Danger of Drilling Into Sealed and Filled Plow Frames

Isaac A. Zlochower, PhD[1] and Janet J. Ehlers, RN, MSN[2]*

KEY WORDS: ***modified frames; hazard; agriculture; injury; explosion; occupational health and safety; work environment***

INTRODUCTION

In two incidents occurring in April 1995 and October 1996, workers received first to third degree burns on their faces and/or upper bodies after drilling into sealed metal frames containing metal ballast. The farmer and farm worker involved in these incidents had just penetrated their plow frames with electric drills when a roar of escaping gas was heard and the victims were thrown back 25–30 feet by the gas jet and engulfed in flames. As in these incidents, farmers commonly drill into such frames to attach safety signs, attach hitches, or otherwise alter equipment. A community based occupational health nurse in New York State, conducting surveillance for agriculturally related injuries and illnesses[3], became aware of the above incidents from hospital emergency room records. Two such incidents within 18 months in the same county aroused concern. The National Institute for Occupational Safety and Health (NIOSH), an agricultural safety specialist, and the community based nurse investigated the matter further. Subsequently, a Midwest researcher reported five additional cases that involved equipment from several manufacturers. Although, records of those other incidents are no longer available [personal communication, Paul Gunderson, 1998], the report indicates that these are not isolated incidents limited to one manufacturer.

[3] Through NIOSH-supported Occupational Health Nurses in Agricultural Communities (OHNAC), nurses conducted surveillance and intervention in 10 states in 1990–1996. NIOSH continued surveillance and added intervention research through 16 Community Partners for Healthy Farming (CPHF) projects. CPHF partners communities, researchers and health departments to reduce the risk of occupational illness and injury in agricultural populations. The New York (NY) Center for Agricultural Medicine and Health, in affiliation with Cornell University, provides engineering consultation to the OHNAC and CPHF projects conducted by the NY State Department of Health.

METHODS

The community based nurse and the New York (NY) agricultural safety specialist initiated the investigation of the 1996 incident by interviewing the workers and viewing the incident site. In a subsequent visit, NIOSH investigators examined the plow which had been left in the equipment barn, and collected gas and solid (fill) samples for analysis. The 6 mm hole in the plow frame had been covered with tape a week prior to the NIOSH visit to allow time for further gas production inside the resealed frame section. Gas samples were extracted through the tape by using a needle connected to evacuated test tubes. After removing the tape, several 2 mm diameter steel disks were recovered by probing the frame interior with a magnetized fine blade. A variety of steel disks (2–8 mm) were recovered from an additional larger hole that was drilled nearby.

The gas samples were analyzed for air constituents—oxygen (O_2), nitrogen (N_2), carbon dioxide (CO_2)—and for carbon monoxide (CO), hydrogen (H_2), methane (CH_4), and other low molecular weight hydrocarbons by conventional gas chromatographic (GC) techniques. The solid disks were examined at various magnifications by using optical and scanning electron microscopy (SEM). Some areas were subjected to qualitative elemental analysis by the X-ray detector used in conjunction with the SEM imaging. Soaking in distilled water led to pH determination, and solvent cleaning of the disks was used to quantify the amount of oil left on the disks.

The plow frame involved in the earlier [1995] incident was later delivered to NIOSH's Pittsburgh Research Laboratory for investigation. The "ignition" hole in this

[1] Pittsburgh Research Lab, Mine Safety & Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA
[2] Division of Surveillance, Hazard Evaluations & Field Studies, National Institute for Occupational Safety and Health, Cincinnati, OH
*Correspondence to: Janet J. Ehlers, National Institute for Occupational Safety and Health, 4676 Columbia Parkway R-21, Cincinnati, OH 45213. E-mail: jje0@cdc.gov

Accepted 1 May 1999

frame had been taped for some time prior to its delivery and NIOSH sampling. The 3.66×2.13 m frame appeared to have been stored outdoors. Gas samples were taken as before, and a small amount of solid material was scraped from inside the 8 mm hole in the $10 \times 10 \times 355$ cm sealed frame member. Another sealed section of this plow frame had been cut open at the manufacturer's plant after the incident, and a more representative sampling of the solid fill was, therefore, available. This fill consisted of sundry machine shop metal scrap (mostly punchings) of various sizes, shapes and thicknesses. Both chemical and SEM/X-ray analysis revealed a variety of metals. Some of the metal fill was placed in sealed jars, with and without some additional water, to monitor pressure development with time. The ‘‘ignition’’ hole itself was fitted with a pressure gauge and a sampling device to monitor pressure development and to collect gas samples periodically. A drill rig especially designed for drilling into pipes containing flammable gas under pressure was used to penetrate the remaining sealed and filled frame section. This drill is mechanically turned (no ignition source) and is designed to contain any gas released.

RESULTS

The results of gas sampling from the plow at the NY farm (1996 incident) showed a substantial reduction in O_2 concentration from 21.0% in air to 4.4% in the frame section after one week of isolation from ambient air (it had been allowed to equilibrate with air for a month after the incident). The presence of H_2 (0.9%) and CH_4 (0.6%) was noted, as well as some reduction in CO_2 (0.02%) from the value in air (0.05%). It was concluded that the contents of the sealed frame section were still consuming O_2 and CO_2, and producing H_2 and CH_4 (both are flammable and easily ignitable gases, particularly H_2). Although the measured concentration of these gases was below the minimum flammable concentrations, it is reasonable to assume that a longer period of isolation from air would have produced higher fuel gas concentrations. The metals in the fill that were sampled were found to be predominantly bare steel and galvanized steel. Soaking in water produced an increasingly alkaline solution with time. Such alkalinity could have produced CO_2 absorption and the observed reduction in CO_2 content. The amount of remaining oil on the metal disks was found to be about 0.2% by mass.

The other plow frame produced more dramatic results. The H_2 content was initially found to be 26% and then 31% after the ‘‘ignition’’ hole had been well sealed and fitted with a pressure gauge. The O_2 content was well below 1%, and the CO_2 content was well below ambient air values. There was no significant CH_4 content, however. The pressure was also found to be increasing by 0.7 kPa/day (0.1 psi/day). When the intact sealed section was penetrated by the special drill, a pressure of 1.3 MPa (185 psi) was found that consisted predominantly of H_2 (94%), and N_2 (6%). The metal fill consisted of various forms of steel (carbon, stainless, and galvanized) and titanium. One sample of the metal fill that had been stored in a sealed jar produced no pressure increase until some water was injected. The resulting pressure increase was due to H_2 production. Subsequent drilling into sealed but unfilled frame sections in this plow frame showed no excess pressure.

Thus all the frame sections tested that had been filled with the metal scrap had undergone near elimination of O_2 and the production of H_2. The reaction(s) responsible for these results appear to involve water. A reasonable explanation of the observations to date is that the reaction of an active metal in the scrap, such as the zinc coating on galvanized steel punchings, has produced both the elimination of O_2, by oxidation of the metal, and the decomposition of water to produce hydrogen and the alkaline hydroxide ion. The above reactions may be chemical (direct) or electrochemical in nature. The hydroxide ion could then react with CO_2 to form stable metal carbonates. The CH_4 that was initially found in the one plow frame of the 1996 incident was probably produced by anaerobic bacteria (methanogens) that were introduced with the metal scrap. The continued exposure to air from the open hole in that plow could have inactivated the bacteria and eliminated subsequent CH_4 production.

CONCLUSIONS

This investigation has produced conclusive evidence of the generation of a highly flammable gas, H_2, in the steel plow frame sections that had been filled with machine shop metal scrap for ballast and then sealed by welding. The use of such sealed box frames that are filled with metal scrap may not be confined to one manufacturer or to one type of equipment frame. The finding of a high pressure of H_2 in the remaining intact sealed and filled section is the most dramatic result of our study. Had this frame penetration been done by using a conventional drill, the resulting release of H_2 at high pressure would have produced a long flame jet through ignition by the drill motor, and anyone in its path would have been burned. Even the pressure of the jet, by itself, is dangerous in that the resulting force applied to a body in its path is sufficient to send it flying, as was the case of the two victims in the above incidents. The evidence to date suggests that the H_2 was generated by reaction of an active metal such as the zinc coating on galvanized steel with water either through direct chemical or electrochemical action.

This investigation has thus shown the hidden danger of drilling or cutting into sealed sections in equipment, particularly if the sections have been filled with a ballast material. Penetrating such sections in order to place safety signs, as was the case in one of the two incidents, is definitely unsafe. Such signs should be attached by clamping devices . Manufacturers should try to exercise more control over the nature of the scrap used. If possible, the scrap should be the same type of steel that is used in the frame. However, until a safe supply of scrap is available, it is recommended that small vent holes be provided such sealed sections in order to prevent a pressure build-up. Some of these recommendations are already in place with one manufacturer. NIOSH has provided hazard alerts to the farming community and other equipment users on this significant and unexpected danger [NIOSH, 1998].

REFERENCE

NIOSH. August, 1998. Hazard ID: Ignition hazards from drilling into sealed frames of agricultural equipment. DHHS (NIOSH) Publication No.#98-146.