

RUNNING ON WATER: FACTS, FICTION, AND OPPORTUNITIES

Yunus A. Cengel

Professor of Mechanical Engineering
University of Nevada, Reno, USA

ICAD 2000

**International conference on automotive
technology**

Istanbul, Turkey

October 19-20, 2000

THE DREAM MACHINE

- The biggest fascination of PMM proposers has been to invent **an engine that runs on water** to solve the world's energy problem
- U.S. Patent office has stopped issuing **patents** for PPMs in 1918.
- A water engine would save the environment by replacing fossil fuel by water since water is practically free and abundant.
- Some engines are claimed to run on **pure water**. These claims are easy to discard since water itself is a combustion product, not a fuel.
- Others run on a **mixture** of hydrocarbon fuel and water with exaggerated claims on performance. These claims are more difficult to deal with.

MISINFORMATION

- There are several **myths** and fast-spreading **misinformation** associated with the use of water in internal combustion engines
- Hardly any year goes by without a news article in a US or Turkish **newspaper** about an engine invention that runs on water.
- The newsmakers lack a basic understanding of the fundamentals of science, which point out the sad state of **scientific education** in this highly technological world.
- The news media then become the means of dissemination of such misinformation, and **mislead the public** they are supposed to inform and educate
- Such news stories confuse the public make them targets for **deception**.

HISTORY

- Water injection **has long been used** in combustion chambers in some special applications.
- Water has long been sprayed into **furnaces** to control furnace temperatures and thus emissions, especially NO_x.
- It is even used in early **aircraft engines** to raise the octane rating of the fuel, which allowed using higher compression ratios and thus increasing the power output considerably.
- A **10% injection** of water vapor by volume during intake, for example, resulted in up to 4 units of increase in **octane rating** and up to 50% increase in the **power output** [Obert, 1948; Johnson, 1977].

EMISSION CONTROL

- **Recent regulations** that further reduce the allowable NO_x emissions has resulted in renewed interest in water injection to combustion chambers or using water-fuel emulsions.
- Numerous tests have confirmed that water injection or using water-fuel emulsions reduces NO_x emissions significantly.
- A water-gasoline emulsion with just 10% water has caused a **reduction of up to 20% in NO_x** [Nicholls, 1969]. Satpov and Lusho [1982] have concluded that each 1% addition of water to emulsified fuel has reduced the NO_x emissions of SI engines by 1.3%.
- Water has long been sprayed into **furnaces** to control furnace temperatures and thus emissions, especially NO_x.
- It is used in modern **Gas turbines** to control NO_x.

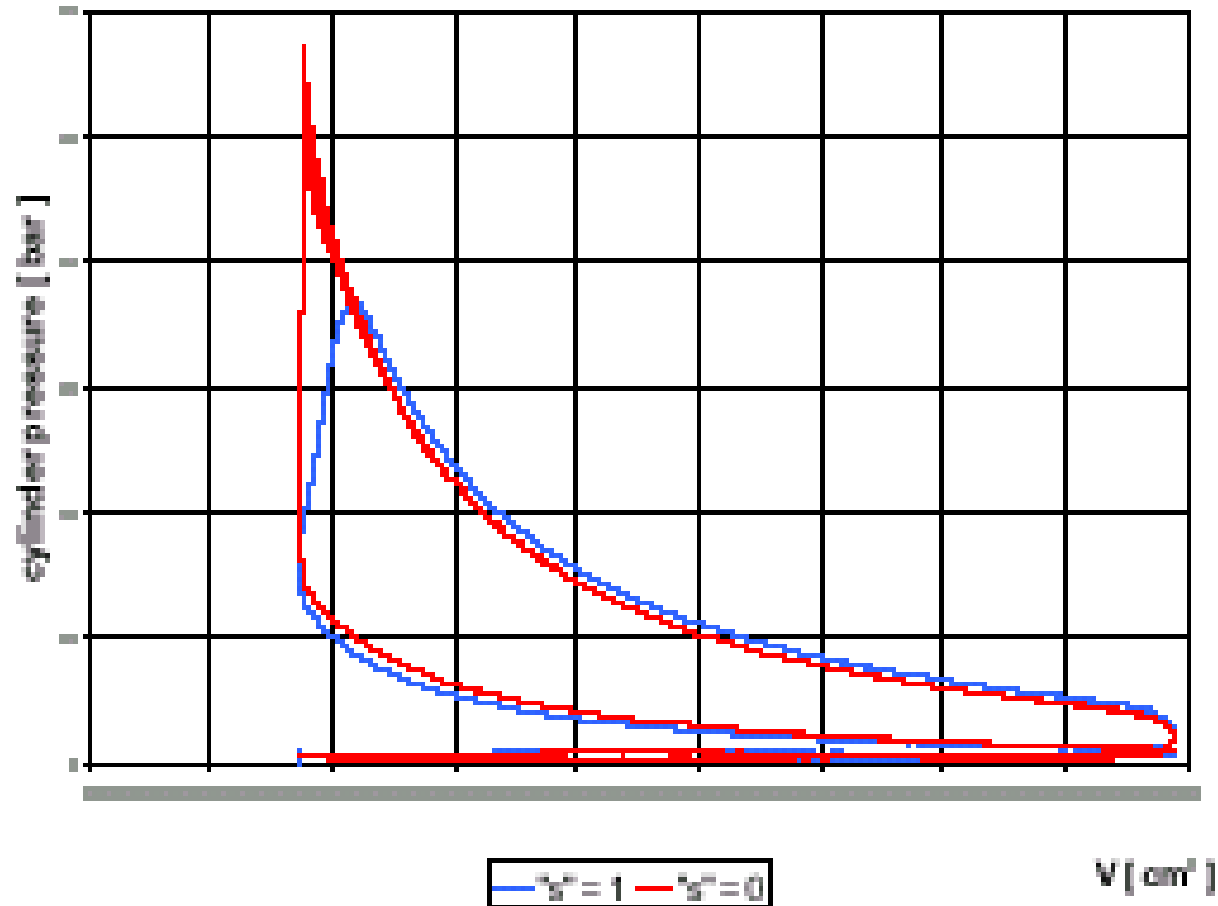
A RECENT INVESTIGATION

- The effect of water-fuel mixtures on engine performance has been the topic of numerous **experimental** and **analytical investigations** [Bassi, 1991; Lanzafame, 1999].
- Lanzafame used a single cylinder gasoline engine to study the **effects of water injection**.
- Water was supplied by a continuous **injection system** equipped with a high-pressure pump. The water was located in the intake manifold downstream from carburetor, shortly before the inlet valve.
- The **ratio** of the mass flow rate of water to the mass flow rate of fuel was varied from $S = 0$ to 1.5 by varying the water supply pressure from 0.5 to 2 MPa. (the value of $S = 1$ corresponds to half water and half gasoline by mass).

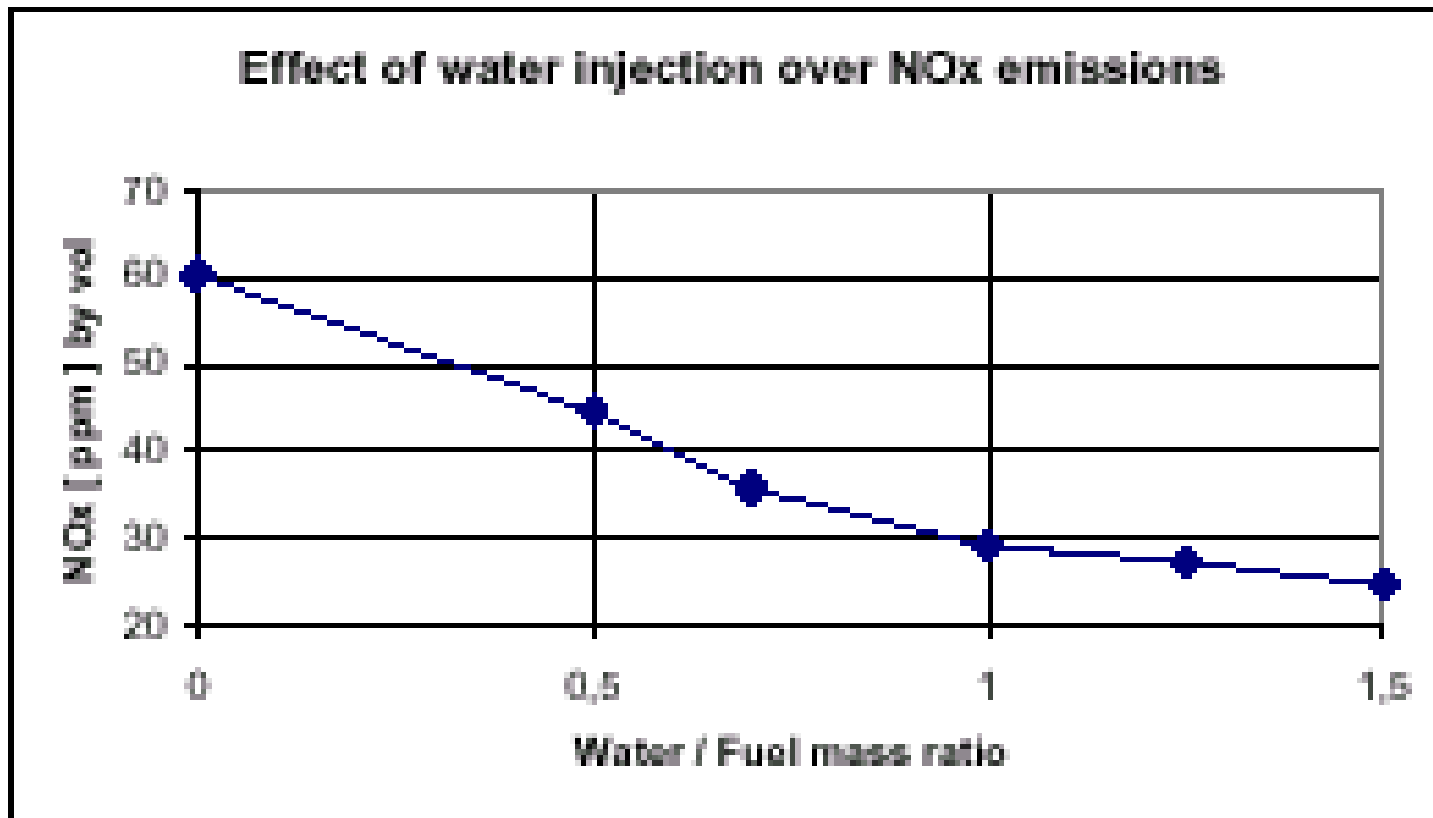
A RECENT INVESTIGATION

- The effect of water injection on various quantities of interest was presented **graphically** by comparing data obtained with pure gasoline and gasoline-water mixture.
- Water injection **increases the octane number** (from 70 to 93 for Research Octane number) and **decreases the amount of NO_x** more than 50% in the exhaust gases.
- Water injection **decreased the CO emissions** in the exhaust gases, more so at rich mixture conditions.
- But it **increased the hydrocarbon emissions** by about 20% when the mass flow rates of water and gasoline were equal.
- The environmental benefits of water injection are more pronounced at higher water mass fractions. However, for a given compression ratio, **the indicated work and thus the efficiency of the cycle may decrease.**

Effect of water injection on the P-V diagram (from Lanzafame, 1999)



Effect of water content on the NO_x emissions of water-injected gasoline engine (from Lanzafame, 1999)



Effect of water content on the anti-knock characteristics of water-injected gasoline engine (from Lanzafame, 1999)



IMPLICATIONS OF WATER INJECTION

- **Environmental impact**

- The growing concern about the environment and the quality of air we are breathing will probably cause the **emission controls** to become even **tighter**.
- It is clear that **water injection reduces the NOx** emissions significantly, and this effect alone may be reason enough to consider water injection in order to meet tighter NOx requirements.
- The experimental **results on the CO emissions are somewhat mixed**, but usually causing a reduction.
- Water emission usually causes the **hydrocarbon emissions to increase**. This is probably due to the decreased gas temperatures and increased thickness of quench layer..

IMPLICATIONS OF WATER INJECTION

- **Octane number**
- Water injection **raises the octane number** of the fuel. This has three profound implications:
 - (1) It can be used as an **inexpensive method** of raising the octane number of the fuel (an alternative to adding anti-knock chemicals to petroleum products).
 - (2) It allows using **higher compression ratios** in SI engines. Using the highest non-knocking compression ratio, the thermal efficiency of the engine and the power output increase, and thus the fuel consumption decreases. This reduces fuel cost.
 - (3) An indirect benefit of increased fuel efficiency is the **reduction in the amount of greenhouse gases** (specifically, CO₂) emitted to the atmosphere.

IMPLICATIONS OF WATER INJECTION

• Engine performance - 1

- The **compression work decreases** when water is injected to the intake pipe. This is due to the cooling of water and the resulting increase in density of the mixture. (A consequence of this is that the maximum pressure at the end of the compression stroke is also lower.)
- The **pressure during the expansion stroke, except the initial part, is also higher.** This is due to the larger amount of gas in the same volume. The net result of these two effects is usually to increase the engine efficiency and power output.
- However, this is **not always** the case .

IMPLICATIONS OF WATER INJECTION

• Engine performance - 2

- Reasons for decline of performance due to water injection:
 - (1) the **pressure at the end of the compression stroke** is lower.
 - (2) The presence of **water slows the combustion process**, and thus the pressure in the cylinder does not rise as much or as fast (thus it is necessary to advance the spark timing to improve combustion). This causes the **average pressure** and thus the work output during combustion to be lower.
 - (3) Water injection **increases the amount of unburned fuel**, as evidenced by an increase in the hydrocarbon emissions. This decreases the amount of gas (and thus pressure) in the cylinder. But this decrease is more than offset by the added amount of water.

IMPLICATIONS OF WATER INJECTION

• Engine performance - 3

- The net result of all of these effects can be a **modest increase or decrease** in performance.
- By careful **engineering of the water injection process**, the performance of the engine can be improved considerably.
- Any significant increase in performance will require **raising the compression ratio** of the engine.
- **Claims of drastic improvements** in engine performance by water injection should be taken cautiously.

IMPLICATIONS OF WATER INJECTION

- **Cold Starts and Warm-up Periods**
- **Cold starts** with emulsified fuels is a problem in winter months.
- It may require the use of a **preheating system** to warm the engine block. This may require a larger battery, and it will require the driver to wait in the cold vehicle for a while before he/she can start the engine.
- The ability to cold start may also **limit the amount of water** in the emulsified fuel.
- The **warm-up period will be longer** with emulsified fuels, and thus it will take longer for the engine to reach peak performance.
- The **direct water injection systems can avoid these problems** by delaying water injection until after the engine warms up.

IMPLICATIONS OF WATER INJECTION

- Freezing of water
- In cold climates, **freezing or gelling** is a serious concern.
- Emulsified fuels can minimize this problem by using some **anti freezing agents in the mixture**, but the direct injection systems will require some measures to be taken.
- Some possible solutions are (1) **adding antifreeze** into the water in cold weather, (2) **draining** the water tank automatically when the temperature drops below a certain value, and (3) **heating the water** using current from the battery.

IMPLICATIONS OF WATER INJECTION

- **Combustion Design**
- The presence of water in the combustion chamber **slows down the combustion process**.
- This **adversely affects the performance** of the engine. Therefore, the combustion chamber and the combustion process **may need to be redesigned**.
- Having **two spark plugs** in the SI engines, for example, may reduce the problem.
- **Preheating the water** with the engine coolant and injecting it into the combustion chamber directly at proper times and amounts may minimize the adverse effects on combustion and the problems associated with direct injection into the cylinder.

IMPLICATIONS OF WATER INJECTION

- Storage of Water
- A disadvantage of water-fuel systems is the **space required** to store water.
- In direct injection systems, there is a need for a separate **water tank**. The size of the water tank should probably be at least **one-fourth of the fuel tank** if it is desired to fill the water tank only during filling the fuel tank.
- Water tank can be placed in the **engine compartment**.
- The tank can be made of **any shape** to occupy an available space.

IMPLICATIONS OF WATER INJECTION

- **Maximum Destination**
- The **direct water injection systems** will not affect adversely the maximum distance a vehicle travels between fill-ups.
- The **emulsified fuel systems** do not require a separate tank, but the capacity of the fuel tank is effectively reduced by one-fourth if the fuel contains one-fourth of water.
- Vehicles on emulsified fuels will need to be **refueled more frequently** unless the performance of the engine improves by a greater fraction when running on the water-fuel emulsion.

IMPLICATIONS OF WATER INJECTION

- Chemical Instability of Water-Fuel Emulsions
 - The engine **fuels and water do not mix**, and thus it is necessary to use some chemicals to bond the fuel with water.
 - The resulting water-fuel emulsion is **not chemically stable**, however, and disintegrates in time.
 - Some emulsions are claimed to remain **stable for several months**, which is adequate for fueling engines.
 - **Direct-injection** water systems do not have this problem.

IMPLICATIONS OF WATER INJECTION



- **Electronic Controls**
- The use of electronic controls had a **profound effect** on engine design, from fuel injection to spark timing.
- Such controls will have **no effect on fuel-water emulsion systems.**
- But electronic controls can be used to **control water injection** to maximize engine performance.

IMPLICATIONS OF WATER INJECTION

- **Public Acceptance and Education**
- The **success of any new product** depends on public acceptance, and education is the key to such acceptance.
- Another key to success is **minimal inconvenience** to the users.
- The sense of responsibility about the environment in the public is on the rise, and the public is receptive to products that are **friendlier to the environment** and preserve the natural resources.
- So far the claims of engines running on water or water-fuel mixtures have been **very deceptive**, and the public at large distanced itself from such products with extravagant claims.
- Public education, credible **demonstration projects**, and **university-industry collaborations** are essential before such products can be marketed successfully.

A STORY FROM TURKEY: *An Invention To Kill For*

- The story in Turkey on water-fueled engines came to the surface in March 2000 after violence that resulted in **one death and two injuries**. At the shootout that occurred in the lobby of **Ankara Hilton hotel**, Ali Tibuk was killed while Nihat Ozbir and Seyithan Nergiz were injured.
- The cause of violence is claimed to be disagreement over the **sharing of the anticipated huge profits** from the manufacture and sale of the water-fueled engine.
- It may also be a **publicity scam** to increase public appetite for this “killer” invention to profit from the sale of dealerships with exclusive rights.
- It appears that some people **made a fortune** selling dealerships.

A STORY FROM TURKEY: *An Invention To Kill For*

- Several newspapers and magazines provided a lot of publicity for this engine, glorifying the hugely exaggerated claims and spreading misinformation.
- Unfortunately, no counter views were presented in the press, and the public was deceived.
- Universities and automotive manufacturers were silent.
- The newspaper articles presented no real technical data and no independent confirmation of the claims.
- It was clear that this was pure sensationalism, and intended to deceive the ignorant public by dwelling on their greed.
- This again shows the importance of scientific literacy to avoid such scams.

A STORY FROM TURKEY: *An Invention To Kill For*

- **Milliyet (14 March 2000):** The fatal shooting caused by “Water.”
- “The attack on Cetin Altan is reported to be over a system that provides **up to 50% fuel savings** on vehicles.”
- “The killing of Ali Tibuk at Hilton is caused by a **water fueled engine** developed and brought to Turkey by an Italian after 25 years of work.”
- “Cahit Dogan said that the system could be used in **helicopters, boats, and any kind of vehicles**. We installed it on 30 vehicles, and realized excellent results. A truck modified with the system traveled from Istanbul to Artvin. The gasoline consumption dropped **from 700 L to just 460 L.**”

A STORY FROM TURKEY: *An Invention To Kill For*

- **Milliyet (14 March 2000) (cont.):** The fatal shooting caused by “Water.”
- “The inventor of the engine Marco explained that a 5-L water tank of any shape is placed in the engine compartment under the hood.
- The water is then supplied to the intake manifold with electronic controls. The water particles that enter an 800°C environment disintegrate and ensure complete combustion of the fuel, providing nearly 50% fuel savings.
- The system **does not pollute the environment, extends engine life, increases torque and speed,** and eliminates the need to replace oil and spark plugs. The system is **tried** on 10,000 vehicles, and passed government inspection in Rome.”

A STORY FROM TURKEY: *An Invention To Kill For*

- Sabah (14 March 2000): Here is the **Engine that caused the shooting**
- “It is becoming more likely that the March 11 shooting at Hilton is planned by some entities that felt threatened by the **engine that works on water**. Nihat Ozbir expressed the **uneasiness of the oil companies** about the project, and said that some groups may be behind the shooting.”
- “Ozbir said that the widespread use of the system throughout the country would **drastically reduce the gasoline consumption**. For this reason, Cahit Dogan, the head of Turkey office of the system, **received a lot of threats**.”

A STORY FROM TURKEY: *An Invention To Kill For*

- Sabah (14 March 2000) (cont.):
- “The system is first used by Germans during the World War II. The conversion kit consists of a system that separates hydrogen from the water and converts it to a fuel. Even the **city water** can be used in the system. One liter of water is needed for every 100 km.”
- “The device that **saves 30 to 60% fuel** and **eliminates almost 100% of air pollution** will be manufactured by RCD with Italian partners Antonio and Marco.”

A STORY FROM U.S.A:

Running on Water-Fuel Mixture

- This story is about a company, now called A-55 Inc., that developed a **water-fuel emulsion** for engines based on a process patented in 1992.
- The company attracted considerable **local, national, and even international attention and press coverage** with its bold claims on efficiency and pollution prevention.
- The company **ran some of its vehicles on the fuel** it developed, with a label "Runs on Water" written on them.
- Some agencies in Nevada and California agreed to **test the fuel** on a few of their vehicles such as **school busses**.
- The fuel contains **20-30% water**, and its effect to reduce the NOx emissions by up to 75% are well documented. The fuel is currently being tested in some power plants.

A STORY FROM U.S.A:

Running on Water-Fuel Mixture

- **Reno Gazette-Journal, May 18, 1992:**
H₂O Makes'em Go
- “A Sparks inventor says he's turned water into motor fuel in a breakthrough that would **increase engine efficiency, save gasoline, and reduce smog**”
- “I have kept it quite,” he said. “People do not believe what I am doing... You ask the **auto companies, they say it is impossible.**”
- “Sparks from catalytic poles in the converted engines break down the water into oxygen and hydrogen, which is burned with the gasoline,” Gunnerman added. “**Hydrogen** has a **higher energy density than carbon,**” he said. “By having that higher energy density you need less to get the same power.”

A STORY FROM U.S.A:

Running on Water-Fuel Mixture

- **Reno Gazette-Journal, May 18, 1992:**
H₂O Makes'em Go
- “He said the conversion cut gasoline use by the Porsche, for example, by more than half, from 20 miles per gallon to about 50 mpg on open highways.”
- “The conversion also sharply reduces emissions of hydrocarbons, carbon monoxide and other tailpipe pollutants, Gunnerman said.”
- “He said he would set up his own shop to offer engine conversions to public if no one else has shown interest in doing the work. Motorists could mix the fuel themselves in their gas tanks, he added.”

A STORY FROM U.S.A: *Running on Water-Fuel Mixture*

- **Reno Gazette-Journal, August 7, 1992: Inventor Fuels Debate.**
- “Being educated in physics, I believe nothing is impossible, if you think it will work,” he said.
- “Some say it could end the U.S.’s reliance on imported oil.”
- “We found that by using 55% water by weight and 45% gasoline we had a fuel which can combust cleanly and is as powerful as gasoline, gallon for gallon,” he said.
- “It also takes a lot of money. In Gunnerman’s case, about \$6 million of his own money from other inventions.”
- “At first, no one in the fuels industry believed the inventor had done what he claimed. “They thought I was a fraud,” he said

A STORY FROM U.S.A:

Running on Water-Fuel Mixture

- Reno Gazette-Journal (May 20, 1996):
Reno Inventor's Fuel Could Cut Gas Use.
- “The technology is not new. World War II fighter pilots could inject water into their fuel for an extra burst of power. Some pilots who compete in the unlimited races at the Reno Air Races use water injection.”
- “Two years ago the RTC (California) ran one of its busses on an earlier version of the fuel for five months. Toward the end of the test, the engine developed compression problems. However, the problem was a common one with diesel engines and could not be traced to the fuel, Harvey said. A-21 inventor Rudy Gunnerman bought the RTC a new engine anyway.”
- “The gas mileage with A-21 is the same as regular gas.”

A STORY FROM U.S.A:

Running on Water-Fuel Mixture

- **Business Week (May 5, 1997):** Would Cars Run Better With Water? Don't laugh. A fuel mixing H₂O and naphtha might just work
 - "He has spent 10 years and \$25 million on the fuel."
 - "Oil companies aren't impressed. "It's curiosity, not a technical breakthrough," says Amoco Corp."
 - "In Australia, Beston-Pacific Corp. of Adelaide recently plunked down \$5 million to license A-55."
 - "Caterpillar teamed up with Gunnerman in 1994, after a Reno city bus had racked up 11,500 miles - with 20% better mileage than it got on diesel fuel."
 - "The claim that A-55 can boost mileage is a sticky point for skeptics."

A STORY FROM U.S.A:

Running on Water-Fuel Mixture

- Reno Gazette-Journal (Oct. 13, 1998):
Public agencies may drop A-55
- “Citifare had used as many as three buses to test A-55’s fuel, but is down to two now and will have those phased out by June.”
- “The school district pared down the test buses from four to two, but A-55 has not been able to fix a series of minor, annoying problems. If we can’t get the bugs worked out of the last two, we may not participate in the program.”
- “Minor problems include sensitivity to temperature extremes. Last winter the fuel gelled up and the buses couldn’t operate in the cold.”
- “Our drivers are becoming frustrated with the problems and we’re concerned about the dependability of the fuel.”

A STORY FROM U.S.A:

Running on Water-Fuel Mixture

- Reno Gazette-Journal (Nov. 20, 1999):
Citifare looking at diesel alternative.
- “A-55 will sell Citifare its fuel to test in buses for 5 cents a gallon less than diesel fuel and will reduce the price accordingly if fuel economy decreases.”
- “Citifare's primary interest in the fuel is pollution reduction, he said.”
- “A-55's business focus has shifted away from vehicle fuels to fuel used in electricity generation, particularly on the East Coast. New air-pollution standards will put pressure on utilities to reduce their emissions”

A STORY FROM U.S.A: *Running on Water-Fuel Mixture*

- From Brochures and Web page of A-55:
- “The A-55 clean fuels achieve not only major reductions in emissions, but at a cost equal to or less than conventional fuels.”
- “Vehicles can be converted to use the fuels without major modification or expense, and with the same or better performance.”
- “The better atomization of the petroleum also can create thermal efficiencies that increase power output from large diesel engines. A-55 offers similar power performance as diesel fuel.”
- “A-55 Clean Fuels also give power producers a competitive edge in the new era of deregulation, because of their ability to employ lower-cost heavy oils as their petroleum base.”

A STORY FROM U.S.A: *Running on Water-Fuel Mixture*

- What a difference 8 years can make:
- **1992**: “The conversion cut gasoline use by the Porsche by more than half, from 20 miles per gallon to about 50 mpg.”
- **2000**: “The A-55 clean fuels achieve not only major reductions in emissions, but at a cost equal to or less than conventional fuels.”

CONCLUSIONS

- Water injection **has long been used** successfully for engines.
- It offers a practical way of meeting the tightening emission controls, especially **NOx emissions**.
- Water injection provides an inexpensive way of **raising the octane number** of the fuel, and it makes it possible to use **higher compression ratios** in SI engines without engine knock, which results in **improved efficiency and higher power output**.
- Engines that run on water-fuel mixtures have the potential to be a viable option in **future vehicles** because of the reduced emissions and better performance.
- Certain **concerns** such as water storage space, precision control of water injection, freezing, impeding combustion, and cold starts need to be resolved if these engines are to find public acceptance and widespread use.