

Evaluating the Safety of a Natural Gas Home Refueling Appliance (HRA)

PROJECT IMPACT

This project evaluated the probability of safety incidents related to use of FuelMaker Corporation's natural gas home refueling appliance, Phill. The results indicate that an individual is 10 times more likely to be struck by lightning than to experience a safety incident resulting from normal use of Phill. The safety evaluation produced an added benefit—FuelMaker incorporated suggestions from the study into its final design of Phill. Home refueling has the potential to increase the availability and convenience of natural gas vehicle refueling infrastructure. It is anticipated that this would lead to more extensive use of natural gas vehicles, resulting in reduced U.S. petroleum consumption.

PROJECT GOALS

Natural gas is a domestically available resource. The U.S. Department of Energy (DOE) supports natural gas vehicle and infrastructure R&D through its FreedomCAR and Vehicle Technologies Program to help the United States reduce its dependence on imported petroleum and to pave the way to a future transportation network based on hydrogen. Natural gas vehicles can also reduce emissions of regulated pollutants compared with vehicles powered by conventional fuels such as gasoline and diesel.

The goal of this project was to evaluate the safety implications of refueling natural gas vehicles at home with a home refueling appliance. Widespread use of natural gas vehicles has been hindered by limited availability of refueling stations. Home refueling could change this by making convenient natural gas refueling available to everyone who has residential natural gas service. The home refueling concept also may be applicable to the hydrogen-powered vehicles of the future.

FUELMAKER'S HOME REFUELING APPLIANCE

Toronto, Canada-based FuelMaker Corporation has manufactured compressed natural gas (CNG) vehicle refueling appliances for more than 15 years. These appliances are designed to provide fast-fill or time-fill (slow-fill) CNG refueling for small fleets such as school buses and government vehicles. FuelMaker's new home refueling appliance—known as Phill—brings CNG refueling capability to the homes of individual drivers (Figure 1).

Connected to standard residential natural gas and electric service, Phill can be installed inside a garage (Figure 2) or outdoors. It provides automated time-fill CNG refueling at a rate of approximately 0.4 gasoline gallon equivalents per hour, appropriate for overnight refueling of commuter vehicles.

In 2005, FuelMaker will begin selling Phill in California for approximately \$3,400 per unit, and there are plans to market it in Canada and Europe as well. Phill is certified and listed by CSA International (a group that includes the Canadian Standards Association, CSA International, CSA America, and others). It is labeled with a safety listing similar to that used for other natural gas household appliances such as water heaters and clothes dryers.

SAFETY EVALUATION

A team was assembled by DOE's National Renewable Energy Laboratory to conduct the safety evaluation of Phill. Various investigations and analyses were used to generate data for accurate safety incident probability calculations. References and databases pertaining to component failure and human error statistics were used. CNG vehicle refueling experience was surveyed to determine which kinds of accidents have occurred in the past. CNG vehicle fuel system designs were analyzed to support estimation of gas releases from vehicles. Experience with water heaters and other garage-installed natural gas



Figure 1. FuelMaker's Home Refueling Appliance, Phill
NREL/PIX 13800



Figure 2. Phill Provides CNG Refueling inside Residential Garages
NREL/PIX 13714



appliances was considered. Thirty-three residential garages were evaluated to determine design, construction, and air infiltration characteristics. Computer modeling was used to calculate garage gas concentrations resulting from possible gas leak scenarios. In some cases, probability estimates were based on failure or error statistics for generically similar components and situations. Data from all these sources were used to generate the calculations and probability results discussed below.

The evaluation employed standard risk-assessment methods. First, scenarios that create potential safety risk were identified. These risk scenarios were grouped into the following categories:

- Equipment failure (e.g., gas leaks from Phill)
- Human error (e.g., driving out of the garage with the refueling nozzle connected to the vehicle)
- Misuse (e.g., attempting to use Phill to inflate a swimming pool toy)
- Maliciousness (e.g., a disgruntled neighbor shuts off Phill's gas supply)
- External event (e.g., a vehicle hits Phill).

Next, the probability of each risk scenario occurring was calculated. Finally, the probability of each risk scenario resulting in a potential safety incident—a structure fire or deflagration—was calculated. The following is an example of these calculations. The annual probability of a vehicle hitting Phill and breaking the gas line was calculated to be approximately 1 in 1.4 million. The probability of a structure fire due to this scenario occurring was calculated to be approximately 1 in 17. Thus, the overall probability of a structure fire occurring because of a vehicle hitting Phill and breaking the gas line was calculated to be approximately 1 in 23 million (1 in 17 multiplied by 1 in 1.4 million).

WHAT'S A DEFLAGRATION?

A deflagration is a rapidly moving flame front, which creates high pressure when it occurs in an enclosed space such as a garage. Deflagrations range from small flash fires, causing no property damage, to explosions, which may cause significant damage. The severity depends on how much of a flammable gas-and-air mixture has accumulated. This study considered the probability of scenarios such as gas leaking, accumulating in a garage, and being ignited (e.g., by an electric garage door opener) to cause a deflagration.

RESULTS AND CONCLUSIONS

Table 1 summarizes the calculated probabilities of safety incidents related to using Phill inside a residential garage. It was determined that most misuse incidents were more likely to occur in the first year after installation of Phill, so the misuse probabilities in Table 1 are probabilities that

Table 1. Calculated Probabilities of Phill-Related Safety Incidents Compared with Probabilities of Other Safety Incidents

Phill-Related Incidents	Annual Probability*
Deflagration, all non-misuse failures	1 in 7,000,000
Deflagration, all misuse failures	1 in 1,400,000
Structure fire, all non-misuse failures	1 in 14,600,000
Structure fire, all misuse failures	1 in 10,700,000
Other Incidents (Not Related to Phill)	Annual Probability**
Residential structure fire	1 in 300
Being killed in a vehicle crash	1 in 6,800
Being struck by lightning	1 in 686,000
Electrocution by a consumer product	1 in 1,880,000

*Probability that a single unit installation will experience the consequence in any year after Phill installation for non-misuse failures or in the first year following installation for misuse failures.
 **Sources of probability data: residential structure fires—U.S. Consumer Product Safety Commission and Census Bureau (1999); fatal vehicle crashes—U.S. National Highway Traffic Safety Administration (2001); lightning strikes—National Weather Service (2001); electrocution by consumer product—U.S. Consumer Product Safety Commission (2000).

the incident will occur in the first year after installation. The non-misuse probabilities in Table 1 are probabilities that the incident will occur in any year after installation of the unit. As Table 1 shows, the annual probability of a deflagration due to all non-misuse failures is 1 in 7 million. An individual is 10 times more likely to be struck by lightning than to experience a non-misuse deflagration. Even if intentional misuse (e.g., attempting to use Phill to inflate a pool toy) is considered, an individual is still more than twice as likely to be struck by lightning than for Phill to cause a deflagration. Structure fires resulting from use of Phill are even less likely.

The safety evaluation produced an added benefit: FuelMaker incorporated suggestions from the study into its final design of Phill. For example, in an early design, the air flow that cools Phill's compressor was fed from and discharged to the inside of the garage. The safety analysis revealed that this design limited beneficial ventilation if a gas leak occurred. Based in part on this analysis, FuelMaker refined the installation instructions to ensure that cooling air is discharged outside of the garage.

RELATED PUBLICATIONS AND WEB SITES

The report, *Safety Evaluation of the FuelMaker Home Refueling Concept*, which describes the safety evaluation of Phill in detail, is available from the Alternative Fuels Data Center at www.eere.energy.gov/afdc. Hard copies are available from the National Alternative Fuels Hotline at 1-800-423-1363 or hotline@afdcweb.nrel.gov. The evaluation was part of DOE's Natural Gas Vehicle Technology Forum. For more information, visit www.nrel.gov/vehiclesandfuels/ngvtf. For more information on FuelMaker and Phill, visit www.fuelmaker.com.

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