ISSN 2347-4289

Novel Technique Of Generating Hydrogen Gas Using Radiowave Energy

Ricardo F. Capistrano

BS Chemistry, M Science University of the Philippines

ABSTRACT: This research revealed that exposure of methane and/or steam to radiowave (*RW*) and microwave (*MW*) energy using copper and rhodium catalysts produced hydrogen gas. The feasible pathways of chemical reactions leading to its production are shown below;
CH_4 + $2H_2O$ +*MW* or *RW* + catalyst → CO_2 + $4H_2$
$4H_2O$ +*MW* or*RW* + catalyst → 2O2 + 4H2
The generation of hydrogen gas was true for both sources of energy whether separately or in combination. The amount of hydrogen produced using *RW* energy was however, greater by more than 53 % as compared to the output of hydrogen using *MW* energy. *MW* at 1,145 W power using 18.3 g rhodium catalyst yielded an average of 15,000 ppm hydrogen. Using *RW* energy, the same quantity of rhodium catalyst net a very high yield of 542,151 ppm hydrogen. Using 153.3 g copper catalyst, *RW* produced an average amount of 30,820 ppm hydrogen gas. The optimum conditions for the above reactions to move forward and yield the highest amount of hydrogen gas, were the following; methane average gas flow rates of 1.0 ml/s, average steam flow rates of 5 g/s, radiowave coil glow time of 1 minute and /or greater , for microwave, time range of 4 to 5 minutes at a power of 500 to 600 W, for *RW* generator, 475 kHz and a coil glow time of 1 minute and higher. In general, methane as well as, steam or in right combinations of both when subjected to *MW* and/or *RW* energy in the presence of catalyst(s) produced hydrogen gas.

Introduction

Taking into account the stoichiometric air – fuel ratio of the currently available fuels, hydrogen has by far the widest air – fuel ratio (1 : 34), and has more than three times higher heating capacity than that of gasoline (Plymouth Univ., 2007). Thus its use as future source of sustainable energy is gaining more and more research and popularity.In fact, almost all automotive vehicle companies worldwide had been consistently testing trial hybrids and/or fuel cell vehicles which has its fuel base on hydrogen.Producing this gas it however, using the traditional Topsoe Steam Reforming process, TSRP (also called Haldor-Topsoe) using natural gas by means of tubular reformer, and partial oxidation of fuel oils and coal require a whole facility similar to an oil refinery in size and engulfs tremendous energy requiring temperature as high as 1,200 ^{o}C. The alternative process is researched herewith by subjecting steam and/or methane to wave energy and catalysts. Various conditions were observed and optimized. The heat supply was via non contact, 'inside out' method as offered by microwave technology and induction heating.

Methodology

The following equipment were used in the conduct of the research;

Equipment	Properties and Specifications
Ammeter	*Escort Digital Ammeter model ECT – 620N*
Analytical balance	*Mettler PC4400 Delta Range, ACS calibrated*
Automatic Signal Scanner	*Dataplex 10 Omega Engineering Inc.*
Flowmeters	*Sho-Rate Flow rate Meter, Model 1355EYZZPGV5A by Brooks Instrument Emerson Co. Range 0 –150 & 0.01-5.0 ml/s*
High Frequency Monitor	*Philips high resolution frequency monitor, model PM 6670*
Microwave oven	*Panasonic NN-S553 Inverter Technology, 1,100 W, 4.9 A, 2,450 MHz, Oven dimension (HXWXD) = 225 X 375 X 386 mm*
Precision RF generator	*Hyforce 6 DMI, 380 – 490 kHz frequency range, Cheltenham 3192 Australia*
Rhodium catalyst	*18.3 g melting point of 1,964 degrees Centigrade*
Steam generator	*Piranha brand model MS-312, 1350 W*
Temperature Monitor	*10 Channel Wide Visibility Temp Monitor, Amalgamated Instrument Co. Pty. Ltd.*
Thermometer, Laser Infrared	*Raytek PM Plus, model RAYRPM20L2G*
Thermocouples	*Type K*
Hydrogen Gas Analyzer	*Drager Hydrogen Monitor, TC detector, with additional oxygen sensor. Sicherheitstechnik Germany GmbH*
Autotransformer	*Variac WIOHMT3 General Radio Co.*

Table 1. List of equipment used

ISSN 2347-4289

The process of subjectingmethane gas and/or steam to these two forms of energy followed the pathways in the experimental rig shown in figure 1 below. Reagent grade methane gas from Liquid Air and steam from distilled water through steam generator quantified precisely by analytical balance, were used. Flow meters monitor the gases passing through catalysts (copper and rhodium) subjected to induction heater and microwave energy. Various conditions likeflowrates, temperature, microwave power, gas combinations and radiowave coil glow time were adjusted to observe the effects on hydrogen gas production. The amount of hydrogen gas produced were measured precisely using *SicherheitstechnikGermany's Drager*hydrogen gas analyzer and monitor with TC detector.

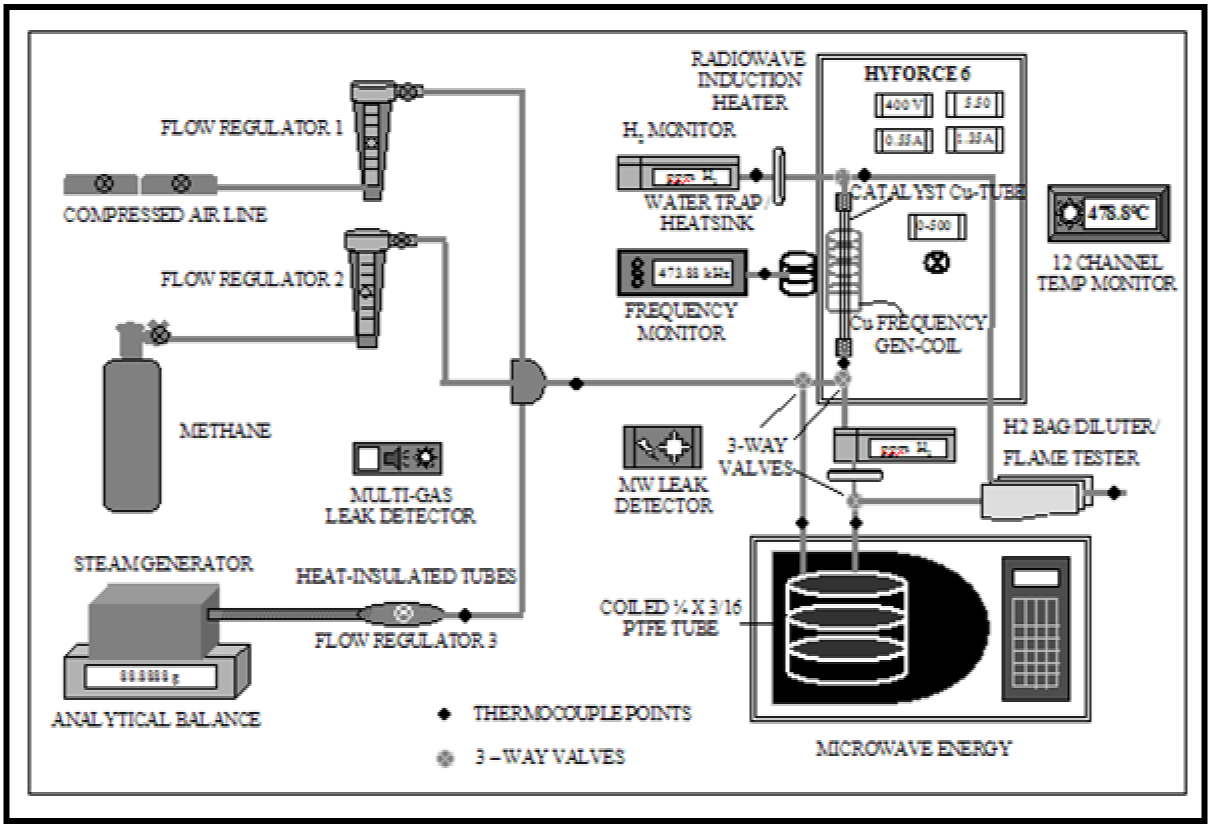

Figure 1. Layout of experimental rig

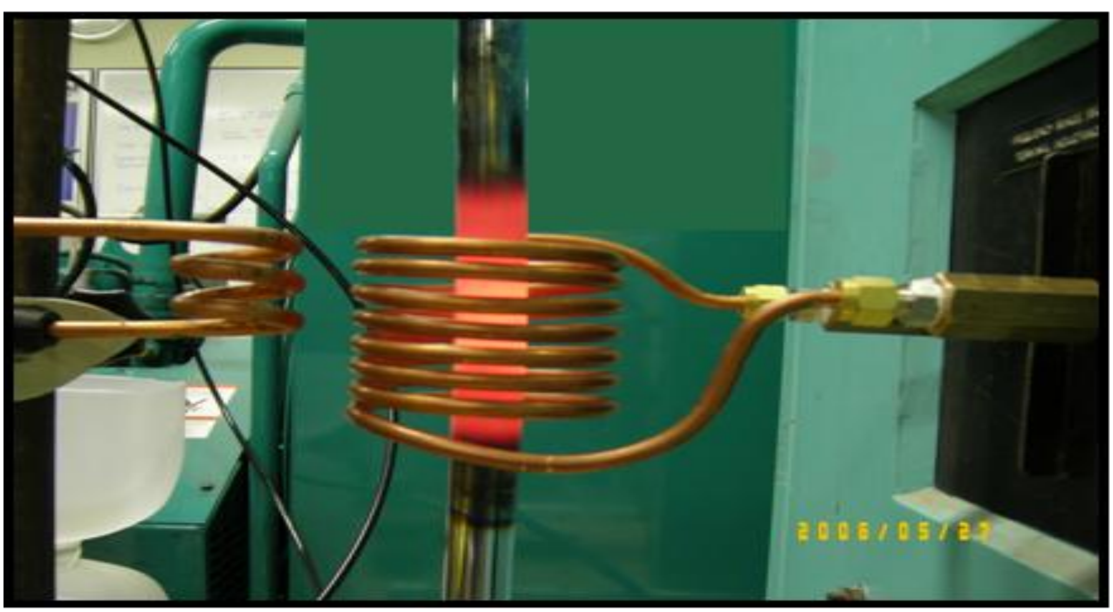

Figure 2 Subjecting the flow of gases through catalysts heated to amber glow by radiowave induction generator.

ISSN 2347-4289

Results and Discussion

Gradually incrementing the time of exposure of 0.1 g/s steam to a microwave power of 1145 W, peak production of hydrogen gas was observed at 5.8 minutes. A maximum 15,000 ppm was measured at the tube output.

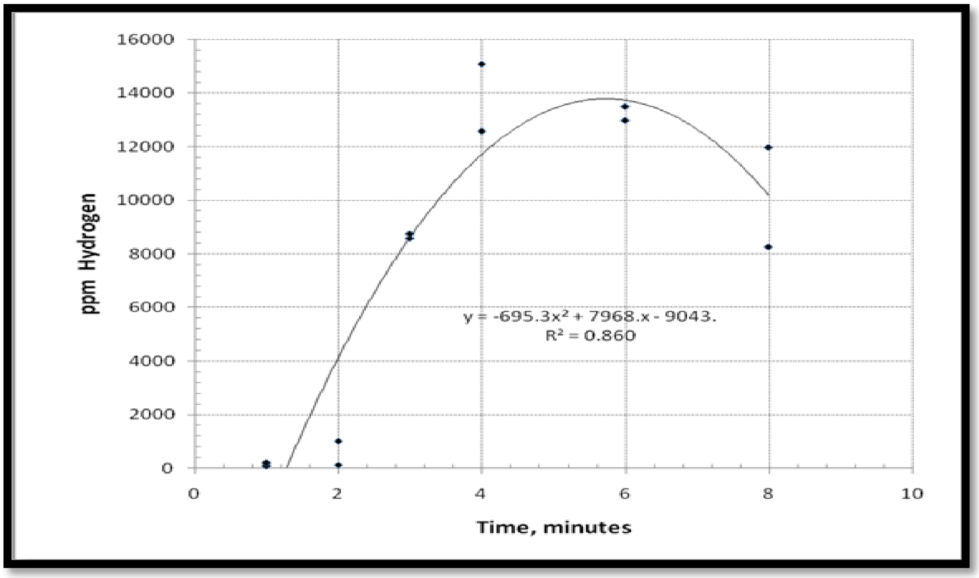

Figure 3 Extending microwave exposure time to know the peak of production of hydrogen. (Power at 1,145W and steam flow rate of 0.1 g/s).

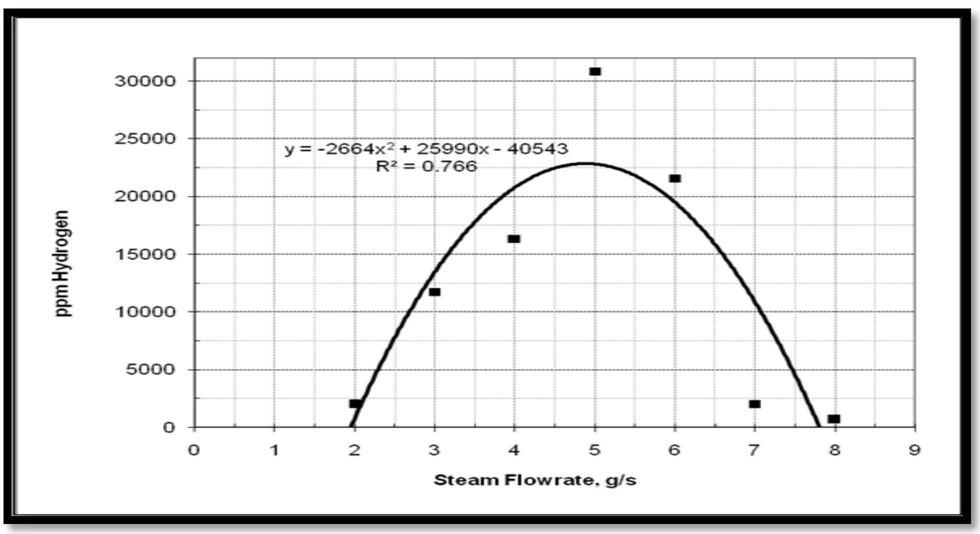

Figure 4. The relationship of steam flow rates with the amount of hydrogen gas generated. (Catalyst = 230 g Cu, Catalyst temperature = 500 ^{o}C, methane flow rate = 5ml/s, Hyforce*RW*Frequency= 473 kHz and coil glow time =1 min.)

ISSN 2347-4289

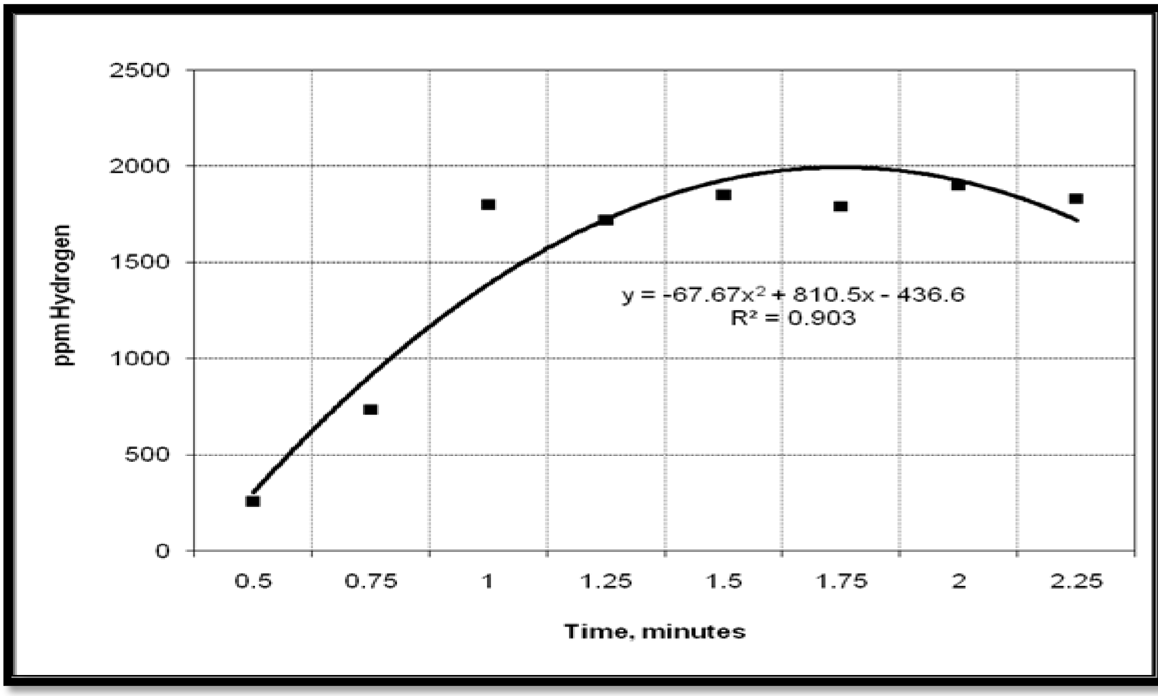

Figure 5. Determination of peak of hydrogen production by varying the glow time of catalyst exposed to 473 kHz radiofrequency. Catalyst = 230 g copper , catalyst temperature = 508 ^oC, air flow rate 10 ml/s and no methane.

E

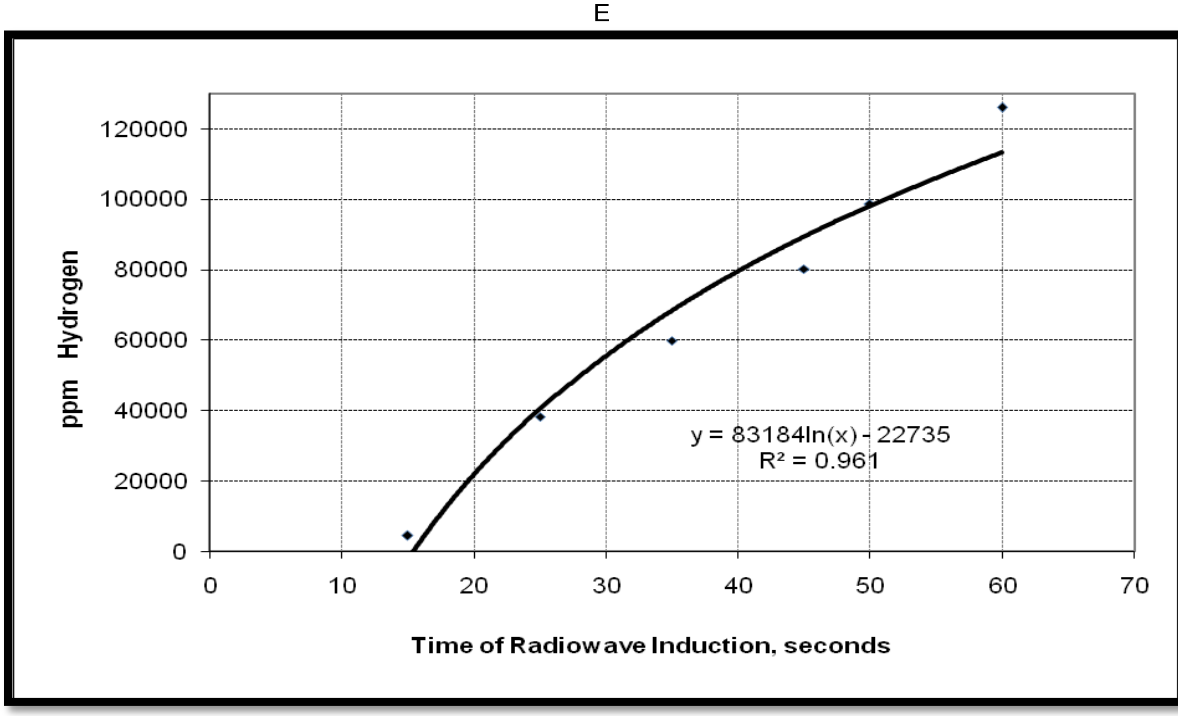

Figure 6. Hydrogen trend was recorded continuously increasing with time of heat Induction or glow time. Steam flow rate 0.059 g/s Catalyst = 18.3 g rhodium ,Catalyst temperature = 475 ^oC, Hyforce frequency = 474 kHz , no air and no methane.

Conclusion and Recommendations

The research have concluded that hydrogen gas can be produced from methane and/or steam using both microwave and radiowave energy sources. Microwave gave peak production of 15,080 ppm. A higher generation of 210, 664 ppm was produced by usingradiowave. Using suppression method by varying reactants, conditions and radiowave generator's parameters, the optimum production of hydrogen was recorded at 542,151 ppm. Base on feasible chemical reaction paths, the research indicated that it follows Rostrup-Nielsen's (1984) methanation reactions (1) and (2), but not reaction (3) in the article, as data collected showed oxygen to even suppress production of hydrogen. The potential likelihood however, of the

ISSN 2347-4289

reaction leading to the optimum production of hydrogen was primarily ;

$$2H_2O + \text{microwave or radiowave energy} + \text{Rh or Cu} \rightarrow O_2 + 4H_2$$

This reaction has never been seen in any literature, but the reactants were known and the products were identified by hydrogen gas analyzer and was validated to support Le Chatelier principle of reactions. It was also highlighted that the addition of small quantity of methane at 1 ml/s, augmented the production of hydrogen tremendously. It is however, recommended that this reaction be authenticatedin further study. The optimum conditions determined for both microwave and radiowave induction energy that produce maximum hydrogen output were namely;

- Rhodium > copper catalyst
- High steam flow rate of 5 g/s and low methane flow rates of 1 ml/s was found optimum gas combination.
- Radiowave coil glowtime of 1 minute or more at frequency of 473 kHz
- Hydrogen peaked at 4 minutes exposure to microwave energy
- Catalyst temperature range of 475 ^oC to 508 ^oC

Whether this is due to temperature or to vibrational spin or both, remains to be validated. One thing is revealed however, it used lower temperature to produce hydrogen as compare to the conventional TopsoeHaldor Steam Reforming process of 1,200 ^oC. The impact of this research, being economical, faster and easier to produce, these two new methods will decrease the cost of hydrogen fuel.The overall contribution of this is that, it scientifically validated that hydrogen can be produced using much simpler method that consumed less energy as compared to the current manufacturing process that uses gigantic facilities. There is also that possibility in the near future, that a reactor following this principle can be incorporated in motor vehicles which can make sea water replace petroleum as fuel. Maybe a possibility of this reactor in tandem with fuel cell reactor built-in fuel cell vehicles, will eliminate hydrogen depot alongside petrol stations. Instead of dwindling petroleum, seawater will just be filled in the vehicle's fuel tank. A sequel and follow up to this research is highly recommended. *The author is the Technical Manager of Sealed Air Inc. Phils. He acknowledged the scholarship granted by AusAid and his Prof. Michael Sek, to do this study at Victoria University in Melbourne, Australia 2006. For communication, he may be reached at his email ric.capistrano@sealedair.com

References

[1] Armor, J.N. (1999) "The Multiple Roles of Catalysis in the Production of Hydrogen". Applied Catalysis A: General 176:p159.

[2] Maiya, P.S., Anderson, T.J., Meiville, R.L., Dusek, J.T., Picciolo, J.J. and Balachandran. 2000)"Maximizing H_2 Production by Combined Partial Oxidation of CH_4 and Water Gas Shift Reaction".Applied Catalysis, A: General. 196(1):pp65-72.

[3] Rostrup-Nielsen, J. R. (1984) "Catalytic steam reforming", in Catalysis science and technology, J. R. Anderson and M. Boudart, Editors. Springer –Verlag :Berlin. p. 1

[4] Plymouth Univ. (2007) " Combustion " (Collaborative Research with NorthAmerican Manufacturing Company).

[5] Praharso, P.(2003) "Autothermal Reforming of Artificial Gasoline". PhD Thesis.University.ofNew South Wales:p14.