TECH BIRIEF

(Nonconfidential)

Eltron Research
& Development

Eltron's New Compact Hydrogen Generation Device

Eltron has recently received funding from the United States Department of Energy to develop a new compact hydrogen generation device. A simplified diagram showing the components of this system is shown in Figure 1. This reactor is based upon a *combination* of several recent technologies that can significantly improve the economics of hydrogen generation. The new technologies included in this reactor are:

1. Eltron's Oxygen Transport Membrane to Separate Oxygen from Air

2. Catalytic Partial Oxidation of Fuel at High Space Velocity

3. Eltron's Hydrogen Transport Membrane That Can Separate Hydrogen From the CO_2 Rich Stream Downstream of the Water-Gas Shift Reactor and Easily Allow CO_2 Sequestration

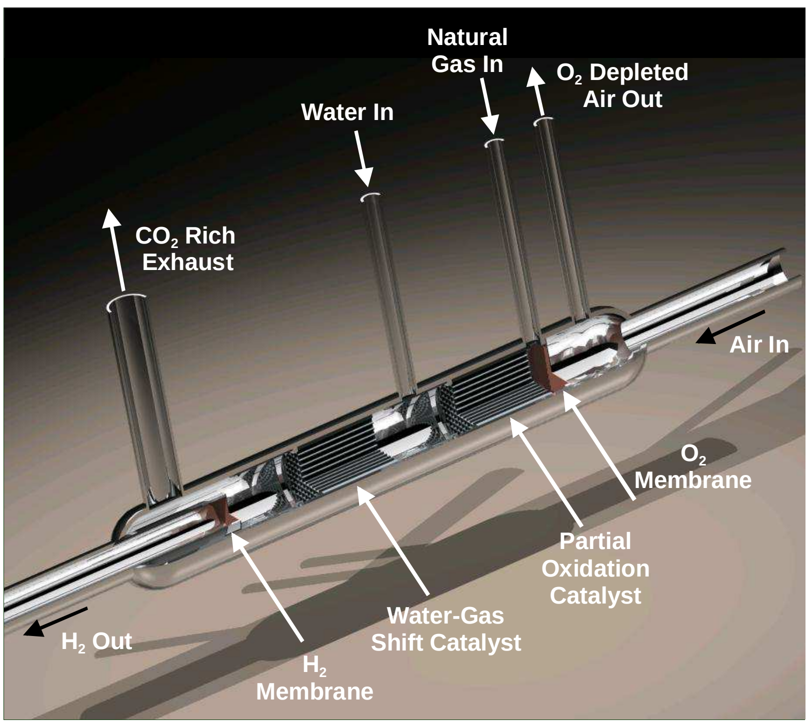

Figure 1. Compact hydrogen generator.

The generation of hydrogen from fossil fuels appears to be the best bridge to the hydrogen economy. However, the efficiency of standard methods to generate hydrogen needs to be improved. Also the need to sequester carbon dioxide from the production of hydrogen is not easily addressed in the current technology.

ELTRON RESEARCH INC. • 4600 Nautilus Court South • Boulder, Colorado 80301-3241
Telephone: (303) 530-0263 • Fax: (303) 530-0264 • e-mail: eltron@eltronresearch.com

The generation of hydrogen from methane proceeds in three modular steps from all fuels with air to hydrogen. First, the fuel and oxygen or air is reacted to produce synthesis gas in the synthesis gas generation module. The synthesis gas is then cooled and fed to a water-gas shift reactor where the CO is reacted with water to produce more hydrogen and CO_2. The hydrogen then must be separated from the primarily CO_2 containing stream by a hydrogen transport membrane.

In current industrial cases,, methane, the main component of natural gas, is steam reformed as follows:

$$CH_4 + H_2O\,(g) \rightleftharpoons CO + 3\,H_2 \quad \Delta H = +206 \text{ kJ mol}^{-1} \tag{1}$$

Heat required for this endothermic reaction in present commercial reactors is obtained by burning natural gas in air to form $CO_2 + H_2O$. Reaction 1 is called the steam methane reforming reaction. It is often performed in reformer tubes where the burning of the natural gas (or fuel gas) provides the heat to drive the thermodynamically controlled steam methane reforming reaction.

The CO formed by steam reforming of methane can be further reacted with steam to form additional hydrogen through the water-gas shift reaction:

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \quad \Delta H = -41 \text{ kJ mol}^{-1} \tag{2}$$

This happens in the CO shift reactor. The exothermic water-gas shift reaction is favored by low temperatures. Inlet gas temperatures in commercial water-gas shift reactors can be as low as 310°C. Exhaust temperatures are typically 420-440°C. Water-gas shift reactors often operate above 31 bar (450 psi).

Although this steam methane reforming process has been commercially performed for number of years, it is not particularly efficient. This is largely due to the endothermic nature of the steam reforming reaction and the indirect heating from the burning of fuel gas and the complexity and expense of the process as practiced.

Compared to Eltron's new technology shown in Figure 1, the current technology is much more complicated. In Figure 1, air is fed to an oxygen transport membrane operated at 800-1000°C. The oxygen is ionically transported across the membrane, where the inside of the membrane is coated with a catalytic partial oxidation catalyst. Fuel, from methane, to LPG, gasoline, or diesel is fed across that membrane face. The partial oxidation reaction occurs and synthesis gas (H_2 and CO) are produced. Liquid water is injected at this point to cool the synthesis gas mixture to about 400°C where the water-gas shift reaction (reaction 2 above) occurs. More hydrogen is produced through the WGS catalyst bed. After the water-gas shift catalyst, a hydrogen transport membrane is used to separate the H_2 from the predominately CO_2 stream. Pure hydrogen is produced and a concentrated CO_2 is ready for sequestration.

We believe that this novel combination of technologies can significantly reduce the cost of hydrogen production and also can provide a CO_2 rich stream ready for sequestration.

Initial development of this new technology is currently under way. We are seeking commercialization and development partners.

If you desire more information, please contact:

David H. Anderson, Chief Engineer
Email: danderson@eltronresearch.com