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Human Factors Considerations in the Detection of Gas Leaks

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ABSTRACT

A scenario of a residential propane fire and explosion case is described. The apparent cause was a corroded pipe in the basement which leaked propane and was ignited by the spark generated by the start of a clothes dryer. The victim who was severely burned reported not smelling gas despite an odorant, ethyl mercaptan, being added to the gas. Reasons why the gas was not detected by smell are described. Electronic gas detectors are available but the gas supplier never communicated this fact to many of its customers. The added value of electronic gas detectors is described.

Keywords: Propane, olfaction, smell, sensors, detectors, warnings

It was a balmy August day in Lincolnville, Arkansas. Jack Simpson was working on a project in the old barn built in the early 1900s. The previous house on their land had burned down about 10 years before their current 1950s ranch-type home was constructed.

Jack's wife, Mary Lee, was in the basement just starting to take the first load of laundry out of the washer. Their two kids were in their bedrooms; Sam was playing a 3-D video game and Jon was watching something on TV. The time was approximately 4:15 pm, nearly time to start thinking about dinner. Suddenly, right next to Mary Lee, there was a large flash of light, explosion, and fire. Later Mary Lee reported that she was in the basement of her home doing routine things related to laundry. She was putting wet clothes in her dryer when the area exploded around her. She did not remember closing the dryer door and pushing the start button, but she might have forgotten because the flash fire happened at about that time. When she first realized what had occurred, she saw she was on fire and started screaming as she ran up the stairs and out of the house.

Hospital records describe severe burns on both 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 will require more surgeries and pain. She describes the pain as intense and unbearable. She is reminded of disfigurement every time she dresses and moves her legs. The scar tissue is not so elastic as her other skin.

Investigation into the cause of the fire points to a corroded, cracked copper pipe supplying propane gas (also called liquid petroleum or LP) to the dryer. Apparently there was water moisture on the pipe at some point and combined with vibrations from the dryer caused the pipe to degrade and crack. That was the explanation given by an engineering expert hired by the Plaintiffs, Mr. Bertrand Rakeholder. He based it on electron micrography (showing discoloration, corrosion, and fracture marks), as well as other situational factors, such as the location of the pipe. He concluded that the flash fire was caused by a propane leak from a fractured corroded copper pipe connected to the dryer. The spark from the electric dryer being started by Ms. Simpson was probably the ignition source. The Defendant's expert had a somewhat different theory about the cause. Dr. Craig Seymour, a metallurgist from California, concluded the pipe had a manufacturing defect that was exacerbated by an installation that failed to include flexible pipe at the dryer connection.

The family had been getting gas from Northern Amalgamated Propane ("Amalgamated") since they purchased the house from the original owner about 15 years ago. Northern owns the tank in the backyard and delivers propane on a regular basis, about every month, but less frequently in the summer compared to the winter. The Simpsons never had a problem with propane before this event. Mary Lee reports that she did not smell gas before the explosion. She knows what

propane smells like because she has sometimes smelt it when she starts the range/stove in the kitchen.

Propane by itself is an odorless gas. Since people cannot smell it, an extra chemical (ethyl mercaptan) is usually added to the gas to give it its characteristic odor to help with leak detection. Sometimes the smell is described as being like sewer gas or the stench of dead rodents. Some gas companies periodically send a sheet to customers with scratch and sniff patches that contain the chemical odorant so that people will learn what propane gas with odorant smells like. Other companies, like Amalgamated, only send these sheets to new customers. Amalgamated started this practice about three years ago when it was purchased by a Little Rock-based conglomerate. Existing customers would not have received this material. None of the Simpsons state that they have seen or smelled a scratch and sniff patch.

Adding the odorant to the gas to help alert users of a gas leak is clearly a good idea. It would aid in detection compared to without it. When gas is smelled, even in small amounts, gas companies advise that people vacate the premises quickly and not to use any electrical switches or anything else that could create a spark, including telephones, until after having exited the premises. However, people commonly report smelling gas when starting their stove, just like Ms. Simpson does, and yet they do not vacate each time they smell it.

However, this odorant warning system is not perfect. Leaks and resulting fires and/or explosions still occur even with the added odorant. Industry associations such as the National Fire Protection Association (NFPA) and the National Propane Gas Association (NPGA) publish materials (e.g., pamphlets/brochures) that state unequivocally that odor detection as a method of hazard protection cannot be counted on as being 100% reliable.

The Simpsons' filed a lawsuit against the propane retailer. As Plaintiffs, they alleged that the Defendant Amalgamated was at fault in causing severe injury to Mary Lee Simpson. The lawsuit documents submitted to Arkansas State Court in the County of Lincoln by the Plaintiffs claim that the seller had superior knowledge about the characteristics and hazards associated with propane but did not communicate them to less knowledgeable consumers like the Simpsons. Amalgamated supplied and retained ownership of the propane tank in the Simpson's yard and delivered propane on a regular basis, but it had not done any kind of inspection or check whether the system had any leaks or potential for leaks, i.e., it did not do any inside-the-home inspections or do any leak tests during the 15 years it supplied gas to the Simpson house. The Simpsons as consumers did not know how to recognize problem pipes that had corroded over time.

The Plaintiffs contend that the LP seller knew or should have known that propane odor is not always detected. In fact, materials found in the Defendant's possession included industry/trade publications that addressed this detection issue. Indeed, some of this information that the Defendant sends to new customers includes this information, although the Simpsons as existing customers would not have received

it. (No records have ever been produced by the Defendant confirming the mailing of any such materials.)

The only printed warning information relevant to this case were on invoices that Jack Simpson received to pay the bills. On the back of them was some warning text in small type in light pink ink and embedded in other print material. This particular warning text concerned egress procedures when the odor is detected: Evacuate immediately and do not to turn on any light switch or use a phone, and call the gas company once outside the home. Mr. Simpson, who pays the bills, says he never noticed anything on the back of the invoices, and the other family members never dealt with paying the gas company bills.

Interestingly, even if one were to assume that all materials that Amalgamated alleges to have provided to its customers (regardless of whether they are actually true or not), the warnings were deficient. This was the opinion of the Human Factors expert that was retained by the Plaintiffs, Dr. Richard Raster, a psychology professor from a major southern university. According to his analysis, the warnings were defective with respect to manner, method, and content. According to him, the point of effective warnings is to alert people about hazards and to motivate them to carry out safety-appropriate actions to avoid harm to themselves and others. The warning information failed to communicate some fundamental aspects of the LP gas detection.

Amalgamated had two major components of their LP leak warning system: (a) ethyl-mercaptan odorant added to the gas to provide an olfactory cue, and (b) printed safety information. To be effective as a warning, the odorant must first be detected by the olfactory receptors before it can alert users to the presence of propane. Olfactory sensitivity can be reduced by several factors. One major factor is that some people chronically lack some or all of the ability to smell the odor. Genetics and illness can cause reduction in the ability to smell. Also chronological age reduces olfactory sensitivity (Doty et al., 1984; Gilbert & Wysocki, 1987; Stevens & Cain, 1985). Conditions that swell or clog the nasal passages and extra mucus will limit or prevent odors from reaching the olfactory receptors (Murphy & Cain, 1980). Colds and other respiratory difficulties can affect olfaction and hinder an individual's ability to detect odorized propane. Moreover there are still other factors that can decrease olfactory function (e.g., Katotomichelakis et al., 2007). Competing odors in the environment could interfere with detection of odorized propane (by disguising or masking the smell). Tobacco smoke, cooking smells, chlorine bleach, and musty damp odors can reduce the likelihood of odor detection (Fang, Clausen, & Fanger, 1998; Gunnarsen & Fanger, 1992; Stone & Bosley, 1965). It is possible that in the basement there were other odors present that could have masked the odor of escaping gas. The washing machine was adjacent to the dryer, so damp odors, detergent, and bleach from the laundry could have interfered with propane detection. Propane gas is heavier than air. The gas tends to settle in lower levels and follows the floor downwards. Basements can collect gas particularly when there is very limited airflow. Ms. Simpson said that she was not using bleach, but the basement sometimes smelled musty and damp. She does not

remember any smell that day before the fire, including the laundry detergent's "fresh" smell.

Another potential shortcoming associated with reliance on odor as a warning mechanism is a phenomenon sometimes called "odor fade." This condition is a loss of detectability of propane that has previously been odorized due to physical/chemical reactions. Another condition is "odor fatigue." Over time, the sensory systems habituate or adapt to the smell, and this adaptation results in reduced awareness of odorized propane. Detecting a momentary scent of propane odor is normal when initiating use of appliances that run on propane. That is how Ms. Simpson says she learned what propane smelled like. Because of adaptation/habituation, people might not detect it even though the gas and odor is present (Dalton, 2004). This effect is important in situations in which the gas odor is present while sleeping. Upon awakening from sleep, individuals may not notice the smell due to adaption/habituation while asleep. Turning on light switches at night is an all too common reaction, unfortunately.

Thus, there are several known factors that result in persons may not smelling propane, and a leak that could go undetected exposing people to a risk about which they are unaware. Clearly, a different, separate way to detect the presence of gas is necessary. Fortunately, electronic LP gas detectors are now currently available. These systems would be beneficial, because they provide an effective additional measure to detect LP gas leaks. These devices could provide detection when humans may not be able to, such as when there are competing smells, odor fade or fatigue, conditions of anosmia, colds/clogging of nasal passages, and during times they are asleep or immediately after awakening, etc. It is a backup warning system for persons who are not adequately sensitive to smell of the odorant due to one or more of the reasons already mentioned.

Mary Lee and Jack Simpson testified that they did not know there were electronic LP gas detectors on the market. They also did not know there were numerous reasons for not smelling a propane gas leak. They were emphatic in saying 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 been sounded, then Ms. Simpson would been adequately warned of the existence of leaking propane gas in their basement. The Simpsons characterized themselves as safety conscious. At the time of the incident, they had two working smoke detectors and a CO detector in their home which was documented in the Lincoln County Fire Department's fire investigation report.

While it is not clear what safety materials the Simpsons received, none of the materials adequately emphasized the availability and need for electronic LP gas detectors. Some LP retailers sell LP gas detectors. Amalgamated did not sell them, although it knew that some LP retailers do. The Plaintiffs argued that information and warnings about electronic LP gas detectors needed to be conveyed by the Defendant sellers of propane. If the company was not going to sell the detectors

directly to consumers then the company should have told them where they could purchase them.

Instead of a loud screeching alarm, currently available technology allows digitally recorded voice warnings to be given. This technology would help distinguish between sounds of other sensor alarms such as smoke and carbon monoxide detectors (e.g., see Haas and Edworthy, 1996). Voice warning and instructions would aid in identifying the hazard, instructing what to do, and providing information about consequences of not complying.

These 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 of LP gas, such as when the batteries are dead or removed. People may over-rely on them. However, if working properly it would provide a benefit by supplementing and extending odor detection. Thus, a working electronic LP gas detector would serve as backup or redundant cue to the total gas detection system and it could also extend detection by placing them in areas where residents are not.

Amalgamated employees overly relied on people's ability to smell a propane leak to avoid fire and explosion events, even though they should have known that detection via smell can fail. Amalgamated's employees testified that they believed the presence of odorant to be an effective method of detection, and that there is little extra value of any added electronic equipment such as a gas detector. Amalgamated had access to information that said electronic detectors had value, but it failed to pass on this relevant safety information to many of their customers including the Simpsons.

In briefs filed with the Court, Plaintiffs also argued that Amalgamated should have performed leak tests and examination of the gas plumbing on some regularly scheduled basis. That no such tests and no examinations were made inside the Simpson house in 15 years constituted negligence by the Defendant.

Ms. Simpson stated that she knew that propane was potentially dangerous, but she did not realize the extent of the danger it posed. Consumers partly base their decision to purchase and use consumer products like propane based on an assumption that companies would not sell (and that government would not allow) truly dangerous products to be sold. People expect an adequate warning for dangerous products, especially those capable of causing severe injury or death. Consequences, such as their house exploding/burning down and risk of occupant injuries or deaths were not effectively warned about. Further, Mary Lee Simpson and family were not made aware of the deficiencies of odor detection and the existence of, the need for, and where to obtain electronic gas detectors.

Authors' Note: Names of entities and details have been changed to protect privacy

and confidentiality rights. The scenario and description are based on several prototypical LP gas fire and exposure cases.

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