COGNITIVE ERGONOMICS

Failure to Detect Gas Leaks: Forensic Human Factors Considerations

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Relying on a single method to warn of propane gas leaks may pose a hazard to consumers.

IT WAS A HOT, HUMID AUGUST DAY IN BENSONVILLE, Arkansas. Richard Brown was working on a project in the old barn in the back of his residence. Richard's wife, Jessica, was in the basement starting to take the first load of laundry out of the washer. Their two kids were in their bedrooms; 12-year-old Kyle was playing a 3-D video game while bouncing on his bed, and 8-year-old Sean was on the floor watching TV. The time was 4:25 p.m., time to start thinking about dinner.

Suddenly, next to Jessica, there was a large flash of light, an explosion, and fire. Later, she reported that she was in the basement of her home doing routine activities related to laundry. She was putting wet clothes into the dryer when the area exploded around her. She did not remember closing the dryer door and pushing the start button, but the flash fire happened at about that time. She saw that her clothes were on fire and shortly thereafter realized what was happening. She screamed as she ran up the stairs and out of the house.

Hospital records described severe burns on both of Jessica's legs, the top of her feet, and her right arm. Medical treatment involved multiple skin grafts over the course of a year. The extensive scarring required more surgeries. She described the pain as intense and unbearable. She was reminded of her disfigurement every time she dressed and moved her legs. The scar tissue was not as elastic as her other skin.

INCIDENT ANALYSIS

Investigation into the cause of the fire focused on a corroded and cracked copper pipe supplying propane gas (also called liquid petroleum or LP gas) to the dryer. Moisture and vibrations from the dryer combined to cause the pipe to degrade and crack. That was the explanation given by an engineering expert, C. David Stinson. He based the explanation on electron micrography (showing discoloration, corrosion, and fracture marks) as well as other situational factors, such as a rigid connection with the dryer. Stinson concluded that the flash fire was caused by a propane leak from this location. The dryer probably ignited the gas-air mixture by a spark when Mrs. Brown started it.

The Browns had been getting gas from Apex Propane Energy since they purchased the house 15 years before the incident. Apex owned the tank in the backyard and pumped propane from a truck into the tank on a regular basis. The Browns never had a problem with propane before this event. Mrs. Brown reported that she did not smell gas before the explosion. She knew what propane smells like; she sometimes smelled it when starting the kitchen stove.

Propane is an odorless gas. Because people cannot smell it, a chemical, ethyl mercaptan, is added to give it odor to help with leak detection. The smell is described as being similar to rotten eggs or a dead rodent. Some gas companies periodically send customers a scratch-and-sniff patch to demonstrate what odorized propane gas smells like. Apex sent these sheets only to new customers. None of the Brown family reported having seen or smelled a scratch-and-sniff patch.

Adding the odorant to propane to alert people of a gas leak is a good idea. Gas companies advise that when gas is smelled, people should vacate the premises quickly and not use any electrical switches that could create a spark, including telephones. Furthermore, after vacating, they should call the gas company. However, this odorant warning system is not perfect. Leaks and resulting fires and/or explosions occur even with odorized gas. Indeed, industry trade associations, such as the National Fire Protection Association and Propane Education Resource Council, publish brochures that state that detecting gas by smell is not 100% reliable.

LAWSUIT

The Browns filed a lawsuit against the propane retailer. As plaintiffs, they alleged that the defendant, Apex, was at fault in causing severe injury to Mrs. Brown. Documents submitted to the court by the plaintiffs claimed that the seller had

FEATURE AT A GLANCE: A scenario based on actual cases is presented in which a consumer fails to detect a gas leak. A spark source ignites the vapor, causing an explosion and fire. Odorant added to alert people of gas leaks is not always detected for a number of reasons, including nasal congestion, sleep, odor fade, masking, and adaptation or habituation. Electronic gas sensors that alarm in the presence of explosive gas are available in the consumer marketplace and could augment leak detection.

KEYWORDS: gas leak, detector, sensor, alarm, odorant, smell, forensics

superior knowledge about the hazards associated with propane but failed to warn less knowledgeable consumers. Apex owned the propane tank in the Browns' yard and delivered propane on a regular basis and thus had service people on the property several times each year. However, Apex had not done any kind of inspection to check whether there were any leaks or potential for leaks during the 15 years it supplied gas to the Brown house. The Browns did not know that they needed to look for and recognize pipe-related problems.

The plaintiffs contended that the LP seller knew or should have known that odor from leaked propane is not always detected. Documents produced by the defendant indicated that it possessed industry and trade publications that stated this. Apex sent material to new customers stating that leak detection by smell is not reliable under certain conditions, but again, the Browns, as existing customers, were not sent those materials. The only printed warnings Mr. Brown received were on the monthly billing statements inserted inside the door at each propane delivery. On the back was small pink text that provided egress instructions in the event of smelling gas; that is, evacuate immediately, do not turn on any light switch or use a phone, and call the gas company when outside the building. Mr. Brown, who paid the bills, stated in deposition that he never paid attention to the back of the invoices and did not remember seeing this warning.

Human Factors Investigation

Given the materials Apex alleged to have provided to its customers, the plaintiffs' human factors expert opined that the warnings were defective with respect to manner, method, and content. The purpose of warnings is to alert and inform people about hazards and to motivate them to carry out safety-appropriate actions to avoid harm. The warning information failed to communicate fundamentals of LP gas leak detection.

There were two major components of Apex's LP warning system: ethyl-mercaptan odorant added to the gas to provide an olfactory cue and printed safety information. To be effective as a warning, the odorant must first be detected by olfactory receptors before it can alert users to the presence of propane. Olfactory sensitivity can be reduced by several factors (e.g., Dalton, 2004; Doty et al., 1984; Fang, Clausen, & Fanger, 1998; Gilbert & Wysocki, 1987; Gunnarsen & Fanger, 1992; Murphy & Cain, 1980; Stevens & Cain, 1985; Stone & Bosley, 1965):

a. Some people are born without the ability to detect some or all odors.
b. Illness and syndromes (e.g., colds, allergies) can swell or clog the nasal passages, and extra mucus can limit odors from reaching the olfactory receptors.
c. Chronological age reduces olfactory sensitivity.
d. Competing odors in the environment, such as tobacco smoke and cooking smells, could disguise, mask, or interfere with detection.
e. People may detect an odor but not recognize it as propane gas or realize it as a hazard.
f. "Odor fade" could occur, a phenomenon in which the odorant is lost because of adsorption onto surfaces or absorption into materials.
g. "Odor fatigue" could occur, when the olfactory sense adapts or habituates, reducing awareness of the odor's presence.
h. Sleeping residents may not detect the odorant and, when newly awakened, may not recognize it.

In the Browns' basement, other odors, such as laundry detergent and bleach, could have masked the odor of escaping gas. Propane gas is heavier than air and tends to settle in lower levels. Gas can collect close to the floor, particularly when there is limited airflow. Mrs. Brown did not recall smelling anything out of the ordinary even when she bent over to put the clothes in the dryer.

Given that numerous known mechanisms can reduce detection of propane's odorant, a leak could go undetected, thus exposing people to a hazard about which they are unaware. Clearly, an alternative way to detect the presence of gas is necessary. Fortunately, electronic LP gas detectors are available and cost about $50 at a major hardware retailer. These devices can do the sensing when humans may not be able to do so. Furthermore, they can be placed in locations in the home where people may not be.

Plaintiffs' Safety Awareness

Mr. and Mrs. Brown testified that they did not know that (a) there are numerous reasons they may not have smelled the leaked gas and (b) electronic LP gas detectors are available on the market. They stated emphatically that if they had been made aware of the need for electronic gas detectors, they would have purchased them. The human factors expert said if an electronic gas detection warning had been sounded, Mrs. Brown would have been adequately warned of the existence of leaking propane gas. The Browns characterized themselves as safety conscious. At the time of the incident, they had two working smoke detectors and a carbon monoxide detector in their home, a fact that was documented in the fire marshal's fire investigation report.

A lengthy booklet sent to Apex's new customers, which the Browns did not receive, included only a few reasons that persons might not smell gas. Although there was a brief mention of gas detectors, its prominence was low relative to other text, and the presentation was not persuasive. Apex reported that it received fewer than five calls from customers asking about gas detectors in the past 5 years. Some LP retailers offer gas detectors for sale, but Apex did not. The plaintiffs argued that information and warnings about electronic LP gas detectors was needed to reduce risk and that Apex should have given adequate warnings about the need for and availability of gas detectors and information about where to purchase them. Without this information, the plaintiffs argued, the product was unreasonably dangerous.

Electronic devices are not perfect, however. For example, they may give false alarms (i.e., alert people when there is no propane hazard) or miss detection, such as when the batteries are dead or removed, when the unit is unplugged, or when the gas is in a location away from the detector. People may rely too much on them. These are all important considerations. Clear communications about proper installation instructions and their limitations are necessary. If working properly, electronic gas detectors could supplement and extend the existing odor detection method.

Apex overly relied on smell as the sole leak detection method. Apex's employees testified that they believed the presence of odorant to be an effective detection method and that there was little or no need for a gas detector. Nevertheless, the company had information that indicated electronic detectors had value but failed to pass on this information to most of their customers, including the Browns. In documents filed in court, the plaintiffs also argued that Apex should have performed leak tests and inspected the gas pipes on a regular basis.

Mrs. Brown stated that she sometimes smelled whiffs when starting her stove. However, she did not realize the extent of danger posed by leaked gas. Consumers partly base their decision to purchase and use consumer products on beliefs they hold. One belief is that companies would not sell dangerous products or that the government would not allow them to be sold. People expect an adequate warning for dangerous products, especially ones capable of causing severe injury or death. There was no effective warning about consequences, such as their house exploding or burning down, and risk of occupant injuries or deaths.

Postscript

The case went to trial and lasted 6 days, with testimony from all the witnesses and experts mentioned earlier. After 2 hours of deliberations, the jury came back with a verdict in favor of the defendant. Outside the courtroom, a few of the jurors were asked what factor(s) led to their decision, and two main points were made. First, they felt that Mrs. Brown should have smelled the gas before the explosion. Second, some jurors stated they did not hold Apex responsible because there was no law or government statute that required that propane gas suppliers tell their customers about electronic gas detectors.

Discussion of this second point is beyond this article's scope. However, the first point suggests that the jurors did not understand the human factors expert's testimony – that people cannot always smell the odor. Perhaps it would have been more effective to say that even people who can smell the odor will not always be able to do so.

Everyone is at risk some of the time, such as during sleep or when experiencing nasal congestion. Clearly, there needs to be greater awareness about the need to supplement the odor cue by using electronic gas detectors.

Human factors and ergonomics (HF/E) professionals could assist the gas industry and other organizations in delivering better warning information. They also can aid in the design of user instructions that accompany gas detectors. The integration of a system of multiple detectors and the use of voice alarms is another area of assistance that HF/E professionals can offer.

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Names of entities and details have been changed to protect privacy and confidentiality rights. The scenario and description are based on several prototypical liquid petroleum gas fire and explosion cases.