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The Explosion Hazard From Hydrogen Gas Generation Inside Sealed Frames

Background

The National Institute for Occupational Safety and Health (NIOSH) recently investigated ignition incidents resulting from drilling holes into sealed and filled plow frame sections. A farmer and farm worker were seriously burned in two separate incidents that occurred in the same county in New York under similar conditions. They had just penetrated sealed sections of their plow frames with electric drills when a roar of escaping gas at high pressure was heard, and the victims were thrown back by the gas jet and engulfed in flames. The flames were quickly extinguished, but the victims suffered burns. NIOSH experts were asked to help find the cause of these hazardous incidents.

Approach

Inspection of the frame sections involved in the incidents showed no discoloration, charring, or blistering of paint in the immediate vicinity of the holes. Probing the holes with a magnetized blade revealed a hard interior fill material and the presence of some metal punchings. This fill material was more extensively sampled from another section that had been cut through (figure 1). This revealed a wide range of metal punchings that was used as ballast in these steel frame sections, which had been welded shut after the filling operation. The punchings were found to consist of various forms of steel (carbon, galvanized, and stainless) and other metals, including titanium. Sealing the holes and sampling the gases present revealed the depletion of oxygen from the original air atmosphere and the presence of hydrogen. The hydrogen concentration was found to increase with time under sealed conditions. The pressure in the resealed sections also increased with time at a steady rate. A safe method of drilling into an intact sealed section was found and was used to determine the gas pressure and composition in this section. This gas was nearly pure hydrogen at an absolute pressure of 185 psi, or over 12 times atmospheric pressure.

Results

The mechanism for the generation of hydrogen has not been definitively proven; however, all available evidence points to an electrochemical reaction involving metals of substantially different activity and electrical potential in the presence of water and oxygen. The oxygen helps provide the relatively high voltage needed to decompose water to hydrogen and hydroxide ion in conjunction with an active metal such as zinc (the coating in galvanized steel) or possibly aluminum. The origin of the water is believed to be an oil/water emulsion that is used as a cutting fluid in machine shops. Only a few tenths of a percent of water in the steel scrap can account for the hydrogen pressures that have been found in frame sections. To date, only metal-filled frame sections have shown evidence of gas formation. However, the possibility exists for the formation of hydrogen from a sealed hollow frame if acidic conditions exist in the section from an acidic flux used in fabrication or from bacterial action. Bacterial action can also produce methane under anaerobic conditions, which was found in one of the frames investigated.

Recommendations

Clearly, the presence of a highly flammable gas such as hydrogen at high pressures inside a simple plow frame is both a serious and unsuspected hazard. When such a frame is penetrated by an electric drill or by an acetylene torch, that gas will be released as

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a powerful jet that will entrain air and be easily ignited by the electric motor or torch flame. The public must therefore be alerted to the potential hazard of drilling or cutting into sealed frame sections on farm equipment and other equipment frames, particularly if the frame has been filled. Signs or lights should be attached to the equipment only with built-in or clamped mounting brackets or other nonpenetrating devices.

Eliminating this hazard will require more stringent control over the ballast material used to fill the frames to ensure that internal gas is not produced or that expansion of the fill does not rupture the frame upon strong heating, as in a welding operation. Under present circumstances, manufacturers should limit their metal scrap fill material to ordinary steel similar in composition to the steel frame; small vent holes should be provided to eliminate the possibility of gas pressure buildup inside the sealed sections.

For More Information

For more information on these findings and how to prevent this explosion hazard, contact Isaac A. Zlochower, Ph.D., NIOSH Pittsburgh Research Laboratory, Cochrans Mill Rd., P.O. Box 18070, Pittsburgh, PA 15236-0070, phone: (412) 892-4276, fax: (412) 892-6595, e-mail **iaz0@cdc.gov**

To receive other information about occupational safety and health problems, call **1-800-35-NIOSH (1-800-356-4674)**, or visit the NIOSH Home Page on the World Wide Web at http://www.cdc.gov/niosh

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Figure 1. Metal fill from exposed section of plow frame.