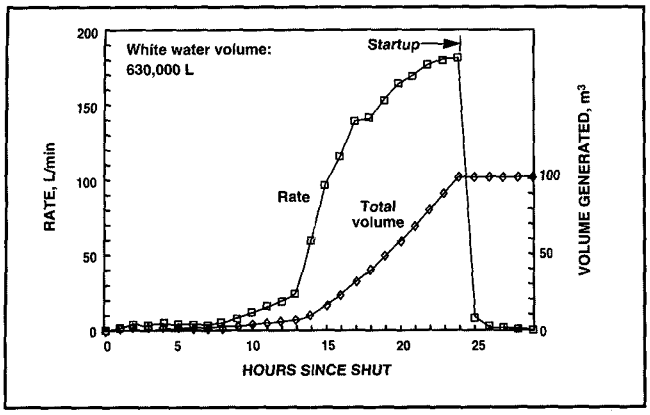
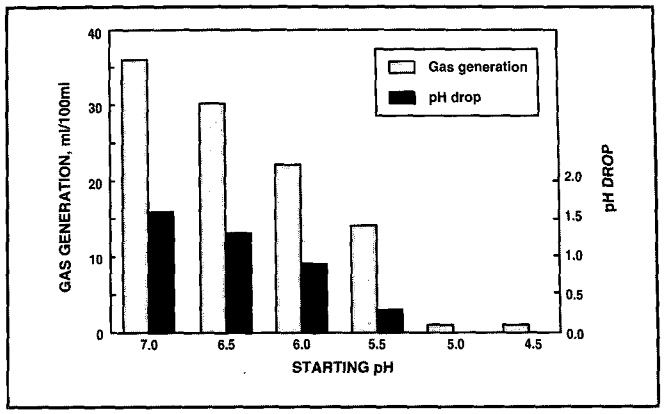
1. Hydrogen generation in white water tank during a mill shutdown



2. Effect of pH on anaerobic activity of a corrugating medium mill white water



conversion to alkaline papermaking, and the increased use of recycled fiber are all likely to increase the exposure to this type of risk in the industry.

For nonacid-based papermaking operations, the prospects for eliminating this type of bacterial activity are not encouraging. The bacteria are commonly present in the environment and have access via numerous routes to white water systems. Moreover, in their spore form, the bacteria are extremely resistant to destruction by physical or chemical means.

Reducing the risk of explosion

Although a means of effectively eliminating this type of activity in white water systems has yet to be identified, various measures can be taken to reduce the risk of explosion. Measures to promote and maintain awareness of the hazard will be essential to limiting risk. The nature of the bacterial activity, dormant under aerated conditions and not easily detected when active, make it easy to ignore. Measures to promote awareness should include instruction to staff, notification of contractors, warning signs, and combustibles monitoring.

Most explosions have been ignited by hot work. Mills should carefully review their approvals procedure for authorization of hot work. Such procedures should include testing of the headspace of any tanks or chests in the immediate vicinity, allowing for the possible travel of sparks or clouds of explosive gas mixtures. Areas for smoking should be restricted.

Two common design deficiencies in white water systems which increase the risk of hydrogen generation are stagnant or semistagnant volumes in storage vessels and inadequate ventilation of headspace. The process should be carefully examined to determine where such conditions require modification. As a further step, specifications for future modifications or additions should be included in the mill's engineering design criteria.

Operating procedures should include specific measures to limit exposure to elevated levels of hydrogen. Startup of stock chests represents a particular hazard if hydrogen has accumulated in the fiber mass. Of the eight reported explosions, four appear to have occurred as a result of release of hydrogen under such circumstances. Startup procedures should require verification that agitators are in operation and that the ventilation system is functioning. Shutdown procedures could include reduction of pulp inventory and verification of operation of agitators and ventilation systems. Abnormal conditions such as power outage or mechanical failure of agitators should also be considered in preparation of operating procedures.

For nonacid-based papermaking operations, efforts to sustain awareness and implement control measures should be given priority to minimize the risk of exposure to explosive levels of hydrogen.

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