Center For Hydrogen and Next Generation Energy

A Polycerf, Inc. Project

HYDROGEN - REFUELING STATIONS - FUEL CELL VEHICLES

For several decades, my company Polypack has manufactured industrial packaging machines. Polypack's business is of a highly technical nature, an interest which extends into The Tampa Bay Automobile Museum, which resides on the same property. While this museum seeks to highlight and preserve automotive engineering that was ahead of its time, we also hold an interest in helping to shape automotive technologies of the future.

We are currently working on a project to bring hydrogen fuel cell vehicles to Florida. This is not an easy project; it is much like the old paradox of the chicken and the egg. Fuel cell cars require hydrogen refueling stations. The refueling stations need a steady income in order to survive, which means they need a steady flow of customers to purchase the hydrogen. Which comes first?

Hydrogen as an alternative to fossil fuels is one that is worthy of further development. The only large experiment in USA is located in California, but the results fall short the projections from 2014. There are less than 1,000 fuel cell vehicles on the road; this number is actually closer to 300 or 400 in August, 2016. There are quite a few stations already in operation (there will be 40 by the end of 2016). The California experiment is based on government subsidies. It is not being looked at as a generator of income. It is also unbalanced, with a huge deficit in cars when compared to the number of available refueling stations.

The driving factor for the development of hydrogen as a fuel is the menace of global warming. There are no CO^2 emissions with fuel cell cars and the hydrogen can be cleanly made without creating any pollution. In fact, it is a green, renewable energy source.

1/ Hydrogen Gas

It does not exist in the nature; it is created or extracted by man-made processes. The majority of the gas is made from reforming another gas, such as natural gas or methane. It is sold mainly to the oil industry for the treatment of petroleum products. If the fuel cells are to deliver electricity with a "green" modus operandi, then converting another gas into hydrogen is not a green/sustainable approach.

The "green way" would be to create hydrogen by electrolysis; extracting hydrogen from water with electrical energy. Of course, the electricity will need to have a green origin too. It can come from wind turbines, solar panels, hydroelectric, tidal or geothermal sources.

Electrolysis is the future for the extraction of hydrogen. For the time being we will have to rely on both methods, but the first priority is to develop a network of refueling stations and increase the sales of fuel cell cars.

The hydrogen gas is sold by the kilo. To make one kilo of hydrogen, we need 64 kwh of electricity. With solar panels, the cost of one kilowatt is 6 cents (based on Polypack's experience - we currently 1000

panels on the roof, to be doubled by 2017) resulting in a production cost of $3.84 for one kilo of hydrogen. We must also take into account the operational costs of running the station, performing scheduled maintenance, and also the cost of depreciation on the station.

One kilo of hydrogen is equivalent for the energy content of one gallon of gasoline, but with one kilo, the Toyota Mirai will go 60 miles, which is a better fuel economy than any automobile outfitted with a traditional combustion engine. Hydrogen gas made from another gas, and delivered by truck to the refueling station should have a lower cost, perhaps as low as $3.00 per kilo. Available technologies to reform the gas, as well as the technology of electrolysers are mature, but their efficiencies will get better with time. This will further lower the production costs of hydrogen gas.

2/ Refueling stations

When hydrogen gas is delivered by truck, the gas has to be stored somewhere. As delivered, the pressure is too low to fill the tank of a car (750 bars required for current vehicles). The gas will need to be compressed to fill a secondary storage tank. The pressure inside the tank of the car is monitored and transmitted by infrared to the pump. When the pressure in the tank is equal to the pressure at the pump, the tank is full. Hydrogen fuel cell cars typically have a capacity of 5 kilos for the fuel tank. The refueling time is 3 minutes. The pump is activated with a credit card.

With an electrolyser, only water and electricity are needed. Solar panels are an added benefit, but they require a large area of coverage. With an electrolyser producing only 40 kilos a day (enough to fill 8 tanks each day or 56 cars a week). We will need 40 x 64 = 2560 kwh, or, 106 kwh per hour. It is equivalent to the energy production of 350 solar panels. The 350 solar panels will require 1,100 square meters (almost 12,000 square feet), but the panels will supply energy for an average of less than 5 hours a day. If we need to run the electrolyser full time, we will need more panels and we would also need to send our energy back to the Utility Company (such as Duke Energy). They will ship back the electricity whenever it is needed, either at night or when it is raining. This is the same process we follow for solar power at Polypack. For the time being, it is done at no cost. For an electrolyser running 24/7, we will need 1,680 panels and they can be installed in a progressive fashion as the sales of hydrogen increase. With the first set of 360 panels, we can generate an average of 8 kilos of hydrogen gas per day; this should be enough for 10 or 11 vehicles.

3/ Our goal

A/ refueling stations.

A typical refueling station in Saratoga, California costs $2 million. The station in Saratoga was opened in April 2016. This is for a station that receives hydrogen gas, pressurizes it to 750 bars, and dispenses it. For the full production, pressurization and dispensing of hydrogen gas, we will be designing our own station.

A division of the company running our museum, Polycerf, Inc. is in charge of the project. Through assembly of existing components and the manufacturing of some others (Polypack Inc. has a full shop

with digital machine tools and laser) we will keep the cost of the station to under one million dollars. This cost includes an electrolyser, but solar electrical energy will be purchased from Polypack.

Polycerf, Inc. will design two versions, one with an electrolyser and another one with tanks to be refilled by trucks. We will have the capability of supplying, installing and conducting the maintenance of hydrogen refueling stations for other locations in Florida. Our station will be dependent on the museum and Polypack. In order to decrease associated labor costs, other stations in Florida could be retrofitted to existing conventional gas stations.

B/ The cars

The cost of the refueling station is one hurdle, but the second is the number of cars on the road running off of fuel cells, whose owners purchase hydrogen to provide an income to the refueling station.

We can use an example of a station with a production of 40 kilos per day or 14,000 a year (with 15 days of allotted downtime for maintenance). Those 40 kilos should cover a fleet of 50 or 60 cars. With a ten year depreciation and sales at 50% for the first 5 years, and 100% the following 10 years, the station will dispense 105,000 kilos on ten years. $8 dollars per kilo will guarantee an income of $840,000 to pay for the depreciation of the station.

In reality, the selling price of the hydrogen (cost + depreciation) will be around 13 or 14 dollars per kilo. This is just one estimate, but we have to start somewhere. The station can grow with the addition of a larger electrolyser, and the cost of the station can be also (and should be) lower. In California, Toyota gives a hydrogen gas card to their clients; the card is good for 3 years and $15,000.

There is a way to develop a fleet of fuel cell cars through car-sharing. It is currently done in Munich, with 60 Hunyadi fuel cell cars. The same operation is happening in Paris. Tampa bay would be a perfect place to start a car-sharing program with hydrogen fueled cars. The cost of the hydrogen is supported by the company doing the car sharing and the clients driving the cars will have a credit card. The extra cost of hydrogen will be partially incorporated in the location of the car.

“Operation hydrogen” in Florida does not need the amount of money required by hydrogen stations in California. A more conservative approach should bring fuel cell cars and hydrogen gas to a cost that is affordable for everyone. If this concept takes hold, in a span of one or two years we should see some progress and the widespread acceptance of fuel cell cars in Florida.

Education and pedagogy are essential to the success of “Operation Hydrogen.” A hydrogen showroom will be added to our museum. It will be dedicated to renewable energy, and of course, to fuel cells and hydrogen as a fuel. A demo car will be on-hand to give demonstrations and rides. Some sessions can be organized at least twice a week; on a week day and on Saturday. Colleges, schools, car clubs, etc. will all be invited. Florida will have to move toward renewable energy, which is better in the long range than to continue to accept damage money from oil companies such as BP.

Alain A. Cerf 8/26/2016