"I believe fuel cells will finally end the 100-year reign of the internal combustion engine."

Bill Ford – Chairman, Ford Motor Company

The Fuel Cell –
Pointing the way to a more sustainable future

The need for clean power

The century-old dominance of the internal combustion engine may be coming to an end as the 21st century world endeavours to come to terms with the challenges of pollution and global warming – and the gradual, though inexorable, depletion of its oil reserves.

Tightening clean-air legislation in the world's major industrial nations has helped curb the growth in emissions of carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NO_x), chiefly through the use of the PGMs platinum, palladium and rhodium in autocatalysts to clean up vehicle exhaust emissions. But because of burgeoning vehicle ownership, particularly in the developing world, and the continuing rise in demand for electrical power, it is proving difficult to reduce total emissions.

In addition, there is the problem of carbon dioxide (CO_2), which is generated by the burning of fossil fuels and by both petrol- and diesel-powered engines – road transport accounts for nearly 25% of CO_2 emissions – and which is thought to be the major cause of global warming. Emissions of CO_2 can be substantially reduced by lower consumption of fossil fuels, allied to changes in the fuel source of road vehicles.

How a fuel cell works

Fuel cells work by combining two of the most abundant of the earth's elements, oxygen and hydrogen, to create a clean source of power and heat. In a fuel cell, electricity is generated via an electro-chemical reaction in which hydrogen and oxygen combine to form water. Hydrogen fuel is fed to the positive electrode (anode), while oxygen is supplied to the negative electrode (cathode). A platinum catalyst on the anode splits the hydrogen into protons and electrons. Electrons flow from the anode to the cathode, generating electricity; meanwhile, the protons travel through an electrolyte to the cathode, where they combine with the electrons and the oxygen to form water.

While there are several types of fuel cell, proton exchange membrane (PEM) technology leads the way in automotive, as well as some stationary, applications. In a PEM fuel cell, the electrolyte is currently a solid polymer membrane made from flurosis resin (though researchers at Japan's Nagoya Institute of Technology have developed a glass-based electrolyte that may in time become the industry standard) that is sandwiched between two electrodes. The electrodes are made from a carbon-based substrate coated with a platinum catalyst.

Fuel cells – the benefits

Fuel cells are in the forefront in man's efforts to develop a clean, efficient power source of the future. Fuel cell technology looks likely to be a principal component of the emerging 'hydrogen economy', bringing about a revolution in the way we power vehicles, houses and offices and house and office equipment. They have the potential to double the efficiency of cars and power generators while drastically cutting down air pollution.

A fuel cell produces virtually no pollution: the only by-product is pure water. The electro-chemical reaction means that fuel cells do not burn the fuel like conventional power sources; therefore, they produce no or negligible exhaust emissions such as NO_2, hydrocarbons and particulate emissions – which cause smog and are linked to serious respiratory disorders, cancer and heart disease. As, the electro-chemical reaction that drives a fuel cell is more energy-efficient than combustion, so CO_2 output is lower too. The fuel

is also free of sulphur – thus, no sulphur dioxide (SO_2) is produced.

The International Platinum Association (IPA) estimates that fuel cells could more than halve CO_2 emissions that arise from coal and other fossil fuels. By the IPA's calculations, fuel cells powered from natural gas-based hydrogen can reduce greenhouse gases, a principal culprit in global warming and overall climate change, by 40% compared with the average petrol-powered internal combustion engine. In stationary applications, the use of fuel cells for combined heat and power generation would bring even more benefits compared with conventional technologies; using co-generation can boost efficiencies of fuel use by around 90%.

Fuel cell technology would simultaneously reduce mankind's dependence on oil, promote the development of renewable energy and cut down greenhouse gas emissions. The US Department of Energy predicts that if only 10% of vehicles in the United States used fuel cells, regulated air pollutants would drop by 1 million tonnes a year and greenhouse gases by 60 million tonnes.

Fuel cell developments

Although very much in the early days of the ramp-up phase to commercial application, by around 2010 fuel cells may start to play a significant role in transport in urban environments. Eventually, too, fuel cell technology will be designed for use with any appliance or system requiring power – from generators to laptop computers. Recent developments include:

Over the next five years, the United States plans to spend $1.7 billion on hydrogen power development under the Freedom Fuel Initiative and the FreedomCar programme;

Japan and China are undertaking practical demonstrations of vehicles, with the Japanese government determined to see sales of commercial hydrogen fuel cell vehicles (FCVs) start in 2005 and have 50,000 vehicles on the road and 2.1 gigawatt installed stationary generation capacity by 2010;

The European Commission has established a new high-level advisory group for hydrogen and fuel cell issues;

Every major auto manufacturer is now investing in the development of commercial fuel cell vehicles. Honda, Toyota, Ford and General Motors have already announced they would begin testing and demonstrating FCVs from 2003. General Motors is planning production-ready FCVs by 2004 and expects to mass produce fuel cell cars by 2010. In a joint venture, Nissan and Renault are investing c. $700 million over the next five years on FCV research. In late 2002, Honda and Toyota delivered the first 'commercial' fuel cell cars to government agencies and universities in Japan and the United States. Ford has announced the fuel cell version of the Ford Focus will be in mass production by 2004, BMW has recently brought out a hydrogen-powered 7 Series, while DaimlerChrysler's FCV NECAR 5 drove across the United States in June 2002;

The European Union has committed to funding research for 27 fuel cell powered buses under the Clean Urban Transport for Europe (CUTE) project targeting nine European cities. This will be the world's largest fleet of fuel cell commercial buses. The first bus was delivered in Madrid in mid-2003;

In Japan, US-based Ballard Power Systems and Osaka Gas are collaborating in the development of stationary PEM-technology generators for residential application. Household-use fuel cell systems are being tested at more than 30 locations across the country;

US-based NEC, a world leader in broadband networking and mobile internet, wants to put fuel cell powered electronic products on the market in 2005. Companies such as Smart Fuel Cell and Toshiba are working on fuel cell powered laptop computers, while Toshiba has announced plans to market a fuel cell powered notebook computer by 2004;

In New York City, the Long Island Power Authority has installed 55 fuel cells to prove the benefits of the new technology.

Sources:
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