Article: Personal Injury Caused by a Steam Explosion Triggered by the Exothermic Reaction of a Caustic Sewer Drain Cleaner and Water

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Commercial household drain cleaners sold in retail stores around the country contain a combination of fairly aggressive chemicals designed to unclog drains by dissolving grease, hair, food proteins, and other organic waste products.

An individual was injured using a caustic cleaner to clear a drain. He filed a claim against the manufacturer. The plaintiff in this case was injured from the spray back of liquid caustic and steam while using the caustic drain cleaner. The expert witness was retained by plaintiff's counsel to testify as to the chemical reactivity of the product and the conditions under which such a steam explosion would be likely. He was also asked to examine the product's label, safety data sheets, and technical bulletin for consistency and accuracy of the warning precautions and recommended PPE (personal protective equipment) when using the product.

The key ingredient which chemically has the ability to solubilize grease and other proteins is caustic, or sodium hydroxide also called lye. It dissolves oils, greases, hair, and various human protein and other drain obstructions into soluble organic salts thereby unclogging the drain pipes. The process of dissolving sodium hydroxide in water is an exothermic reaction causing the released heat to raise the temperature (and therefore the solubilizing strength) of the solution.

$$NaOH_{(s)} + H2O_{(l)} \longrightarrow Na^{+}_{(soln)} + OH^{-}_{(soln)} + \text{Heat} \qquad (1)$$

In order to increase the effectiveness of these drain cleaners, some manufacturers formulated a product mixture of sodium hydroxide with aluminum metal and sodium nitrate salt.

The purpose of the aluminum metal was to react with the caustic and generate hydrogen gas, which functioned as a scrubbing agent to agitate the caustic solution for more efficient breaking down of the clogs and scouring of the drain. This reaction too was exothermic and released heat into the solution.

$$Al(s) + Na^{+}_{(soln)} + OH^{-}_{(soln)} + H_2O \longrightarrow Na^{+}_{(soln)} + [Al(OH)_4]^{-} + H_{2(g)} + \text{Heat} \qquad (2)$$

Finally, the nitrate salt was added as an oxidizing agent to destroy excessive amounts of the dangerously flammable hydrogen gas generated in the above reaction. This reaction which converts hydrogen gas to ammonia gas is of secondary importance for the purposes of this discussion and will be ignored.

The exothermic reactions (1) and (2) generate sufficient heat to bring the drain contents to boiling (depending on the amount of water present). The quantity of heat generated in these reactions is directly related to the amounts of NaOH, aluminum, and water reacted. The aluminum is the limiting reagent,

which means, once the aluminum is consumed, the heat and hydrogen gas released from reaction (2) cease while only the heat from the dissolution of caustic solid from reaction (1) continues.

Therefore, the higher the % composition of aluminum and/or NaOH formulated in the cleaner product, the greater the heat rise for each pound of product added to a given amount of water in the treated drain or pipe. The water provides a "heat sink" to absorb the heat released in the reactions causing the temperature rise but is limited in its ability to absorb and dissipate all the heat generated. Once the boiling point of the mixture is reached (212 ^{o}F or higher depending on the amounts of dissolved salts in solution), the excess heat is released as steam and other gases.

If insufficient water is present to maintain the boiling point at or near 212 ^{o}F, the excess heat can be released very violently spraying gases, steam, and caustic in an explosive manner from the drain opening.

Another complicating factor is that the percentage of caustic solid and aluminum metal may not be the same in each portion of the product because the solid particles of caustic, aluminum, and other salts having different shapes and sizes settle and mix in a different manner, that is, the percentage of Al is not exactly say 5% in each portion drawn from the container as stated on the label but could vary quite a bit depending on where the spoonful is taken from the container.

A helpful analogy to explain this phenomenon is Kellogg's Raisin Bran cereal. Everyone has experienced when pouring the cereal from the box into a bowl for the morning breakfast how the number of raisins in one bowlful of cereal is never the same as the number in the next bowl that is poured. That is because the mixture of raisins and bran flakes is not uniform but instead is a heterogeneous mixture and therefore cannot deliver the exact same percentage of raisin and bran with each pour. The same is true with the caustic drain cleaner consisting of caustic solids and aluminum metal particles.

It is important that the consumer carefully reads the manufacturer's instructions for each product and the type of drain to which it is going to be added. Different drains in different fixtures have a different drain configuration and a different amount of standing water in the trap. The less the amount of water the more vigorous the reaction for the same amount of drain cleaner. If too little water is present when the drain cleaner is added, the exothermic reaction could generate enough heat to cause the water to boil over or even convert a portion of it rapidly to steam forcing a stream of hot caustic solution and steam to erupt forcibly from the drain opening onto the user.

The jury returned a verdict in favor of the plaintiff with a comparative fault distribution of 25% fault on behalf of the plaintiff and 75% fault with the defendant. The defendant's fault was attributed mostly to lack of a predictable and uniform product mixture and lack of consistency in warning labels and safety data sheets. The plaintiff was assigned a lesser degree of fault for not strictly following all the instructions for use and exercising good judgment.

Some manufacturers of these caustic drain cleaners have reformulated the products in an effort to make them safer. The caustic continues to be the main ingredient but some products no longer contain the aluminum metal. The removal of this limiting reagent removes a substantial portion of the heat generated in the reaction and the dangerously higher temperatures. The product recommended dosages for each type of drain has also been reduced to safer levels. A gelling agent is added to increase the retention time of the product inside the drain and some products also contain bleach to enhance the oxidizing and sanitizing effects.

The safest approach for consumers to take when using chemical products with associated hazards is to carefully read the safety data sheet, the product specification literature, the product container label, and customer reviews (including reports of any minor injury or mishap) before using or perhaps even before purchasing the product. Finally, always use the personal protective equipment recommended by the manufacturer and ample protective clothing.