**References Validating the Technology of HHO**

The material in these links is very dry. They are scientific papers written for a scientific community. But for those that are interested in the tests done to validate this technology, the results can be found here. Most of these documents are by and for the SAE (Society of Automotive Engineers). The SAE links are to the short abstracts of the paper. At the bottom of the list are references to patents that have been applied for. These patents go back to 1914. This subject is not new!

There are a couple of abbreviations used frequently in these documents: ICE - Internal Combustion Engine, and SI - Spark Ignition; as in an "SI engine".

Cassidy, J.F., “[Emissions and Total Energy Consumption of a Multi-Cylinder Piston Engine Running on Gasoline and a Hydrogen-Gasoline Mixture](http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19770016170_1977016170.pdf),” Technical Note Report # E-9105, May, 1977, National Aeronautics and Space Administration, Washington, D.C.

* Adding hydrogen to gasoline significantly increased flame speed and allows for a leaner air/fuel ratio. All emissions levels decreased at these leaner conditions.

Department of Transportation report, "[Guidelines For Use Of Hydrogen Fuel In Commerecial Vehicles, Final Report](http://www.fmcsa.dot.gov/facts-research/research-technology/report/Guidelines-H2-Fuel-in-CMVs-Nov2007.pdf)", November 2007.

* Gives the guidelines for using hydrogen in vehicles. Includes sections on hydrogen on demand systems.

“[Onboard Generation of Hydrogen-Rich Gaseous Fuels - A Review](http://home.weblung.org/meyer/onboardh.htm),” , Y. Jamal and M.L.Wyszynski, School of Manufacturing and Mechanical Engineering University of Birmingham, Birmingham UK

* Covers the use of hydrogen to lower emissions and increase fuel combustion efficiency. Includes results from numerous researchers.

“[Effect of Hydrogen Enriched Hydrocarbon Combustion on Emissions and Performance](http://www.fuelsaver-mpg.com/doc/other/jacob_wall.pdf),” by Jacob Wall, Department of Biological and Agricultural Engineering, University of Idaho

* Shows research done that demonstrates a reduction in emissions and an increase in performance using hydrogen from electrolyzers.

Allgeier, T., Klenk, M., Landenfeld, T., Conte, E., Boulouchos, K., Czerwinski, J., “[Advanced Emission and Fuel Economy Concept Using Combined Injection of Gasoline and Hydrogen in SI Engines](http://www.sae.org/technical/papers/2004-01-1270),” Publication #2004-01-1270, March, 2004, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline produces improvements in engine efficiency and emissions.

Apostolescu, N., Chiriac, R., “[A Study of Combustion of Hydrogen-Enriched Gasoline in a Spark Ignition Engine](http://www.sae.org/technical/papers/960603),” Publication #960603, February, 1996, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline produces improvements in engine efficiency and emissions, due to accelerated combustion.

Conte, E., Boulouchos, K., “[Influence of Hydrogen-Rich-Gas Addition on Combustion, Pollutant Formation and Efficiency of an IC-SI Engine](http://www.sae.org/technical/papers/2004-01-0972),” Publication #2004-01-0972, March, 2004, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline results in lower emissions and a significant increase in engine efficiency.

Fontana, G., Galloni, E., Jannelli, E., Minutillo, M., “[Performance and Fuel Consumption Estimation of a Hydrogen Enriched Gasoline Engine at Part-Load Operation](http://www.sae.org/technical/papers/2002-01-2196),” Publication #2002-01-2196, July, 2002, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline increases the flame speed at all gasoline air/fuel ratios, so engine operation at very lean mixtures is possible.

Goldwitz, J., Heywood, J., “[Combustion Optimization in a Hydrogen-Enhanced Lean Burn SI Engine](http://www.sae.org/technical/papers/2005-01-0251),” Publication #2005-01-0251, April, 2005, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline can extend the lean limits of the air/fuel ratio.

Green, J., Bromberg, L., Cohn, D., Rabinovitch, A., Domingo, N., Storey, J., Wagner, R., Armfield, J., ”[Experimental Evaluation of SI Engine Operation Supplemented By Hydrogen Rich Gas From a Compact Plasma Boosted Reformer](http://www.sae.org/technical/papers/2000-01-2206),” Publication #2000-01-2206, June, 2000, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline can reduce exhaust emissions and increase efficiency. A large reduction in nitrogen oxide emissions can be achieved without a catalytic converter due to very lean operation under certain conditions.

Henshaw, P., D’Andrea, T., Ting, D., Sobiesiak, A., “[Investigating Combustion Enhancement and Emissions Reduction With the Addition of 2H2 + O2 to a SI Engine](http://www.sae.org/technical/papers/2003-32-0011),” Publication #2003-32-0011, September, 2003, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline resulted in improved engine.

Houseman, J., Cerini, D., [“On-Board Hydrogen Generator for a Partial Hydrogen Injection Internal Combustion](http://www.sae.org/technical/papers/740600),” Publication #740600, February, 1974, Society of Automotive Engineers, Troy, MI.

* A compact onboard hydrogen generator has been developed for use with a hydrogen-enriched gasoline internal combustion engine.

Jing-ding, L., Ying-ging, L., Tian-shen, D., “[An Experimental Study on Combustion of Gasoline-Hydrogen Mixed Fuel](http://www.sae.org/technical/papers/830897),” Publication #830897, April, 1989, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline produces improvements in engine efficiency and emissions due to accelerated flame speed and combustion rate.

Lang, O., Habermann, K., Thiele, R., Fricke, F., “[Gasoline Combustion with Future Fuels](http://www.sae.org/technical/papers/2007-26-021),” Publication #2007-26-021, January, 2007, Society of Automotive Engineers, Troy, MI.

* This paper describes current and future gasoline combustion systems with emphasis on efficiency improvement and emission reduction.

Shinagawa, T., Okumura, T., Furuno, S., Kim, K., “[Effects of Hydrogen Addition to SI Engine on Knock Behavior](http://www.sae.org/technical/papers/2004-01-1851),” Publication #2004-01-1851, June, 2004, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline reduced knock due to accelerated fuel burn and shortened combustion period.

Sjarstrarm, K., Eriksson, S., Landqvist, G., “[Onboard Hydrogen Generation for Hydrogen Injection into Internal Combustion Engines](http://www.sae.org/technical/papers/810348),” Publication #810348, February, 1981, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline showed a potential for very low pollutant emissions with increased energy efficiency.

Stebar, R., Parks, F., “[Emission Control with Lean Operation Using Hydrogen-Supplemented Fuel](http://www.sae.org/technical/papers/740187),” Publication #740187, February, 1974, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline resulted in significant efficiency improvements due to the extension of the lean operating limit.

Tully, E., Heywood, J., “[Lean-Burn Characteristics of a Gasoline Engine Enriched with Hydrogen from a Plasmatron Fuel Reformer](http://www.sae.org/technical/papers/2003-01-0630),” Publication #2003-01-0630, March, 2003, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline extended the lean limit of engine operation, resulting in greater efficiency and reduced emissions, both hydrocarbons and nitrogen oxides.

Conte, E., Boulouchos, K., “[A Quasi-Dimensional Model for Estimating the Influence of Hydrogen- Rich Gas Addition on Turbulent Flame Speed and Flame Front Propagation in IC-SI Engines](http://www.sae.org/technical/papers/2005-01-0232),” Publication #2005-01-0232, April, 2005, Society of Automotive Engineers, Troy, MI.

* Adding hydrogen to gasoline produces lower emissions due to increased flame speed and resultant accelerated fuel burn.

Heywood, J., [Internal Combustion Engine Fundamentals](http://www.amazon.com/Internal-Combustion-Engine-Fundamentals-Heywood/dp/007028637X), McGraw-Hill International Editions Automotive Technology Series, McGraw-Hill, New York, NY, 1988.

* This text, by a leading authority in the field, presents a fundamental and factual development of the science and engineering underlying the design of combustion engines and turbines. An extensive illustration program supports the concepts and theories discussed. It is referenced in many of the papers listed in this document.

Lewis, B., Von Elbe, G., [Combustion, Flames, and Explosions of Gases](http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=5307484), 3rd ed., Academic Press, Orlando, FL, 1987.

* The fundamental principles of gas combustion are. Extensive diagrams, graphs, photographs, and tables of numerical data are provided. Referenced in the links in this document.

Taylor, C. [The Internal Combustion Engine in Theory and Practice](http://mitpress.mit.edu/catalog/item/default.asp?ttype=2&tid=6992), 2 Vols., 2nd ed., Revised, MIT Press, Cambridge, MA, 1985.

* This revised edition of a classic work incorporates changes due to an emphasis on fuel economy and reduced emissions.

**Relevant Patents:**

United States Patent #1,112,188 issued on September 29, 1914 to Leonard Atwood

* A means for improving combustion by mixing different fuels.

United States Patent #1,262,034 issued on April 9, 1918 to Charles Frazer

* A hydro-oxygen generator for use with internal combustion engines.

United States Patent #1,490,975 issued on April 15, 1924 to William Howard

* Improving internal combustion engines by introducing hydrogen gas to increase flame speed.

United States Patent #1,876,879 issued on September 13, 1932 to Walter Drabold

* Improving internal combustion engines by varying the proportions of energized gases to supplement normal carburetion.

United States Patent #2,509,498 issued on May 30, 1950 to George Heyl

* Supplementing the fuel-air mixture in an internal combustion engine by adding oxygen and hydrogen produced by electrolysis.

United States Patent #3,311,097 issued on March 28, 1967 to Georg Mittelstaedt

* Introduction of hydrogen and oxygen produced by electrolysis improves fuel economy, increases power, and reduces emissions.

United States Patent #4,023,545 issued on May 17, 1977 to Edward Mosher and John Webster

* An on-board electrolysis unit powered by the existing electrical system comprises a stainless steel tank, anode and cathode.

United States Patent #6,209,493 issued on April 3, 2001 to Bill Ross

* An on-board electrolysis unit includes a sealed plastic body, reservoir, and shut-offs for low-level, high temperature, and high pressure.