TORT LAW CONSIDERATIONS FOR THE HYDROGEN ECONOMY

*Russell Moy**

I.

Hydrogen and fuel cell technologies are being championed as the way to further environmental and national security policy objectives.[1] The widespread enthusiasm accompanying these technologies is apparent in recent policy initiatives.[2] For example, in his 2003 State of the Union Address, President Bush proposed $1.2 billion in funding to develop "clean hydrogen-powered" automobiles.[3] In January 2002, Secretary Abraham of the U.S. Department of Energy (DOE) announced the Administration's plan to develop a hydrogen fueled "Freedom CAR."[4] State governments[5] and a number of industrial firms[6] are also involved. These programs have created a fervor where potential obstacles to widespread deployment of hydrogen technologies to the general public are rarely discussed and liability implications are seldom considered. Furthermore, none of the current studies or policy initiatives on the hydrogen economy address tort liabilities that could be associated with the unique physical properties of hydrogen.

The unique physical properties of hydrogen lead to significant differences in the use, hazard detection, and likelihood of injuries as compared to other conventional or alternative fuels. Therefore, consideration of tort law issues associated with hydrogen, including negligence, products liability, and abnormally dangerous activity could impose additional operational costs as insurance premiums or in the management of potentially adverse publicity.

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* Mr. Moy holds a Juris Doctor from Wayne State University Law School, as well as a Ph.D. in Chemical Engineering from the University of Michigan. The author is also a member of the Bars of Michigan and the District of Columbia and is a licensed Professional Engineer. He was formerly Group Leader for Energy Storage Programs and Project Manager for the design and construction of hydrogen storage and vehicle refueling facilities at the Ford Motor Company. This article is based on the author's work at the Ford Motor Company and at the Georgetown University Law Center. The views expressed in this article are those of the author and do not necessarily represent the position of his current or former employers.

1. *See generally* Frederick Moring, *Book Review: The Hydrogen Economy*, 24 ENERGY L.J. 151, 151-154 (2003) (reviewing JEREMY RIFKIN, THE HYDROGEN ECONOMY (2002)).

2. Alan C. Lloyd, *The Power Plant in Your Basement*, SCI. AM., July 1999, at 80.

3. Dana Milbank, *Bush Budget Uses Fuzzy Math, Democrats Say, Critics Say Funding Isn't as Advertised*, WASH. POST, Feb. 7, 2003, at A4.

4. David Malakoff & Robert F. Service, *Bush Trades Hybrid for Hydrogen Model*, SCI., Jan. 18, 2002, at 2.

5. Cecil Angel, *Engler to Push Plan for Fuel Cells*, DETROIT FREE PRESS, Apr. 18, 2002, at 1A.

6. Lawrence D. Burns et al., *Vehicle of Change*, SCI. AM., Oct. 2002, at 64.

These additional costs have yet to be considered in the discussion of the hydrogen economy.

II.

The heart of the hydrogen economy is the fuel cell. Fuel cells are similar to batteries in that they chemically combine two reactants to generate electricity.[7] In a battery, the reactants and reaction products are permanently contained. Some batteries can be recharged with an external power supply that drives the discharge chemical reactions in reverse. A fuel cell differs from a battery because it does not permanently contain either the reactants or reaction products.[8] A fuel cell operates by pumping reactants into the cell, as reaction products are vented and electricity is generated. Fuel cells are not electrically rechargeable but, in principle, can operate indefinitely as additional reactants are supplied.

The reactants used in virtually all fuel cells are oxygen, obtained from air, and hydrogen, with water as the reaction product. A few experimental systems substitute methanol for hydrogen because engineering the reactant storage system for direct methanol fuel cells is simplified as methanol is a liquid at room temperatures.[9] These systems, however, have lower current densities than hydrogen fuel cells and produce carbon dioxide (CO_2). Furthermore, there are serious concerns that because methanol is water soluble, leaks in storage tanks associated with the distribution infrastructure could contaminate groundwater supplies.[10] Some engineers have proposed hydrogen distribution systems based on chemical compounds such as sodium hydride.[11] However, at least a few of these systems involve recycling procedures that are subject to the Resource Conservation and Recovery Act (RCRA), and are burdened with compliance costs for Environmental Protection Agency (EPA) regulations associated with the handling of hazardous wastes.[12]

Devices called reformers, designed to convert gasoline or methanol to

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7. *The Future of Fuel Cells*, SCI. AM., July 1999, at 72.

8. Zinc air batteries, commonly used in hearing aids, are a cross between a fuel cell and a battery because they rely on air for the positive electrode reactant and contained zinc for the negative electrode. *Zinc-Air Batteries*, TECH. REVIEW, Sept. 2001, at 86.

9. SHARON THOMAS & MARCIA ZALBOWITZ, LOS ALAMOS NAT'L LAB., U.S. DEP'T OF ENERGY, FUEL CELLS – GREEN POWER 26 (1999), *available at* http://education.lanl.gov/resources/fuelcells/fuelcells.pdf (last visited Sept. 11, 2003) [hereinafter FUEL CELLS].

10. Todd A. Frampton, *Private Well Owners Pay Price as MTBE Contamination Exposes the Lack of Groundwater Protection in Federal and New York Law*, 18 PACE ENVTL. L. REV. 135, 139-40 (2000). Methanol is more soluble in water than MTBE and has comparable toxicity. BURDICK & JACKSON, MATERIAL SAFETY DATA SHEET FOR METHANOL (Dec. 13, 2001), *available at* http://bandj.com/BJMSDS/MSDS_PDF/METHANOL.pdf (last visited Sept. 11, 2003); BURDICK & JACKSON, MATERIAL SAFETY DATA SHEET FOR METHYL-T-BUTYL ETHER (June 2000), *available at* http://bandj.com/BJMSDS/MSDS_PDF/MTBE.pdf (last visited Sept. 11, 2003).

11. J. PHILIP DIPIETRO & EDWARD G. SKOLNIK, ENERGETICS, INC., ANALYSIS OF THE SODIUM HYDRIDE-BASED HYDROGEN STORAGE SYSTEMS BEING DEVELOPED BY POWERBALL TECHNOLOGIES, L.L.C. (Oct. 29, 1999), *available at* www.eere.energy.gov/hydrogenandfuelcells/pdfs/28890pp2.pdf (last visited Sept. 11, 2003).

12. 42 U.S.C. § 6902 (2003); 40 C.F.R. § 261.22(a)(1) (2003).

hydrogen (and CO_2) on demand, are being developed, because they take advantage of the existing energy infrastructure.[13] However, it will be a challenge for those self-contained chemical plants, combined with already expensive fuel cells, to compete with conventional or alternative fuel systems (e.g., natural gas, batteries) in terms of cost, weight, or packaging volume.

Certain characteristics of hydrogen are attractive and widely touted. Unlike petroleum or other hydrocarbon fuels, hydrogen used in vehicles or stationary fuel cell applications produces only water vapor emissions. Furthermore, hydrogen can be obtained from domestic feedstocks such as natural gas and coal or from renewable sources such as wind or solar energy.[14] However, hydrogen also differs from other fuels in ways that are rarely discussed. Both hydrogen gas and its flame are invisible and odorless.[15] The heat radiation from a hydrogen flame is slight,[16] and the ignition energy is more than an order of magnitude lower than that of gasoline and natural gas. In addition, the flammable composition of hydrogen in air is much wider than any of the other conventional or alternative fuels in use or under consideration for future use. Figure 1 compares the ignition and combustion properties of hydrogen to methane, the primary constituent of natural gas. Table 1 lists the ignitable and combustible properties of hydrogen and most common fuels.

Hydrogen requires more extensive handling precautions than conventional or alternative fuels because its physical properties differ significantly from those fuels. For example, the Occupational Safety and Health Administration (OSHA) regulations require a more stringent "Group" rating for explosion proof equipment (e.g., light fixtures, motors, thermostats, heaters, switches, and telephones) where hydrogen is handled than for areas designed for the safe handling of other fuels.[17]

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13. FUEL CELLS, *supra* note 9.

14. Hydrogen produced from natural gas and coal will generate CO_2, a greenhouse gas. Electrolytic production of hydrogen using wind or solar energy has been proposed for transportation, but hydrogen proponents do not advocate that for stationary applications because it is too expensive. This argument, of course, completely ignores the fungible nature of electrical energy. *Overview of the DOE's Hydrogen R&D Program: Hearing Before the Subcomm. on Energy of the House Comm. on Sci., Space, & Tech.*, 103d Cong. 131-37 (1994) (testimony of James Birk from the Hydrogen Panel and the Electric Power Research Institute). *See also* Dan Roberts, *Will Hydrogen be the Cheap Fuel of the Future?*, FIN. TIMES, May 12, 2003. Hydrogen can also be used in internal combustion engines. However, this produces nitrogen oxide emissions when nitrogen and oxygen in the air react together at hydrogen combustion temperatures.

15. There is no known way to odorize hydrogen that is used in fuel cells. Sulfur compounds, like those added to natural gas, will poison the platinum and other catalysts used in fuel cells. No known catalyst-safe odorants meet U.S. Department of Transportation (DOT) regulations for water solubility, olfactory delectability, toxicity, and corrosiveness. AM. PETROLEUM INST., FUEL CHOICES FOR FUEL CELL POWERED VEHICLES 11, 13. *See also* Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements, 65 Fed. Reg. 6698, 6729 (Feb. 10, 2000) (to be codified at 40 C.F.R. pts. 80, 85, 86).

16. OCCIDENTAL CHEM. CORP., MATERIAL SAFETY DATA SHEET FOR HYDROGEN GAS (Dec. 6, 2000), *available at* http://www.oxychem.com/products/msds/m1142.pdf (last visited Sept. 11, 2003). "It would be possible for personnel to inadvertently walk into a hydrogen fire or flame." *Id.* at 11. *See also* AIR PRODS. & CHEMS., INC., MATERIAL SAFETY DATA SHEET FOR HYDROGEN (1994), *available at* http://www.airproducts.com/msds (last visited Sept. 26, 2003).

17. This means that electrical devices approved for garages or other work areas where conventional fuels are handled may not be acceptable where hydrogen is handled. 29 C.F.R. § 1910.307 (2003); 29 C.F.R. §

There have been a number of cost studies on the hydrogen economy and infrastructure, but those studies focus on engineering issues (e.g., pipe, pump, or seal compatibility) or financial incentives to attract initial consumers (e.g., tax credits).[18] Safety is rarely addressed in these analyses,[19] and to the extent that it is, it is the *severity* of injury and not the *likelihood* or *frequency* of injury that is considered.[20]

Industrial experience has shown that 22% of hydrogen accidents are caused by undetected leaks,[21] despite the standard operating procedures, protective clothing, and electronic flame and gas detectors provided to the limited number of specially trained hydrogen workers. With this track record, it is difficult to imagine how the general public can manage hydrogen risks acceptably. A wide-scale deployment of these safety precautions would be costly and public compliance impossible to ensure.[22] Hydrogen advocates rely on the development of electronic sensors to guarantee safety.[23] The National Aeronautics and Space Administration (NASA) hydrogen systems are equipped with the most sophisticated (and expensive) electronic sensor technologies.[24] However, NASA safety engineers know that all such sensors are subject to malfunction or improper placement. NASA workers are therefore advised to use

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1926.407 (2003); NAT'L FIRE PROTECTION ASS'N, NFPA 497 RECOMMENDED PRACTICE FOR THE CLASSIFICATION OF FLAMMABLE LIQUIDS, GASES, OR VAPORS AND OF HAZARDOUS (CLASSIFIED) LOCATIONS FOR ELECTRICAL INSTALLATIONS IN CHEMICAL PROCESS AREAS, § 2-4.2 (1997).

18. M. WANG ET AL., ARGONNE NAT'L LAB., TRANSP. TECH. R&D CTR., U.S. DEP'T OF ENERGY, ASSESSMENT OF PNGV FUELS INFRASTRUCTURE, PHASE 2 REPORT (1998). *See also* DIRECTED TECHS., INC. ET AL., HYDROGEN INFRASTRUCTURE REPORT (1997).

19. Hydrogen advocates and the DOE frequently rationalize the safety of hydrogen based upon research by Addison Bain relating to the 1937 Hindenburg accident that occurred in Lakehurst, NJ. The research concluded that the fire was caused by the Hindenburg's painted covering, rather than the hydrogen the airship contained. Mr. Bain's research has not been peer-reviewed and was most widely reported in a 1997 *Popular Science* article. Although the *Popular Science* article presented interviews with engineers who questioned Mr. Bain's conclusions, those criticisms are absent in the lore created by the on-going rationalization. Mariette DiChristina, *What Really Downed the Hindenburg*, POPULAR SCI., Nov. 1, 1997, at 71; *See also* FUEL CELLS, *supra* note 9; ENERGY EFFICIENCY & RENEWABLE ENERGY, U.S. DEP'T OF ENERGY, THE HINDENBURG MYTH, *available at* http://www.eere.energy.gov/hydrogenandfuelcells/codes/safety_feature.html (last visited Sept. 11, 2003); Jacquelyn Cochran Bokow, *Hydrogen Exonerated in Hindenburg Disaster*, HYDROGEN NEWSLETTER SPRING (Nat'l Hydrogen Ass'n), 1997, *available at* http://www.hydrogenus.com/advocate/ad22zepp.htm (last visited Sept. 11, 2003).

20. *See generally* MICHAEL R. SWAIN, UNIV. OF MIAMI, FUEL LEAK SIMULATION, *available at* http://evworld.com/library/Swainh2vgasVideo.pdf (last visited Sept. 11, 2003) (report includes photos of hydrogen flames, taken using a silicon CCD camera, which is sensitive to the infrared (IR) radiation emitted from hydrogen flames that are invisible to the human eye).

21. OFFICE OF SAFETY & MISSION ASSURANCE, NAT'L AERONAUTICS & SPACE ADMIN., SAFETY STANDARD FOR HYDROGEN AND HYDROGEN SYSTEMS – GUIDELINES FOR HYDROGEN SYSTEMS DESIGN, MATERIALS SELECTION, OPERATIONS, STORAGE, AND TRANSPORTATION, A-109 (1997) [hereinafter NASA REPORT].

22. *See generally* Michael P. Maslanka & Theresa M. Gegen, *Employment Law in a Virtual Workplace*, 64 TEX. B.J. 476, 477 (2001) (observing that there are activities that are "[p]erformed by professionals; do not try this at home. . . ."). *See also* Alexander M. Sanders, Jr., *Newgarth Revisited, Mrs. Robinson's Case*, 49 S.C. L. REV. 407, 412 (1998). "This stunt is being performed by a professional. Do not try it at home." *Id.*

23. U.S. DEP'T OF ENERGY, NAT'L HYDROGEN ENERGY ROADMAP 15, 16, 39 (Nov. 2002), *available at* http://www.afdc.doe.gov/pdfs/national_h2_roadmap.pdf (last visited Sept. 11, 2003).

24. NASA REPORT, *supra* note 21, at Ch. 6 & Appendix A6.

a "dry corn straw or sage grass broom" to supplement electronic flame sensors because the fail-safe broom "easily ignites as it passes through a flame."[25] Brooms, used as sacrificial hydrogen flame detectors, are one of only four categories of detection technologies that the rocket scientists at NASA have identified.[26]

Hydrogen technology development programs focus on safety through the use of electronic equipment such as flame and leak detectors.[27] Those programs do not rely on the development of the intrinsic safety features such as the visible flame and distinctive odor that are expected and required for other fuels.[28] Furthermore, these programs do not consider liability costs associated with sensor or alarm failures, or situations where those devices could be ineffective. Liability and safety are, of course, separate and distinct concepts, as any car owner with an unblemished driving record is reminded every time she pays the liability insurance premiums.

In fact, leaks from hydrogen systems are already being reported in public settings. The most recent reported incident involved one of Toyota's fuel cell vehicles that had been leased to the Japanese Ministry of the Environment.[29] That leak was detected by "a strange noise in the car when [the driver] was filling up the hydrogen tank," and not by onboard sensors or alarms.[30] This leak occurred despite certification from the Japanese Ministry of Land, Infrastructure, and Transport that the vehicle was market-ready.[31] Fortunately, no injuries were reported. Nevertheless, Toyota recalled all of its fuel cell vehicles, which were leased to Japanese cabinet ministries and to universities in California.[32]

III.

There are three long established torts that should be considered in the context of possible injuries associated with the hydrogen economy; negligence, products liability, and abnormally dangerous activity.

Negligence refers to injuries that result from a breach of a duty of care.[33] This duty includes situations where "the defendant['s] conduct create[s] a foreseeable zone of risk," in addition to where the defendant could foresee the

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25. *Id.* at 6-8.

26. NASA REPORT, *supra* note 21, at 6-8.

27. The development of "[l]ow cost sensors for detecting hydrogen leaks and other safety related requirements" is the only safety component of the DOE's hydrogen research programs. ENERGY EFFICIENCY & RENEWABLE ENERGY, U.S. DEP'T OF ENERGY, FUEL CELL REPORT TO CONGRESS 16 (Feb. 28, 2003), *available at* http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/fc_report_congress_feb2003.pdf (last visited Sept. 11, 2003).

28. 49 C.F.R. §192.625 (2003).

29. *Toyota Recalls Fuel-cell Cars Due to Hydrogen Leak*, AGENCE FRANCE-PRESSE, May 20, 2003 [hereinafter *Toyota Recall*].

30. *Id.*

31. *Toyota to Recall Fuel-cell Hybrid Cars Due to Hydrogen Leak*, JAPAN TRANSP. SCAN, May 27, 2003.

32. *Toyota Recall*, *supra* note 29.

33. RESTATEMENT (SECOND) OF TORTS §§ 281, 282, 302A, 497 (1965).

performance and cost improvements have been made.[70] What future performance and cost improvements are possible remain to be seen. One thing, however, is certain: with his experience as a practicing lawyer and judge,[71] Sir William would not have ignored liability issues associated with the hydrogen economy. There is no reason why policymakers and technologists should ignore these issues today.

TABLE 1.[72] COMPARISON OF THE OSHA HAZARD RATINGS AND PHYSICAL PROPERTIES OF HYDROGEN AND OTHER FUELS[73]

	Ignition Energy in Air (mJoules)	**Flammability Composition in Air**	**OSHA "Ignitable or Combustible Group" Rating**	**Flame Visibility**	**Odor**
Gasoline	0.24	1.0 - 7.8%	D	Visible	Yes
Diesel		1.0 - 6.0%	D	Visible	Yes
Hydrogen	**0.02**	**4.1 - 75%**	**B**	**Invisible**	**No (not possible)**
Methane (natural gas)	0.29	5.3 - 15%	D	Visible	Yes w/additive
Propane (LPG)	0.26	2.1 - 10%	D	Visible	Yes w/additive
Ethanol		4.3 - 19%	D	**Invisible**	Yes
Methanol		7.3 - 36%	D	**Invisible**	Yes
E85 (85% ethanol + 15% gasoline)		Between M85 and gasoline	D	Good (then decreases)	Yes
M85 (85% methanol + 15% gasoline)		> gasoline	D	Good (then decreases)	Yes

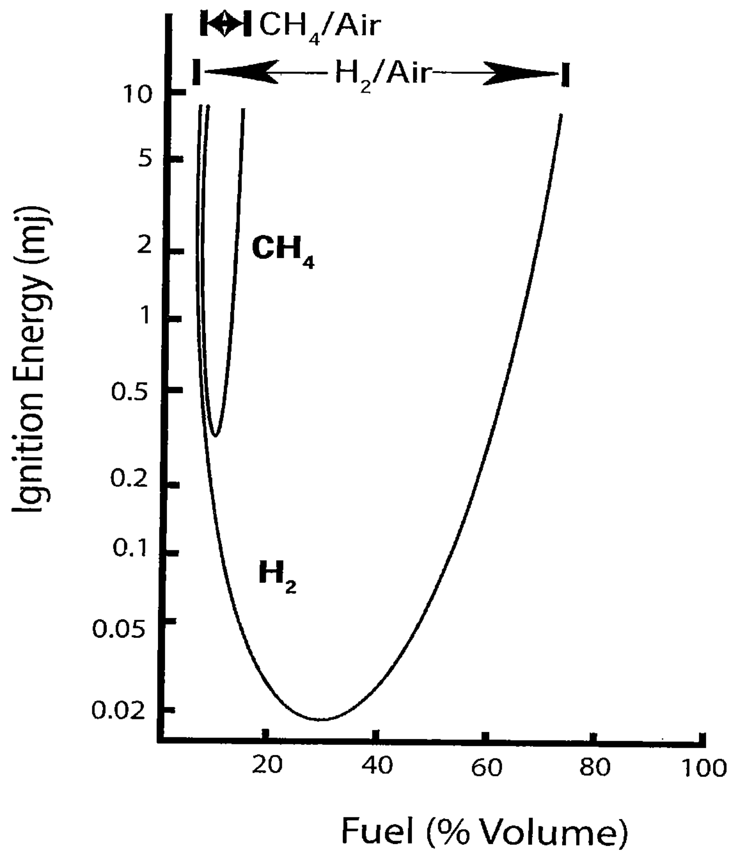
70. 18 ENCYCLOPEDIA BRITANNICA 400 (15th ed. 1992).

71. 5 ENCYCLOPEDIA BRITANNICA 520 (15th ed. 1992).

72. Liability concerns are indicated in bold type.

73. James G. Hansel, Safety Considerations for Handling Hydrogen – A Seminar for Presentation to Ford Motor Co. (June 12, 1998) [hereinafter Safety Presentation]; WALTER PESCHKA, LIQUID HYDROGEN – FUEL OF THE FUTURE 248-86 (Edmund A. Wilhelm & Ulrike Wilhelm trans., Springer-Verlang Wien 1992); RICHARD L. BECHTOLD, ALTERNATIVE FUELS GUIDEBOOK 48, 53, 57, 60, 66 (1997).

FIGURE 1. COMPARISON OF THE IGNITABLE AND COMBUSTIBLE PROPERTIES OF HYDROGEN AND METHANE (NATURAL GAS)[74]



74. Safety Presentation, *supra* note 73; *See also* BERNARD LEWIS & GUENTHER VON ELBE, COMBUSTION, FLAMES & EXPLOSIONS OF GASES 341-61 (Academic Press 3d ed. 1987).

TABLE 2. TRANSPORTATION INCIDENTS INVOLVING HYDROGEN

Year	Location	Deaths	Injuries	Major Hazard	Reference
2003	Japan			Hydrogen Leak from Fuel Cell Vehicle	75
2003	Italy	14	85	Fire	76
2002	Massachusetts		1	Explosion	77
2001	Oklahoma	1	1	Explosion and Fire	78
2000	Indiana			Fire	79
1998	Canada		2 (minor)	Tanker Overturns	80
1998	Utah			Tanker Overturns	81
1996	Florida			Hydrogen Leak	82
1995	New Hampshire			Explosion and Fire	83
1993	New Hampshire		1	Tanker/car Collision (no leaks reported)	84
1992	Israel			Explosion and Fire	85

75. *Toyota Recall, supra* note 29.

76. *Fourteen Dead as Speed and Fog Cause Road Carnage in Italy*, AGENCE FRANCE-PRESSE, Mar. 13, 2003, 2003 WL 2751509 (some of the deaths and injuries were likely due to the crash and not to the hydrogen fire).

77. *Canada Truck Driver Burned in Explosion*, BOSTON HERALD, July 31, 2002, at 14, 2002 WL 4082540.

78. Rod Walton & Ashley Parrish, *Truck Driver Killed in Explosion*, TULSA WORLD, May 2, 2001, at A1, LEXIS, News Library, Tworld File.

79. *Residents Evacuated when Explosion Feared*, EVANSVILLE COURIER & PRESS, Apr. 16, 2000, at B3, 2000 WL 11833234.

80. *London Driver Escapes Serious Injury in Tanker Crash*, LONDON FREE PRESS, Dec. 29, 1998, at A13, LEXIS, News Library, Lfreepress File.

81. Michael Vigh, *Tanker Topples, Shuts Down Portion of I-15*, SALT LAKE TRIB., Dec. 16, 1998, at D2, 1998 WL 21662123.

82. Dale White, *Brainless Visitor Dazzles Students*, SARASOTA HERALD-TRIB., Feb. 9, 1996, at 3B, LEXIS, News Library, Sheraldtribune File.

83. Mark Hayward & Roger Talbot, *Blast Closes Town Down*, UNION LEADER, Mar. 5, 1995, at A1, LEXIS, News Library, Unionleader File.

84. *Car, Hydrogen Tanker Collide*, UNION LEADER, Jan. 20, 1993, at 3, LEXIS, News Library, Unionleader File (injuries caused by collision and not hydrogen fire).

85. Yigal Kotzer, *Hydrogen Canisters Explode in Haifa Blaze*, JERUSALEM POST, Dec. 28, 1992, LEXIS, News Library, Jpost File.

Year	Location	Deaths	Injuries	Major Hazard	Reference
1987	Ohio			Tanker Overturns	86
1987	Louisiana			Fire	87
1984	Maryland			Tanker Overturns	88
1983	Arizona		2	Explosion and Fire	89
1981	Washington			Explosion and Fire	90
1975	Indiana			Tanker Stuck Beneath a Railroad Underpass	91

TABLE 3. FACILITY INCIDENTS INVOLVING HYDROGEN

Year	Location	Deaths	Injuries	Major Hazard	Reference
2002	California			Hydrogen Leak	92
2002	Wisconsin		2	Explosion/Hydrogen Leak	93
2001	New Mexico		1	Balloon Explosion; Damage to Fire Truck	94
2000	New Jersey			Explosion – University Laboratory	95
1999	Finland			Fire/Hydrogen Leak	96

86. Paul Leavitt, *5,100 in Ohio Flee Gas Leak*, USA TODAY, Aug. 26, 1987, at 3A, 1987 WL 4579596.

87. *No Injuries Reported in Waterford 3 Fire*, BATON ROUGE ST. TIMES, Mar. 6, 1987, at 4B, 1987 WL 5026717.

88. Keith F. Girard, *Chemical Concern 200 Evacuated After Md. Truck Accident*, WASH. POST, Nov. 17, 1984, 1984 WL 2007023.

89. *Trouble-shooter*, *supra* note 44 (brooms used to detect invisible flames).

90. UPI, Feb. 26, 1981, LEXIS, News Library, UPI File.

91. *Hydrogen Truck Jammed*, N.Y. TIMES, Mar. 22, 1975, at L19.

92. Robert Airoldi, *Gas Leak Sparks Evacuation of 30 People in East Bay firm: 200 Workers Unable to Leave Businesses in Fremont*, ALAMEDA TIMES-STAR, Sept. 7, 2002, LEXIS, News Library, US Newspapers and Wires File.

93. *Hawthorn Suites Hotel Construction Starts*, WIS. ST. J., May 24, 2000, at 1E, LEXIS, News Library, Wisconsin State Journal File.

94. *City Investigates Balloon Explosion*, SANTA FE NEW MEXICAN, July 11, 2002, at B-3, LEXIS, News Library, US Newspapers and Wires File (firemen were filling latex balloons with hydrogen).

95. Michael A. Wattkis, *Rutgers Explosion Tied to Hydrogen Gas Leak - Newark Lab Reopens After being Cleaned*, STAR-LEDGER, Sept. 20, 2002, 2000 WL 26961003.

96. *Nuclear Notebook*, SEATTLE TIMES, Oct. 5, 1999, at A3, LEXIS, News Library, US Newspapers and Wires File.

Year	Location	Deaths	Injuries	Major Hazard	Reference
1999	India			Fire/Hydrogen Leak	97
1999	Florida	2	49	Explosion	98
1996	Bulgaria		4	Explosion/Hydrogen Leak at Refinery	99
1996	Texas			Fire/Hydrogen Leak	100
1996	New Jersey			Explosion (small)	101
1993	India			Fire/Hydrogen leak	102
1993	Scotland			Hydrogen Leak	103
1993	Canada			Fire/Hydrogen Leak	104
1992	Arizona		1 (minor)	Explosion/Fire/Hydrogen Leak	105
1990	Russia	2	3	Explosion/Hydrogen Leak	106
1990	Florida			Explosion/Fire/Hydrogen Leak	107
1990	New Jersey			Fire	108
1990	Nebraska			Fire	109
1989	California		9	2 Explosions (Chevron refinery)	110
1989	California		2	Explosion/Fire (Shell refinery)	111

97. *Panel to Probe Refinery Mishap*, CHEM. BUS. NEWSBASE: BUS. LINE, May 25, 1999, 1999 WL 20064676.

98. Phil Long & Amy Driscoll, *2 Dead, 49 Injured as Explosion Rocks Tampa Power Plant*, MIAMI HERALD, Apr. 9, 1999, at A1, 1999 WL 8781156.

99. *Bulgaria*, PLATT'S OILGRAM NEWS, Sept. 12, 1996, 1996 WL 13192797.

100. *OSHA fines Champion International*, HOUS. CHRON., July 6, 1996, 1996 WL 5607948.

101. Bob Ivry & Alex Nussbaum, *Generating Fear; Indian Point Casts Nuclearshadow over North Jersey*, THE REC., Apr. 7, 2002, at A1, LEXIS, News Library, US Newspapers and Wires File.

102. *Property and Business Interruption*, WORLD INS. REP., Apr. 9, 1993, 1993 WL 9860904.

103. *Gas Alert at BP Refinery*, THE HERALD, Mar. 26, 1993, at 3, LEXIS, News Library, Non-US Newspapers and Wires File.

104. *Refinery Blaze Forces Evacuation of Reserve*, HAMILTON SPECTATOR, Dec. 16, 1993, at B8, LEXIS, News Library, The Hamilton Spectator File.

105. Carmen Duarte, *Worker Suffers Minor Burns in Gas Explosion at Mobile Lab*, ARIZ. DAILY STAR, Sept. 18, 1992, at B4, 1992 WL 7632385.

106. *Occurrence and Reports: Property and Business Interruption*, WORLD LOSS REP., Mar. 9, 1990, LEXIS, News Library, Major World Publications File.

107. *Fire at Turkey Point Hits Non-Nuclear Area*, J. OF COM., Apr. 12, 1990, at 7B.

108. *Hydrogen Tank Fire Controlled in Kearny*, STAR-LEDGER, July 16, 1990, 1990 WL 3523072.

109. Mary de Zutter, *'Runaround' Upsets Chief Another Federal Probe Unlikely in Arcadian Fire*, OMAHA WORLD-HERALD, Apr. 5, 1990, at 23.

110. Sherry Joe, *Chevron Agrees to Fire Fine OSHA Agreement Drops 109 Alleged Violations*, OAKLAND TRIB., Mar. 20, 1991, at A31, 1991 WL 8223699.

111. *Shell Tells Cause of Big Blaze*, S.F. CHRON., Sept. 19, 1989, at B6, 1989 WL 7168091.

Year	Location	Deaths	Injuries	Major Hazard	Reference
1988	California			Fire (Chevron refinery)	112
1987	Pennsylvania		2	Fire (storage tank)	113
1986	India			Explosion/Fire	114
1985	Iowa		8	Explosion/Hydrogen Leak	115
1984	California			Explosion/Fire/Hydrogen Leak	116

112. *Blaze at Chevron Refinery*, L.A. TIMES, Mar. 13, 1988, at 11, 1988 WL 2285449.

113. *Most Evacuees from Gas Fire in Butler Return to Homes*, HARRISBURG PATRIOT & EVENING NEWS, June 10, 1987, at B13, 1987 WL 2763715 (one of the tanks involved contained liquid hydrogen).

114. *Nuclear Utilities Fight Liability Challenge,* NUCLEONICS WK., Aug. 20, 1987, at vol. 28, no. 34, 1987 WL 2114790.

115. *"Building Coming In Around Me," Worker Recalls*, ASSOCIATED PRESS, July 7, 1985, 1985 WL 2867596.

116. *Nuclear Experts Probe A-plant Leak and Fire*, CHRISTIAN SCI. MONITOR, Mar. 21, 1984, at 2.