A. Odorant History

The history of gas odorization had its beginnings in the 1880s, when ethyl mercaptan was added to natural gas, which was manufactured as "town gas" at that time. Town gas was odorized primarily because of its toxic carbon monoxide content. When natural gas was initially used as a fuel, its sulfur compounds—which are common components of pipeline natural gas—often resulted in a detectable odor. However, concentrations of natural sulfur vary from different gas sources: some natural gas sources do produce odorless gas. Because of this variability, efforts to find an effective odorant for natural gas began in the 1920s, although there was no consideration for its use in automotive applications.

In 1937, a tragedy occurred at the New London High School in New London, Texas, that spurred a complete revamping of the practice of odorizing natural gas. New London High School used odorless natural gas, which was provided by a pipeline located in their oil- and gas-rich community, for heating and cooking. A leak occurred at the school that went undetected until the moment an electric sanding machine in the woodshop was unplugged causing a spark that ignited the accumulated gas. The explosion killed 239 people, mostly children. This accident is reported as the worst school disaster to date, and ranks with airline crashes as the most devastating in U.S. history.

Following the tragedy, Texas and other states adopted regulations that standardized natural gas odorization for pipeline gas for consumer use. A variety of synthetic odorants were used until the early 1950s, but by 1960, almost all natural gas was odorized by one or more odorant compounds of the following types:

Mercaptans
Alkyl sulfides
Cyclic sulfides

Today, pipeline natural gas delivered to consumers in the United States must contain an odorant that alerts the whole distribution chain of this problem. Liquefied petroleum gas (LPG), or propane sold in or dispensed into containers, is also odorized. Originally, however, the premise for odorization of these two gases did not take into account automotive applications or the expansion of available automotive gases such as hydrogen, nitrous oxide, and methane-hydrogen mixtures.

Federal regulation 192.625 addresses pipeline gas, and is not application-specific outside of the delivery of pipeline natural gas to locations throughout the United States. Note that CFR 192.625 is written in terms of the odorization effect rather than the required odorant chemistry and concentration. Specifically, Subpart (a) states, "A combustible gas in a distribution line must contain a natural odorant or is odorized so that at a concentration in air of one-fifth of the lower explosive limit, the gas is readily detectable by a person with a normal sense of smell." This is taken directly from Federal regulation 192.625, which does not provide for automotive applications or automotive application validation.

B. Individual Odor Perceptibility

Relying on an individual's odor perceptibility and sense of smell presents numerous challenges when taken in light of automotive applications. The perception is that, if a person can smell odorized natural gas within a home, heater closet, or basement, it follows that one can smell gas in and around a vehicle or refueling station at one-fifth the lower explosion level. Unfortunately utilization of human olfactory senses for a singular safety measure is at best challenging. The following are examples of why using an odorant without gas detection as a single safety device for commercial trucks, transit, school bus, hotel, shuttle and refueling station applications does not meet today's real-world demands:

- State of mind e.g., attentiveness: distractions can provide lessened awareness.

- Permanently impaired sense of smell some individuals have a reduced sensitivity to certain odors, and there are those who have no sense of smell at all.
- Temporarily impaired sense of smell e.g., due to colds, allergies, smoking.
- Olfactory fatigue caused by exposure to other strong odors.
- Olfactory adaptation over time, an individual can become accustomed to odors, including odorized gas.
- Other odors present may mask natural gas odorants.

The precise functions of the human olfactory system remain somewhat obscure, especially in regard to accurately determining odorant level. Sensitivity to an odor varies among individuals, and can also vary with the same individual, depending on the circumstances. Quantification of odor perception has, therefore, proved difficult. Early measures of odor included the 1931 Bureau of Mines odor scale used by Fieldner, which involves five levels:

0	-	No odor	1	-	Very faint odor
2	-	Faint	3	-	Moderate
4	-	Strong	5	-	Very strong

Factors that reduce human odor sensitivity include head colds, medicine used, smokers, sinus problems, advanced age, the presence of several odors simultaneously, and length of exposure. In addition, a small percentage of individuals are unable to detect specific odors, levels of odors or their olfactory systems do not function at all. Studies of odorants have shown a distinction between "detection" and "recognition" thresholds. Furthermore, sensitivity or insensitivity to specific odorants varies from one individual to another. Sensitivity to an odor varies and depends upon a multiplicity of human circumstances that may change hourly.

C. Natural Gas Automotive Applications – CNG

For automotive applications the NFPA 52-2006 CNG document relates to an odorant specification as follows: "Natural gas introduced into any system covered by this standard shall have a distinctive odor potent enough for its presence to be detected down to a concentration in air of not over one-fifth of the lower limit of flammability." The inclusion of odorant references in the NFPA document assumes that

the pipeline odorant specification will be an effective carryover for safe warning in automotive gas applications. It does not refer to specific levels or types of odorants, and offers no reference validation that an odorant at this level will serve as an effective safety function for the automotive end user.

Note that NFPA 52-2006 also states the following: "Natural gas or blends not meeting this definition shall have site and onboard methane detection systems installed and certified by a qualified engineer wit expertise in methane detection or fire protection." Therefore, safety considerations for gas releases are highly dependent upon two items: use of proper odorants, and the sense of smell of the individuals working in natural gas facilities, or that of drivers of natural gas powered vehicles. Assuming that a vehicle driver possesses the finite ability to smell odorant at safe levels prior to the gas reaching dangerous levels is a serious risk. Running out of a building when you smell gas is much easier than jumping out of a vehicle.. In addition, transit, school buses, vehicles for hire, and special needs buses require time to evacuate their passengers. Close attention must be paid to employee sensory abilities and dependence on odorants in automotive applications if they are a single warning agent for gas leaks.

Basic odorant literature indicates that odorants are only intended to provide a warning, within the boundaries of known limitations. Gaseous automotive applications that depend solely on the use of an

odorant to warn of gas leaks depend on unknown sensory abilities, and daily health of individual drivers. All of which lack consistency from a safety perspective.

NGO does not have access to your customers. NGO provides this warning to educate you and strongly suggests that you educate your customers. You should confirm that all persons having contact with the product, including your customers, are adequately warned about the properties, characteristics, propensities, and limitations of natural gas and natural gas odorants when used as a warning agent in natural gas. For instance, persons having contact with natural gas should know that natural gas vapor is lighter than air.

Information from California Energy Commission (CEC) project for the odorization of vehicle LNG. Project successfully odorized LNG . Project information can be found on the CEC website.