Analysis of Gas Condensates-waste from the Gas Industry with Plasmochemical and Manufacture of Hydrogen by Electrolysis of Water

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ABSTRACT
Present the findings of hydrogen production studies on water electrolysis and plasma-chemical processing gas condensate-waste of the gas industry. The electrolysis was exposed to electro-sedimentation of the river water afterwards. It was observed that the surface of electrodes during electrolysis is filled by conglomerates composed of a set of chemical elements owing to the complicated chemical structure of river water. Compared for the use of electrodes made of stainless steel, the threshold voltage is changed to a lower value. A large amount of hydrogen is produced during the electrolysis of electro-sedimented water with the use of electrodes from stainless steel. The key probability of adding low-temperature plasmas to condensate production. Gas condensate pyrolysis with a molecular weight of 140 (C₉H₂₀) and a mean boiling point of approximately 55 °C revealed that in the case of the use of nitrogen as a plasma stream turbulence agent, gas condensate pyrolysis was followed by acetylene (.43 % vol.), ethylene (.5 % vol.), carbon pyrolysis (.67 % vol.)

Keywords—Plasmochemical, Hydrogen, Electrolysis, Electrode, Gas Industry, electrodes.

I. INTRODUCTION
Hydropower accounts for 82 and 96 % of the internal production structure of primary fuel and energy supplies (PFER). However the proportion of hydropower in the total fuel and energy balance structure of the country is now negligible (about 2 %). According to the United Nations Economic Programme for Asia, the revived hydropower capacity in Asia is 460 Bln. KW/h every year and only 10 % is still used. India's hydroelectric power potential is estimated at 148,700 MW at 60 % load factor. In the financial year 2014–15, the total hydroelectric power generated in India was 156 TWh (excluding small hydro) with an average capacity factor of 38.71%. Hydroelectric power stations develop more than 95 % of all electric power in republic. Water resources focuses, basically, on the large rivers – Brahmaputra, Mahanadi, Chambal and others. [1,2]

Climate change is one of the threats facing the whole world, posing a significant danger to both environmental and economic complexes, including water and land supplies. It is clear that the main component in global climate change mechanisms is the accumulation of greenhouse gases in the atmosphere. In 2005, emissions of polluting substances in the Asian zone accounted for the overall value of emissions of polluting substances from stationary sources of gaseous and liquid substances (70.0%). The major air contaminants are particulate matter (35%) and SO₂ (31%), CO₂ (14 %) and oxides of nitrogen (10 %) [3]. The challenge of preserving the atmosphere and reducing the dynamics of global warming encourages alternative and renewable energy studies. Hydrogen power should be considered in this proposal as a possible candidate for filling the electricity market with cheaper and renewable fuels. The current study discusses issues with the usage of water supplies from the upstream countries of the Asian.

II. GENERATION OF HYDROGEN BY WATER ELECTROLYSIS
One of the known methods for the processing of pure hydrogen (99.6-99.9 % H₂) in one technical level is water electrolysis. Ability of the hydrogen production process by electrolysis, calculated mainly by the cost of electricity (85 %). When excess capacity can be used for hydrogen production and storage, electrolysis can be successfully conducted directly at hydropower, thermal and nuclear power plants. Effective electrolysis with a capacity of 1.0 Mln will be used for this purpose. A day, m³ H₂. Water electrolysis on a large plant with a capacity of 450 tons per day and a power consumption of 1 m³ of hydrogen can be achieved with a capacity of up to 4-kWt/h.

At such a cost, electricity will become a competitive method for the processing of hydrogen in certain cases, even under current circumstances, to power the electrolysis of water. The energy consumption for the output of one m³ of O₂ under standard conditions and the potential equilibrium voltage of decomposition of water (1.23 V) will be as follows:

\[ W_T = 1.23(2/26.8:0.0224) = 2.95 \text{ kWt/h} \]

Where, 26.8-number of Faraday's number (A/h) on mole; 2-number of Faradays expended on 1 mole H₂ allocation; 0.0224-volume 1 mol. Hydrogen under natural situations. [4]
At a thermo-neutral voltage of 1.48 V, around 3.54 kWt/h of electrical power is consumed for the output of 1.0 m³ H₂. The actual cost of electrical power for modern electrolysis is up to 5.5 kWt/h per 1.0 m³ H₂. 805 gallons of water is required under standard conditions for the processing of 1.0 m³ H₂ and 0.5 O₂. Gaseous hydrogen is transportable and can be stored in natural underground storage facilities in large amounts. An equal sectional pressure flows into the pipes with the same volume of energy in the form of hydrogen or methane. Pipeline delivery in the form of hydrogen is nearly 4 times more desirable than the movement of the same energy in the form of electricity. 15 trillion kWt/h of hydropower is now generated and used in India, which rises during the summer time. Nowadays however, the use of hydropower is not deliberate. With the implementation of hydropower reform, rising hydropower production has lowered demand by up to 25 %. We will own 6 billion kWt/h of useful hydropower solely for hydrogen gas output. [5]

For us the idea of a hydrogen electrolyses was used, as seen in Fig.1. Electrolysis of water kept from 2.4 to 4.4 V at voltage stamps.

**Figure 1:** Schematic diagram of electrolysis cell. 1 - Cell, 2-electrode holder, 3 – pipe, 4- electrodes, 5 - cell basis, 6- feet, 7-connecting tube

Stainless steel and copper electrodes were used for the electrolysis. The cell’s current-voltage characteristics of stainless steel and copper were significantly different. After the softening process, river water and water are used for electrolysis. It should be noted that when river water was used without treatment, deposition was found on conglomerate electrodes of complex composition and the water electrolysis process was almost not observed. Monitoring of the formation of hydrogen qualitatively determined by the formation of bubbles on the electrode surface and quantified by cell-connected manometer measurement (Fig.1). The formation of bubbles on the electrode surface is known to affect the electrostatic field; decrease the intensity of the field between the plates and the chain current. The external oscillatory device that causes plates to vibrate is typically used to eliminate this effect. Mechanical vibration has been used for removing bubbles from the surface of electrodes. Fig.2 shows the current-voltage characteristic of the stainless steel electrode cell at river water electrolysis and after electro-sedimentation. [6]

**Figure 2:** Volt -ampere characteristic of the electrolyze cell by electrodes from stainless steel at electrolysis of river water (▲) and after its electro-sedimentation (■)

Fig.2 shows that the presence of ions and cations of chemical elements in the composition of non-conditioned river water is the generation of division processes at lower voltage values. The complex physical and chemical studies were carried out for the purpose of determining deposits of components of water composition to change voltage values at electrolysis (Fig. 3). [7]
The composite chemical composition of river water describes the observed conglomerate aggregation mechanism on the surface of electrodes and defines the need for preliminary cleaning for the application of electrolysis. [8-10]

III. PLASMOCHEMICAL TREATMENT OF GAS CONDENSATE

Study on the probability of gas condensate treatment in low temperature plasma for the processing of non-limiting hydrocarbons is dedicated to this work. In nature, gas condensate matches the liquid fraction taken from natural gas (2-6 % by weight at the rate of output of 1.0 t of gas) and in individual deposits. The gas condensates are characterized by a boiling temperature of 60-350 °C, depending on the storage of simple and hard fractions. [11]

Gas condensate plasma chemical pyrolysis expended on plasma chemical machinery. The 'EDP 104' plasma generator runs on a direct current and provides the requisite plasma stream heating regime, as in nitric and air conditions. By means of turbulence stabilization of the arch, the mode of combustion of the plasma arch in near-electrode space was given. In turn, the turbulent gas stream was produced through a ring with four apertures, tangentially guided to the axis, by means of the chamber in the coupling sleeve. Cylindrical flow and cooled reactors with internal diameters of 8-120 mm, lengths of 20-120 mm and a radial supply of raw materials to the heat-vehicle have also been used for this purpose.

IV. RESULT AND DISCUSSION

Gasochromic analysis techniques were used for the detection of the plasmochemical elements, pyrolysis of gas condensate in the plasma stream and its quantitative description. Analysis of gases H₂, N₂, O₂, CH₄, CO, CO₂ expended using "Gazohrom". Using helium as a gas vehicle at the cost of 55-60 sm3. Pure nitrogen, hydrogen, oxygen and methane were used for the "Gazohrom" calibration. Calculation of the concentration of gaseous materials expended on the calibration curve process by comparison of peak portion settlement areas. The chromatograph UX-2 was used to describe the amounts of ethane, ethylene, acetylene, propylene and homologous impurity. For this reason, the dividing column by volume of 150 sm3 filled with a sorbent of 27 % dibutilphatalate deposited on INZ-600 was used. The temperature of the studied column was sponsored at 50°C and the gas-vehicle (helium) cost was roughly 35 sm3/min. [12]

| No. | Parameters | Experiments |
|-----|------------|-------------|
|     |            | 1  | 2  | 3  | 4  | 5  |
| 1   | P, kWt     | 7.6| 8.0| 9.2| 8.8| 9.8|
| 2   | G·10⁻³, m³/sec | 6.7| 6.7| 6.7| 7.0| 7.0|
| No. | Parameters                          | Experiments       |
|-----|------------------------------------|-------------------|
|     |                                    | 1    | 2    | 3    | 4    | 5    |
| 3   | M·10⁻¹, g/sec                      | 6.67 | 5.68 | 5.00 | 5.02 | 7.67 |
|     | T, K                               | 1800 | 2000 | 2200 | 2100 | 2100 |
| 4   | Gas products, % vol.               |       |      |      |      |      |
|     | nitrogen                           | 50.0 | 46.7 | 47.0 | 46.7 | 45.0 |
|     | hydrogen                           | 26.0 | 25.0 | 23.0 | 26.6 | 26.10|
|     | methane                            | 1.39 | 0.80 | 0.40 | 0.10 | 0.20 |
|     | ethane                             | -    | -    | 0.21 | 0.20 | 0.40 |
|     | ethylene                           | 9.20 | 9.60 | 5.01 | 4.60 | 6.80 |
|     | acetylene                           | 10.70| 13.00| 14.39| 12.00| 13.60|
|     | propylene                           | 1.91 | 1.40 | 1.10 | 0.20 | 0.40 |
|     | cyanic hydrogen                    | 3.40 | 4.40 | 8.00 | 9.20 | 6.90 |
| 5   | Total conversion of raw materials  | 92.8 | 94.40| 88.90| 89.6 | 94.2 |
|     | to gas form products, %            |      |      |      |      |      |

**Note:**
P – useful power, G – expense of plasma forming gas, 
M – expense of gas condensate, T- temperature of reaction [13]

Table 2: Results of the plasmochemical treatment of gas condensate in nitric plasma and training of products by stream of initial gas condensate

| No. | Parameters                          | Experiments       |
|-----|------------------------------------|-------------------|
|     |                                    | 1    | 2    | 3    | 4    | 5    |
| 1   | P, kBr                              | 6.9   | 7.2  | 8.4  | 9.2  | 9.8  |
| 2   | G·10⁻³, m³/sec                      | 7.0   | 7.0  | 7.0  | 6.7  | 6.7  |
| 3   | M·10⁻¹, g/sec                       | 5.83  | 6.68 | 5.00 | 5.01 | 5.32 |
| 4   | m·10⁻¹, g/sec                       | 2.50  | 1.70 | 1.70 | 2.00 | 2.00 |
|     | T, K                                | 1900  | 2000 | 2200 | 2200 | 2300 |
| 5   | Gas products, % vol.                |       |      |      |      |      |
|     | nitrogen                            | 50.0  | 49.0 | 44.0 | 47.0 | 48.0 |
|     | hydrogen                            | 14.5  | 15.2 | 20.7 | 20.5 | 18.1 |
|     | methane                             | 4.3   | 4.10 | 2.8  | 2.1  | 2.0  |
|     | ethane                              | 0.4   | 0.50 | 0.4  | 0.3  | 0.2  |
|     | ethylene                            | 12.3  | 13.2 | 10.0 | 9.8  | 10.6 |
|     | acetylene                           | 9.10  | 8.10 | 12.4 | 12.7 | 11.9 |
|     | propylene                           | 2.8   | 3.2  | 2.8  | 2.0  | 2.1  |
|     | cyanic hydrogen                     | 3.0   | 3.5  | 4.2  | 3.6  | 4.8  |
| 6   | Total conversion of raw materials   | 78.0  | 71.0 | 86.0 | 82.0 | 89.0 |
|     | to gas form products, %             |      |      |      |      |      |

**Note:** P – useful power, G – expense of plasma forming gas, 
M – expense of gas condensate, m – expense of raw materials on training, T- temperature of reaction [14]
Table 1 describes the effects of the handling of gas condensates in nitric plasma during the training of reaction products in the heat exchanger housing tubing. We used a method of compulsory training of reaction products by manipulating reaction products by steam initial gas condensate at an exit from the reactor to avoid the provided influence, the results of which are presented in Table 2. [15]

Table 2 shows that the rise in exits of non-limiting hydrocarbons has been observed in the compulsory method of cooling and training of reaction products by raw material steam. It has been revealed that the device operates indefinitely and the procedure is sent to product exit management. When the real energy of the plasma stream is changed from 1.8 to 10.8 MJ/m3 and the parity of the plasma forming gas to raw materials (φ = N2/raw materials) is equal to 0.5 cyanic hydrogen exit (7 % vol.) it is accompanied with no limiting hydrocarbons C2H2 (12 % vol.) and C2H4 (10 % vol.). As a result, the optimum value is achieved at a particular plasma energy of 7.2 MJ/m3. The pyrolysis products contain hydrogen (20-22 % vol.) and homologous impurity in the number of the pyrolysis products (1.5-2.5 % vol.). 25-30 % of the weights were made by the exit of pyrolysis carbon. In the case of an increase of φ per unit at the same basic energy levels, the increase of φ per unit results in a growth of HCN production to 9 % vol. And to decrease the concentration of C2H4 and C2H4 no-limiting hydrocarbons to 8% vol. And, accordingly, 10 % vol. In the case of the use of non-cooled reactors, a drop in the exit of no restrictive hydrocarbons is found and the HCN concentration rises to 10-12 %. Six outcomes of experiments on the effect of particular energy from the plasma stream on the escape of gas condensate pyrolysis target products are presented.

Fig.4 shows that the relative development of the HCN concentration with an increase in specific energy and a decrease in the C2H2 and C2H4 exits was observed at φ = 0.5. Furthermore, if the maximal concentration of HCN at φ = 0.5 leads to higher specific energy values (7.2 MJ/m3), the rise in φ results in the displacement of the maximum escape of HCN to a lower plasma stream specific energy value (5.4 MJ/m3). Pyrolysis carbon exits in recalculation on transformed raw materials at particular energy in non-cooled reactors - 7.2 MJ/m3 correlates to 23-28 % weight. In reactors with compulsorily cooled walls at the same basic energy levels, the weight of the outlet approaches 30 %. It is concerned with the hashing of reagents in the field of target product formation and temperature distribution in the reaction zone of the chemical decomposition of raw materials. [16]

The great effect of the raw materials (IH) in the reactor on the exit of the target items was observed. HCN increases and the escape of the pyrolysis carbon increases...
as the time of stay of raw materials in the reactor concentration increases, but decreases of no limiting properties are seen at the same time. In the opposite, the reactor concentration of cyanic hydrogen decreases and the escape of ethylene and homology impurity increases with the reduction of the length of stay of raw materials. In addition, if gas condensate pyrolysis is followed by compulsory preparation for hydro carbon raw materials, acetylene and ethylene exits are increased along with acetylene impurity homologies. It concerns non-cooled and cooled reactors in which the gas condensate stream is provided for training. The use of a non-cooled reactor on the cooled reactor walls is ideally due to intense soot deposition. Optimal temperature distribution conditions and high-speed fields have been created in non-cooled reactors. Thus, on the basis of the results obtained, it can be argued that pyrolysis of gas condensate in cooled reactors and cyanic hydrogen in non-cooled reactors should be used for the maintenance of the maximum exit of non-limiting products (C₂H₂ and C₂H₄). [17]

V. CONCLUSION

The development of hydrogen energy as an alternative and ecological source of energy. Gas condensate pyrolysis in nitric plasma has shown the fundamental possibility of producing non-limiting hydrocarbons and cyanic hydrogen. The major impact of cooling processes and training on the exit of the target products has been established. The dependence of the %age parity of non-limiting hydrocarbons and cyanic hydrogen exits from the plasma stream is shown by the specific power and time of residence of raw materials in the plasma stream specified in the pyrolysis process management possibilities for maintaining the maximum exit of the separate components of the reaction products.

REFERENCES

[1] Normatov, I., Narzulloev, N., Muminov, A., & Petrov, G. (2013). Estimation of the Carbon Dioxide Formation in Heat-Power Complex of the Central Asia and Prospective of Development of Hydrogen Power Engineering, vol.2B, No 2: 231-239.
[2] http://www.eabr.org.
[3] http://www.hifzitabiat.tj.
[4] Nurmakhamadov, D.N. (2005). International collaboration Ministry of energy of the Republic of Tajikistan about joint use of water- energy resources. Journal Water Resources, No. 2: 35-49.
[5] Kudo, A., Miseki, Y. Heterogeneous photocatalyst materials for water splitting. Chem. Soc. Rev. 2009, 38, 253–278.
[6] Kamat, P.V. Graphene-based nano architectures. Anchoring semiconductor and metal nano particles on a two-dimensional carbon support. J. Phys. Chem. Lett. 2010, 1, 520–527.
[7] H. Matsushima, T. Nishida, Y. Konishi, Y. Fukunaka, Y. Ito and K. Kuribayashi, Electrochim. Acta, 48 (2003) 4119.
[8] Guttman F and Murphy OJ, Modern Aspects of Electrochemistry. New York: Plenum Press, 1983.
[9] Zhang, P., et al., Overview of Nuclear Hydrogen Production Research through Iodine-Sulfur Process at INET, International Journal of Hydrogen energy, 35 (2010 ) 2883 – 2887.
[10] IAEA Nuclear Energy Series, No. NP-T-4.2 Hydrogen Production Using Nuclear Energy, 2013
[11] Status of HTTR Project in JAEA, Hirofumi OHASHI, Technical Meeting on the Safety of High Temperature Gas Cooled Reactors in the Light of the Fukushima Daiichi Accident, 8 - 11 April 2014, IAEA Headquarters, Vienna, Austria
[12] Greg F. Naterer, Ibrahim Dincer, Calin Zamfirescu Hydrogen Production from Nuclear Energy, Springer, 2013
[13] Armor, J. N., “The Multiple Roles for Catalysis in the Production of H2”, Applied Catalysis A: General. 1999; 176: 159-176.
[14] Benemann J R. Hydrogen Biotechnology: Progress and Prospects. Nature Biotechnol 1996; 14:1101–3.
[15] Momirlan M, Veziroglu T N. Current Status of Hydrogen Energy. Renewable Sustainable Energy Rev. 2002; 6:141–179.
[16] Collet C., Adler N., Schwitzguébel J P., Paul Peringer P., Hydrogen Production by Clostridium thermolacticum during Continuous Fermentation of Lactose, Int J Hydrogen Energy. 2004; 29(14):1479-1485.
[17] Oh, Y. K., Kim S. H., Kim, M. S., and Park, S., Thermophilic Biohydrogen Production from Glucose with Trickling Biofilter. Biotech Bioengineering. 2004; 88(6): 690–698.