Looking Good
NH3 – Safety Issues

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NH3 VI

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Bottom Line

Based on the results of a highly credible comparative quantitative risk analysis (CQRA) and decades of widespread acceptably safe usage of NH3, it is a fact that NH3 would be safer than propane and as safe as gasoline when used as a transportation fuel.

Side Issues - Methamphetamine

Ammonia	**NH_3**
Ephedrine and Pseudoephedrine	**$C_{10}H_{15}NO$**
Methamphetamine	**$C_{10}H_{15}N$**

There are several ways to make methamphetamine without NH3. There are no ways to make methamphetamine without ephedrine or pseudoephedrine. Regulate the cold medicine properly and eliminate the meth. problem.

Ammonium Nitrate - Scapegoat?

VOC's + NOx + O2 + Sunlight = ozone = smog+
NOx + H2O + ammonia = ammonium nitrate = smog-
If the NOx doesn't form ammonium nitrate it goes to ozone (worse)

Fossil fuels (the source of NOx) plus fugitive NH3 emissions from animal feed lots are the problem, not NH3 fuel. NH3 is actually used to clean up NOx emissions at coal plants

Health And Safety

- NH3 is classified by DOT as a non-flammable liquid and an inhalation hazard (not a poison)
- Iowa Energy Center funded comparative quantitative risk assessment (CQRA) study completed in March 2009, Quest Consultants Inc., Norman, Oklahoma
- "Safety assessment of ammonia as a transportation fuel", Nijs Jan Duijm, Frank Markert, Jette Lundtang Paulsen, Riso National Laboratory, Denmark, February 2005
- WWI (Fritz Haber)
- Terrorists
- Ammonia plant operators
- Ammonia safety is an engineering issue. It can be made to be as safe as is necessary. It is safer than propane and as safe as gasoline when used as a transportation fuel.
- Shelter in-place, escapability

Health And Safety

- DOE white paper
- Recent email paper
- Escapabilty

On-Board Vehicle Fuel Tank Risks Not Analyzed

The National Safety Council maintains an extensive data base covering injuries and fatalities due to accidents. One of the largest subsets of this data base pertains to accidents involving motor vehicles. A review of the data base indicates that most of the fatalities associated with motor vehicles are not due to the fuel in the vehicle. In short, whether the motor vehicle is powered by gasoline, LPG, natural gas, or some other fuel has little to do with whether a fatality occurs during an accident.

Source: Quest Consultants Inc.

Conservative (on the Safe Side) Approach

For this reason, Quest uses a modeling package, CANARY by Quest®, that contains a set of complex models that calculate release conditions, initial dilution of the vapor (dependent upon the release characteristics), and the subsequent dispersion of the vapor introduced into the atmosphere. The models contain algorithms that account for thermodynamics, mixture behavior, transient release rates, gas cloud density relative to air, initial velocity of the released gas, and heat transfer effects from the surrounding atmosphere and the substrate. The release and dispersion models contained in the QuestFOCUS package (the predecessor to CANARY by Quest) were reviewed in a United States Environmental Protection Agency (EPA) sponsored study [TRC, 1991] and an American Petroleum Institute (API) study [Hanna, Strimaitis, and Chang, 1991]. In both studies, the QuestFOCUS software was evaluated on technical merit (appropriateness of models for specific applications) and on model predictions for specific releases. One conclusion drawn by both studies was that the dispersion software tended to over predict the extent of the gas cloud travel, thus resulting in too large a cloud when compared to the test data (i.e., a conservative approach).

Source: Quest Consultants Inc.

Three Ways to Expire

1. **Fires – torch, flash and pool**
2. **Vapor cloud explosions**
3. **Exposure to hazardous gas**

Acceptable Risk Levels

6.3.1 Individual Risk Criteria Summary

Figure 6-7 presents a summary of the risk acceptability criteria. The most common acceptable level of risk for members of the public is 1.0×10^{-6}. A review of Figure 6-7 shows that an individual risk level less than 1.0×10^{-6} would be acceptable by all authorities, with the possible exception of the more restrictive guidelines published in the Netherlands. Thus, 1.0×10^{-6} could be suggested as an acceptable public risk standard for the fuels evaluated in this study.

Source: Quest Consultants Inc.

Acceptable Risk Levels

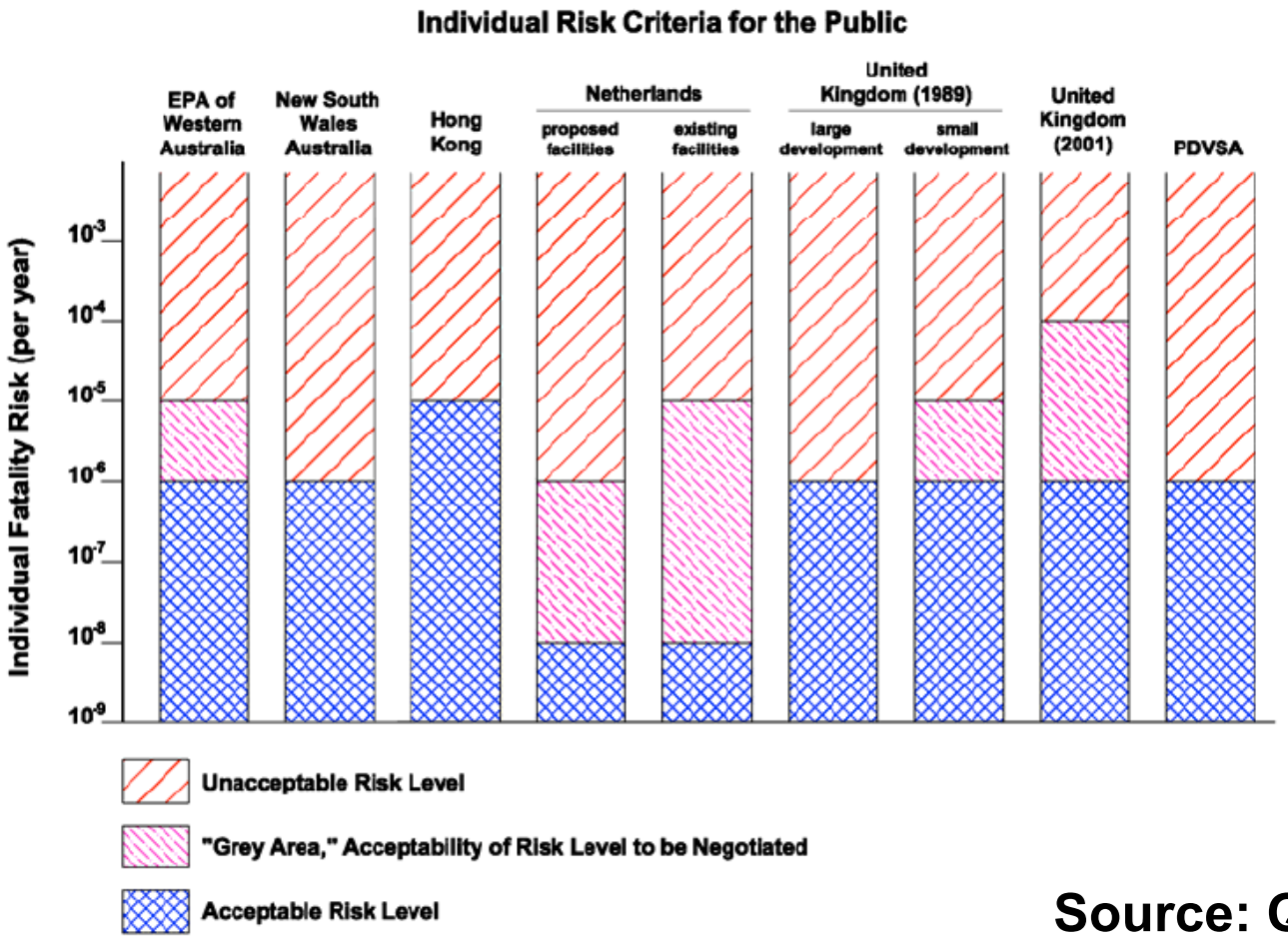


Figure 6-7
Acceptability Standards for Individual Risk

Source: Quest Consultants Inc.

Ammonia Storage & Transport

Ammonia Storage & Transport Model

Chilled NH3:

1. **bulk storage**
2. **truck transport and**
3. **refueling station storage**

Fuel Station Layout

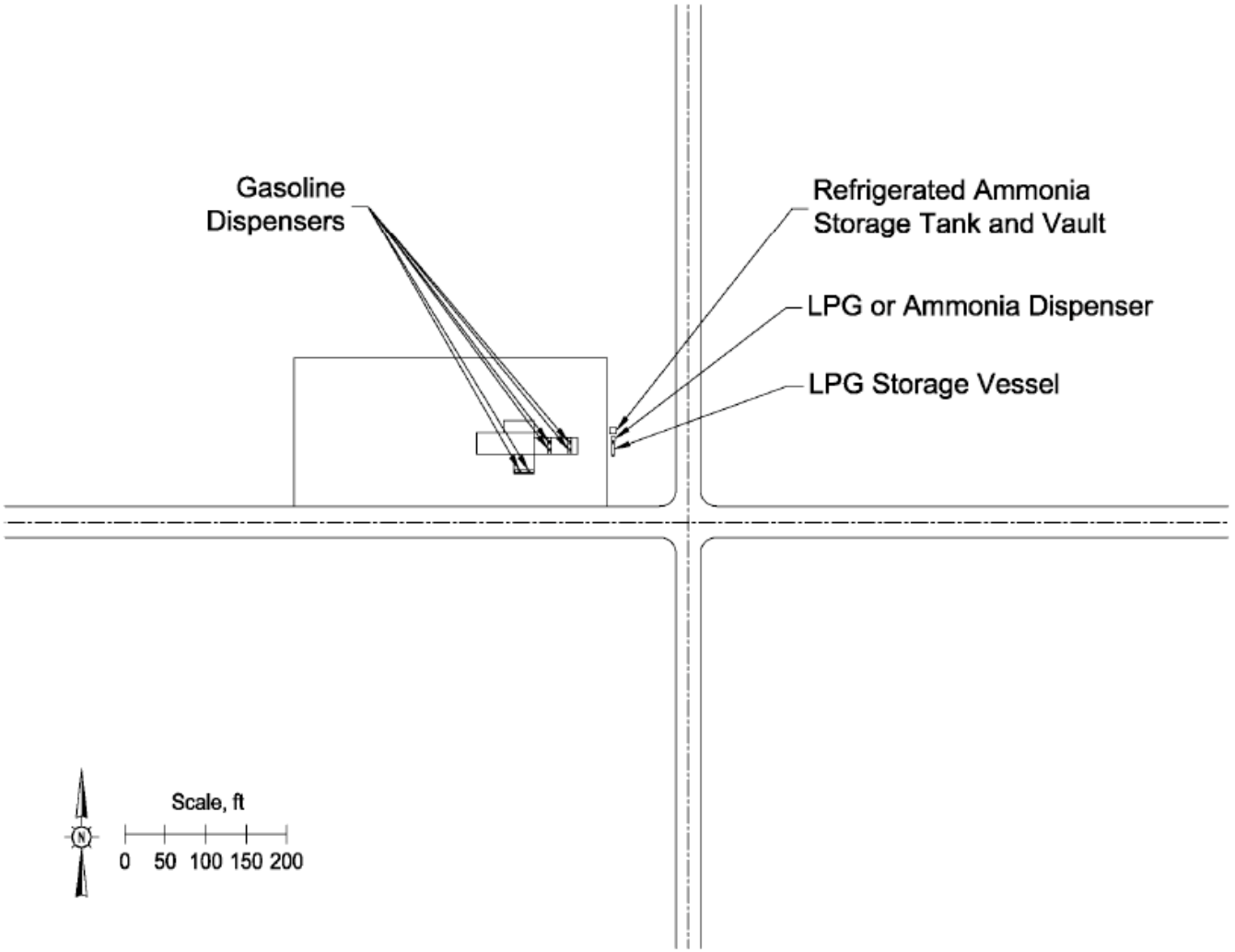
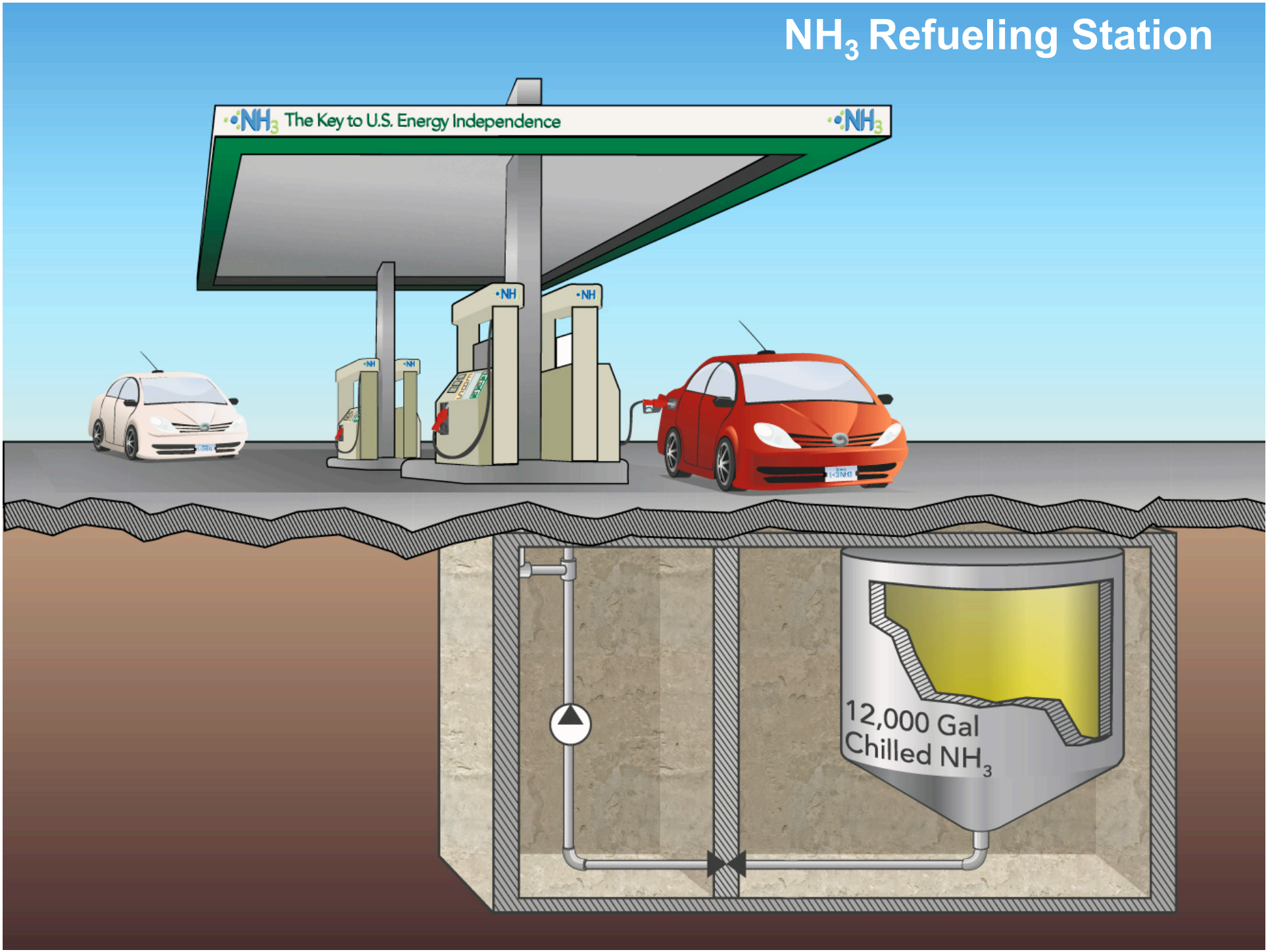


Figure 2-1
Basic Service Station Layout


NH_3 Refueling Station
NH_3 The Key to U.S. Energy Independence
NH_3
12,000 Gal
Chilled NH_3

Safe NH3 Refueling Station Storage

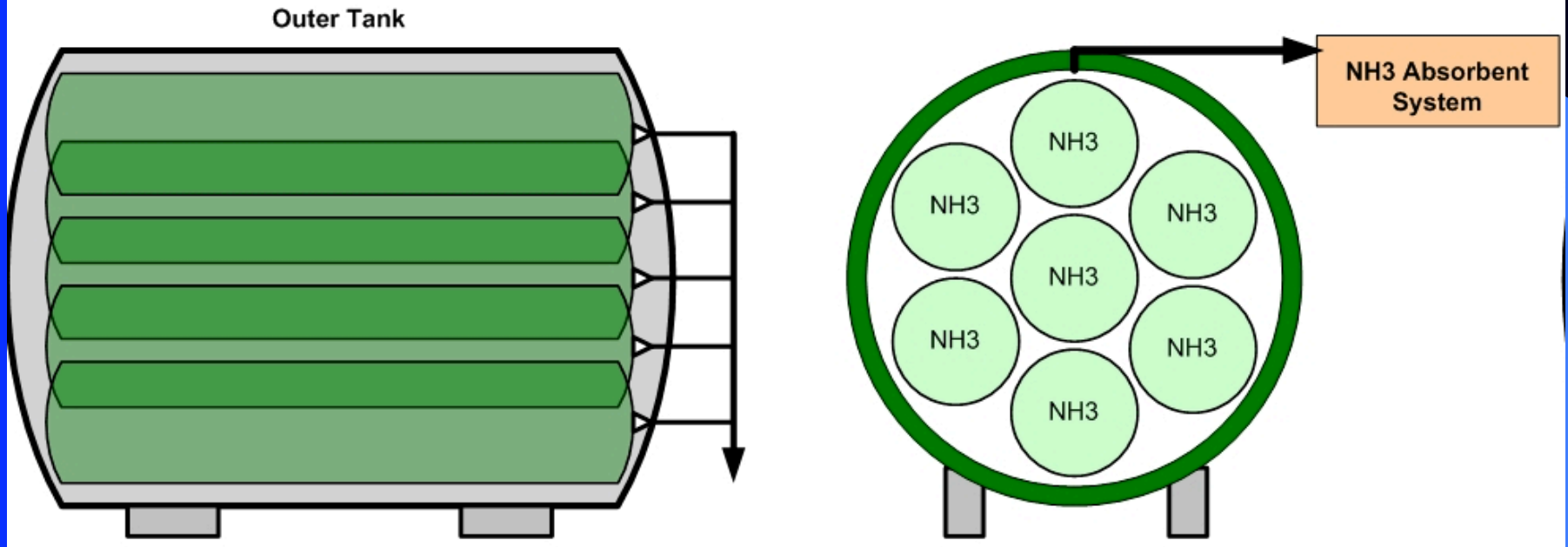
The refrigerated ammonia storage system is designed such that if a small or significant release of ammonia were to occur in the storage, heating, or pumping systems, the released ammonia liquid and vapor would be contained in a vault and vented through a vertical stack extending upward. As the ammonia vapors warm and disperse from the elevated stack, the ammonia/air plume will be positively buoyant and will have no ability to slump back to grade. This storage method essentially eliminates the grade-level risk associated with the storage of refrigerated ammonia.

Source: Quest Consultants Inc.

Other "Super Safe" NH3 Storage Options

Highest Risk Design

Mackinaw Associates
Super Safe Ammonia Tanks



Radiant Heat Hazards (Gasoline and Propane)

The choice of thermal radiation flux levels is influenced by the duration of the fire and the potential time of exposure to the flame by an individual. All combinations of incident heat flux (*I*) and exposure time (*t*) that result in equal values of "radiant dosage" ($t \times I^{4/3}$) produce equal expected mortality rates. An exposure time of 30 seconds was chosen for this analysis for torch fires and pool fires. People who are exposed to radiant hazards are aware of the hazards and know in which direction to move in a very short time period.

NH3 Concentration/Exposures

Table 3-5
Hazardous Ammonia Concentration Levels for Various Exposure Times

Exposure Time (minutes)	Probit Value	Mortality Rate* (percent)	NH_3 Dosage ($ppmv^{1.36}$-min)	NH_3 Concentration (ppmv)
5	2.67	1	853,000	7,031
	5.00	50	2.38×10^6	14,955
	7.33	99	6.64×10^6	31,809
15	2.67	1	853,000	3,135
	5.00	50	2.38×10^6	6,667
	7.33	99	6.64×10^6	14,182
30	2.67	1	853,000	1,883
	5.00	50	2.38×10^6	4,005
	7.33	99	6.64×10^6	8,519
60	2.67	1	853,000	1,131
	5.00	50	2.38×10^6	2,406
	7.33	99	6.64×10^6	5,117

*Percent of exposed population fatally affected.

Source: Quest Consultants Inc.

Thermal Radiation

Table 3-1
Hazardous Thermal Radiation Levels for Various Exposure Times

Exposure Time (sec)	Probit Value	Mortality Rate* (percent)	Incident Thermal Radiation Flux	
			(kW/m^2)	($Btu/(hr \cdot ft^2)$)
5	2.67 5.00 7.33	1 50 99	27.87 55.17 109.20	8,833 17,485 34,610
15	2.67 5.00 7.33	1 50 99	12.22 24.20 47.39	3,873 7,670 15,178
30	2.67 5.00 7.33	1 50 99	7.27 14.39 28.47	2,304 4,561 9,025
60	2.67 5.00 7.33	1 50 99	4.32 8.55 16.93	1,369 2,709 5,365

*Percent of population fatally affected.

Source: Quest Consultants Inc.

Thermal Radiation Probit Relations

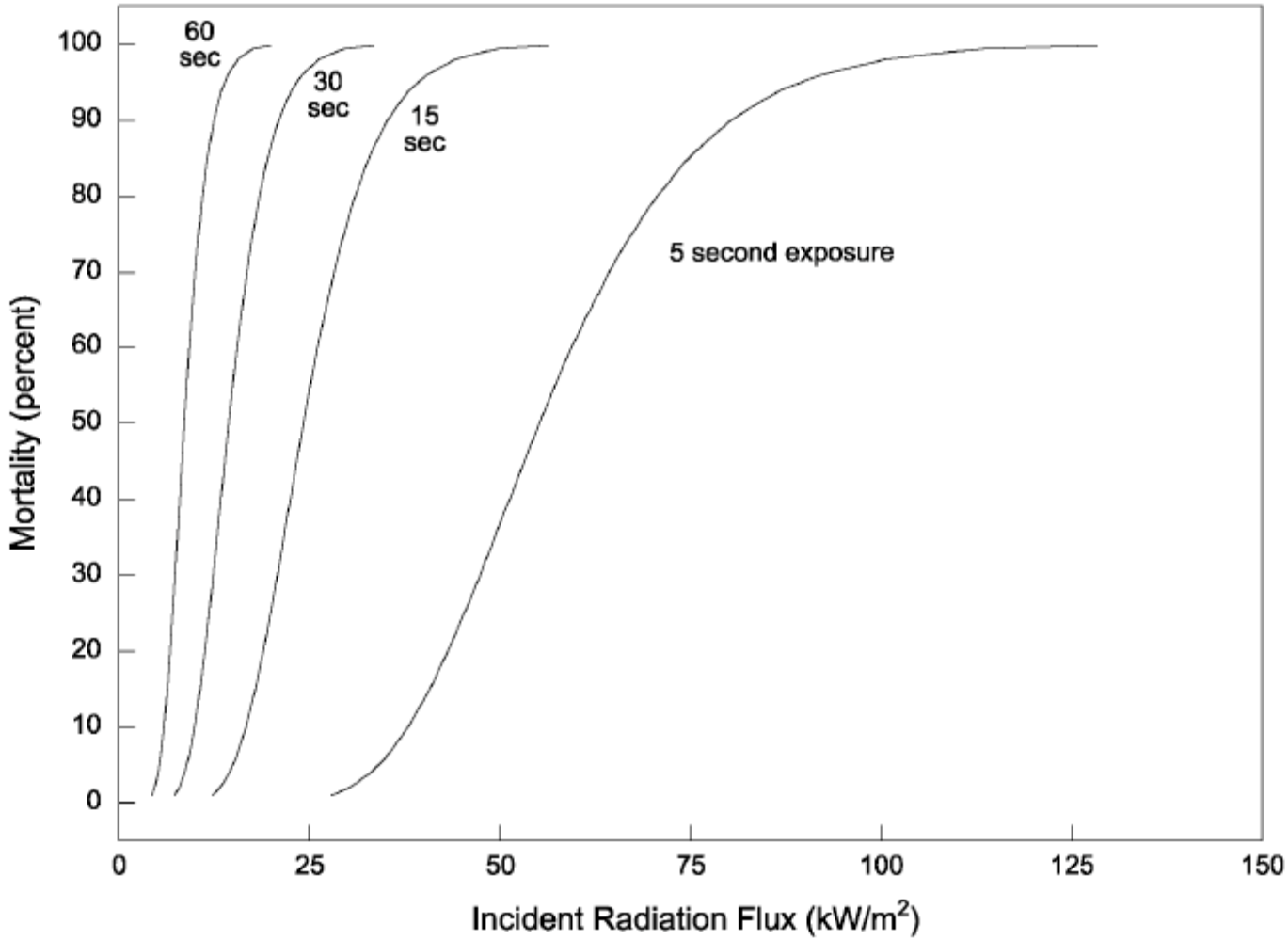


Figure 3-1
Thermal Radiation Probit Relations

Source: Quest Consultants Inc.

Very Important!
Assumed Exposure Time

The assumed minimum exposure time for thermal radiation risks was 30 seconds. 30 seconds was chosen based on the assumption that a normal human reaction to high intensity thermal radiation is to quickly react and move away as quickly as possible.

The assumed minimum exposure time for NH3 inhalation was assumed to be 5 minutes. The assumption was that normal human reactions would not result in recognizing and moving away from an NH3 hazard as quickly as from a thermal radiation hazard. The mathematical model used also had some characteristics that made it inaccurate at exposure times of less than 5 minutes. Practical experience shows that escape from NH3 vapor clouds is probably as enthusiastic and immediate as escape from intense thermal radiation. (Smelling salt.)

NH3 Probit Relations

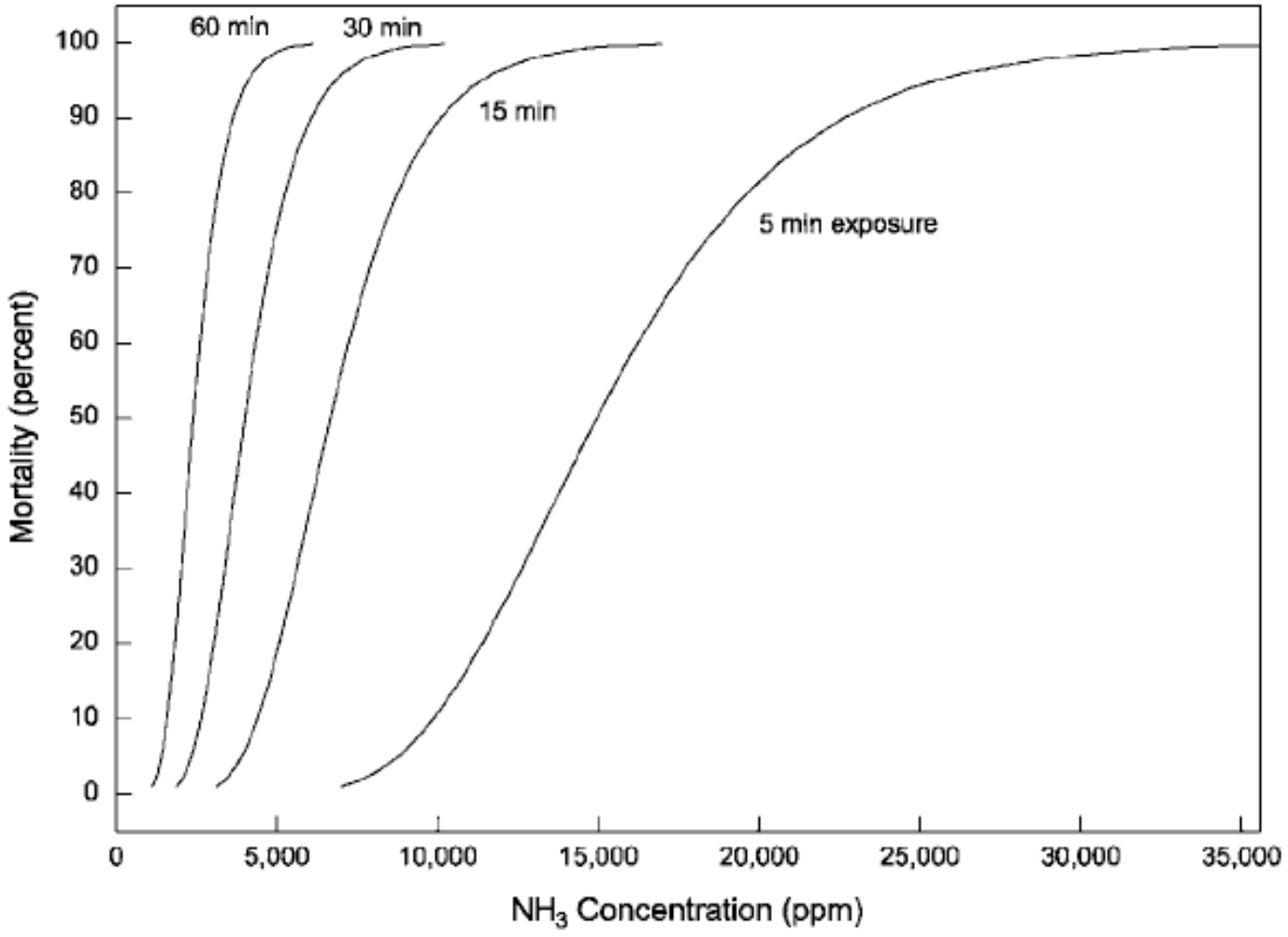
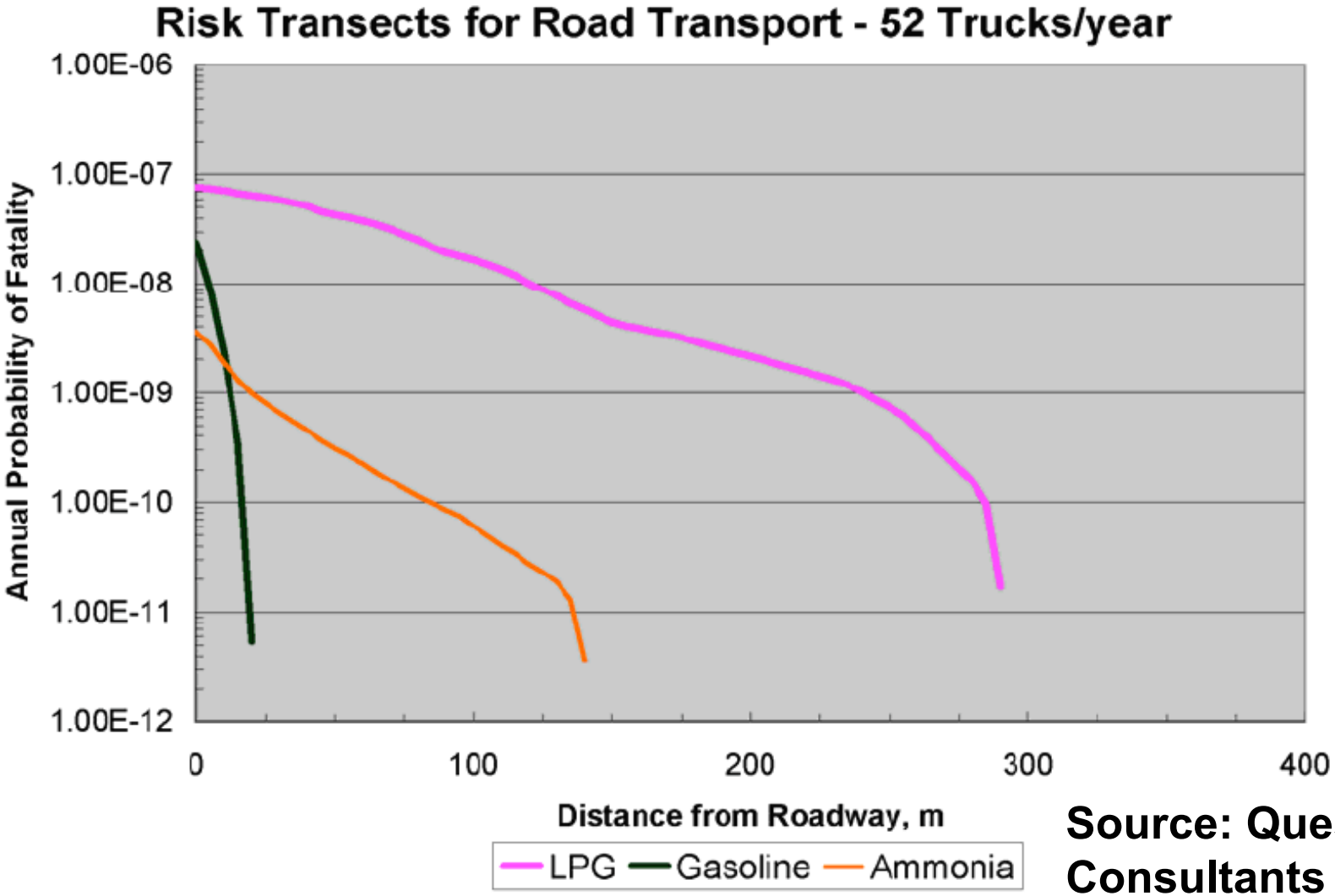


Figure 3-3
Ammonia Probit Relations

Source: Quest Consultants Inc.

CQRA Study – NH3, Propane, Gasoline Transport Trucks



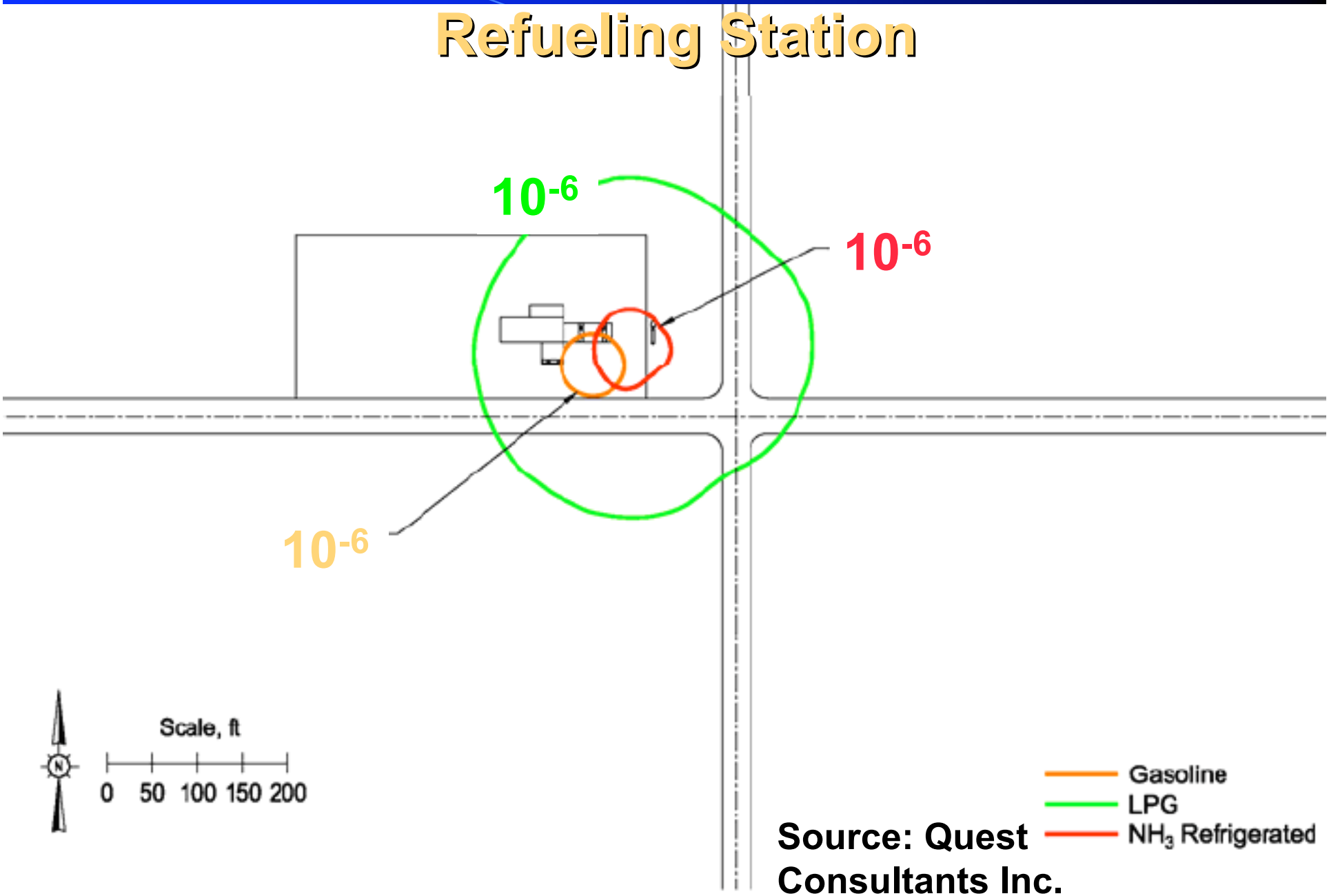
Source: Quest Consultants Inc.

Comments on Truck Transport

Truck transport of NH3 is very safe.

CQRA Study – NH3, Propane, Gasoline

Refueling Station



Source: Quest Consultants Inc.

Refueling Station

NH3 is shown to be safer than propane and very comparable to gasoline at a properly designed refueling station. It must be noted that in the Quest CQRA a 5 minute exposure time is used for NH3 while a 30 second exposure time is used for flame thermal radiation from gasoline and propane. Practical experience has shown that it is normally relatively easy to quickly identify and escape from a NH3 release. Note that a 10^{-6} probability of a fatality is generally accepted world wide.

NH3 Safety Literature

"Comments on *Potential Roles of Ammonia in a Hydrogen Economy – A Study of Issues Related to the Use of Ammonia for On-Board Vehicular Hydrogen Storage,* Peter J. Feibelman1 and Roland Stumpf2, Sandia National Laboratories*

"Safety assessment of ammonia as a transport fuel", RISO National Laboatory, Denmark, 2005

"Comparative Quantitative Risk Analysis of Motor Gasoline, LPG, and Anhydrous Ammonia as an Automotive Fuel" was conducted by Quest Consultants Inc, Norman, Oklahoma.

"Effectiveness of Common Shelter-in-Place Techniques in Reducing Ammonia Exposure Following Accidental Release", Center for Toxicology and Environmental Health, April 2009.

"Potential Roles of Ammonia in a Hydrogen Economy", U.S. Department of Energy, February, 2006.