PLASMA-CHEMICAL DISSOCIATION OF HYDROGEN SULFIDE

D.S. Filatov, S.A.Rakhmanov
Scientific Supervisor: PhD, Associate professor Y.B. Shvalev
Language advisor: Senior teacher N.N. Zyablova
Tomsk Polytechnic University, Russia, Tomsk, Lenin str., 30, 634050
E-mail: fds2517@mail.ru

Abstract

This article summarizes the existing achievements for hydrogen and elemental sulfur production by plasma-chemical dissociation of hydrogen sulfide. Because of the fact that oil and natural gas will soon end, development of environmentally clean hydrogen-based energetic is especially actual. Also possibility of obtaining the elementally pure sulfur, which is used in the wide range of industries from construction to agriculture, looks attractive. During the industrial test a reactor was designed and the parameters, that allow to proceed the hydrogen sulfide dissociation with minimal energy consumption and acceptable yields of the final products, were found.

Keywords: alternative energy, plasma, dissociation of hydrogen sulfide, hydrogen production, plasma torch.

Introduction

It is well known that reserves of natural hydrocarbon fuel will run out in the coming decades. Moreover, already there is an acute problem of the environmental effects of using fossil fuel. In this way introduction of hydrogen as energy carrier becomes very actual. Development of hydrogen energetic and reduction of natural fuels consumption allow alleviating the energy problem in the near future, and afterward when the industrial using of thermonuclear fusion will be disbursed completely solving it. A major challenge for wide industrial use of hydrogen energy in the moment is the lack of highly efficient methods of producing hydrogen. A new approach to generating hydrogen from the hydrocarbon feedstock may be based on the phenomenon of catalytic activity of non-equilibrium plasma in chemical reactions. The aim of this work is to highlight the current developments on the process of energy efficient hydrogen sulphide decomposition using plasma to yield hydrogen gas and solid sulfur.Review of existing methods of hydrogen sulphide dissociation

1.1 The chemistry of the hydrogen sulfide dissociation

First of all it is necessary to consider the process from a chemical point of view. The dissociation of hydrogen sulfide in the thermal plasma consists of the following steps [2]:

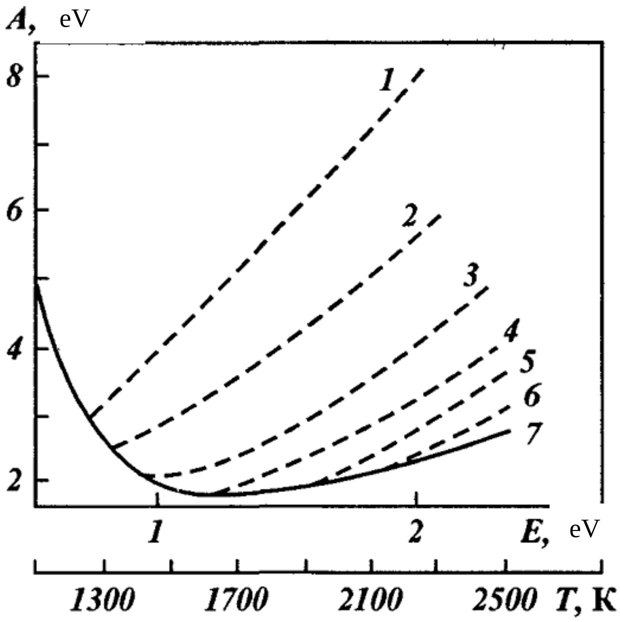
1) $H_2S \leftrightarrow H^\bullet + HS^\bullet - 4$ eV;
2) $H^\bullet + H_2S \leftrightarrow H_2 + HS^\bullet + 0,55$ eV;
3) $HS^\bullet + HS^\bullet \leftrightarrow H_2S + S^\bullet + 0,39$ eV;
4) $S^\bullet + H_2S \leftrightarrow H_2 + S_2 + 1,83$ eV;
5) $S^\bullet + HS^\bullet \leftrightarrow H^\bullet + S_2 - 0,45$ eV;
6) $H^\bullet + HS^\bullet \leftrightarrow H_2 + S^\bullet + 1,12$ eV;

7) $HS^{\bullet} + HS^{\bullet} \leftrightarrow H_2 + S_2$ +2,9 eV;

8) $S^{\bullet} + S^{\bullet} \leftrightarrow S_2$ +4,55 eV;

The mechanism of these reactions is radical.

The dependence of the specific energy consumption A for hydrogen production on specific energy input E (heating temperature) is found on the basis of thermodynamic calculations. This relationship is shown in Figure 1:



1 - ω = 10^1 K / s, 2 - 10^2 K / s, 3 - 10^3 K / s, 4 - 10^4 K / s, 5 - 10^5 K / s, 6 - 10^6 K / s, 7 - 10^7 K / s

Figure 1 - The dependence of the specific energy consumption for hydrogen production on specific energy input (heating temperature) at cooling rates [2]

From the graph in figure 1 we see that at cooling rates of10^7 K / s ideal hardening is observed in the whole range of temperatures actually, i.e. radicals produced during heating recombine into products increasing the hydrogen yield. Moreover, at temperatures corresponding to the minimum energy value (A = 1.8 eV, T = 1700 K), a relatively low cooling speed ω = 10^4 - 10^5 K / s is sufficient to complete stabilization of the dissociation products[2].

2.2 Technological scheme of plasma-chemical hydrogen sulfide dissociation.Pilot production testing of plasma-chemical hydrogen sulfide gases dissociation was implemented in technological development workshop on the court of the Orenburg gas processing plant. All-Russian Scientific Research Institute of High Frequency Current created two plasma-chemical blocks [3]:

- powerof 500 kW and frequency of 915 MHz;
- powerof 600 kW and frequency of 440 kHz.

Block diagram of the experimental-industrial stand with plasma-chemicalunit (power of 600 kW and frequency of 440 kHz) is shown in Figure 2.

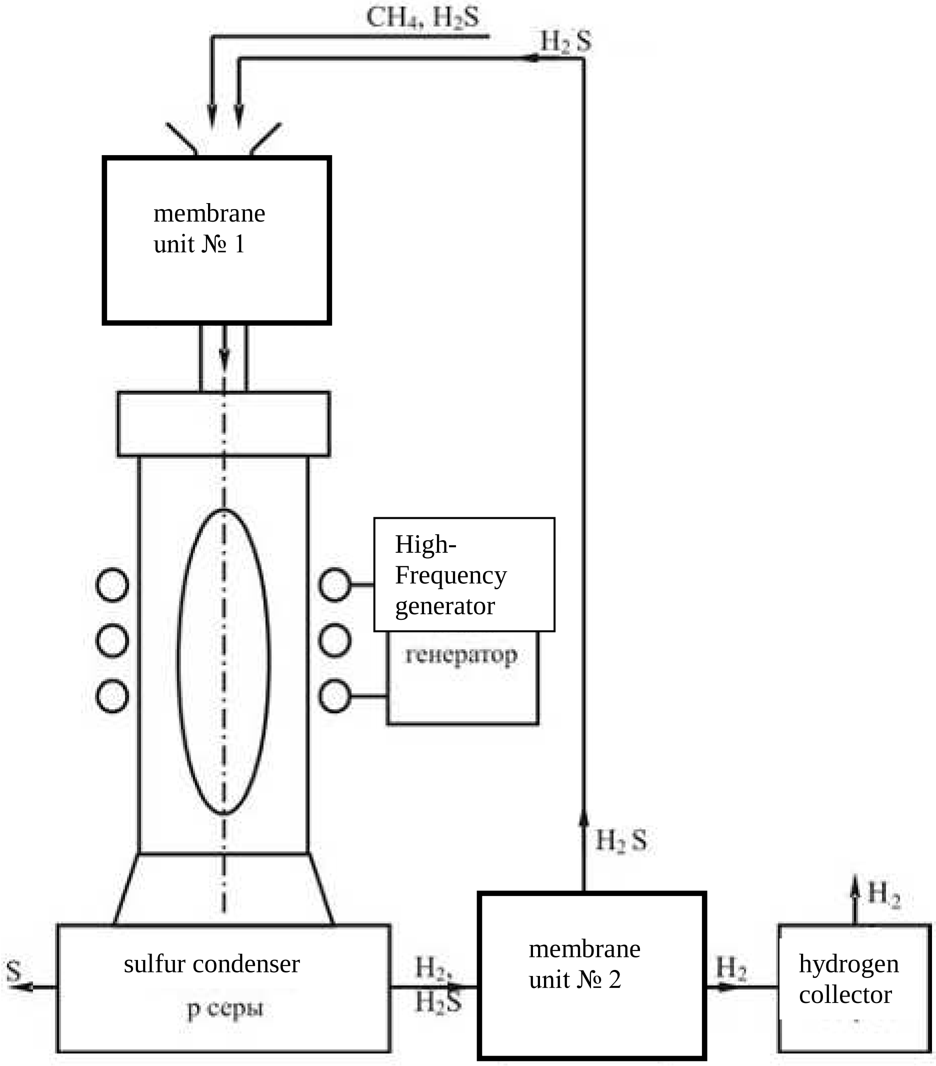


Figure 2 - Block diagram of high-frequency stand for separation and decomposition of hydrogen sulfide [3]

The stand consists of a high-frequency generator with oscillation capacity of 600 kW and the current frequency of 440 kHz, plasma torch unit including a plasma torch, an inductor and the capacitor battery, input (№1) and output(№2) membrane units, sulfur condenser and hydrogen collector. Undecomposed sulfide is directed to recycling.Plasma-forming gas is a mixture of H_2S and CH_4. The discharge initiation is carried under argon atmosphere. In order to reduce power losses structure of a quartz discharge chamber and vortex stabilization of discharge (shown in Figure 4c) is used in the plasma torch. The outer diameter of the pipe is 180 mm, length is 750 mm.Plasma-forming gases are supplied through 32 tangential holesthat are made in gas-forming head of the plasma torch [3]. When designing high frequency (HF) power plants with induction plasma important task is minimizing the ohmic losses in the inductor, which can be 10 percent or more of the output HF power unit (that is unacceptable in terms of energy). All-Russian Scientific Research Institute of High Frequency Current designed and manufactured inductor (shown in Figure 7), which litzcurrent source was applied in.

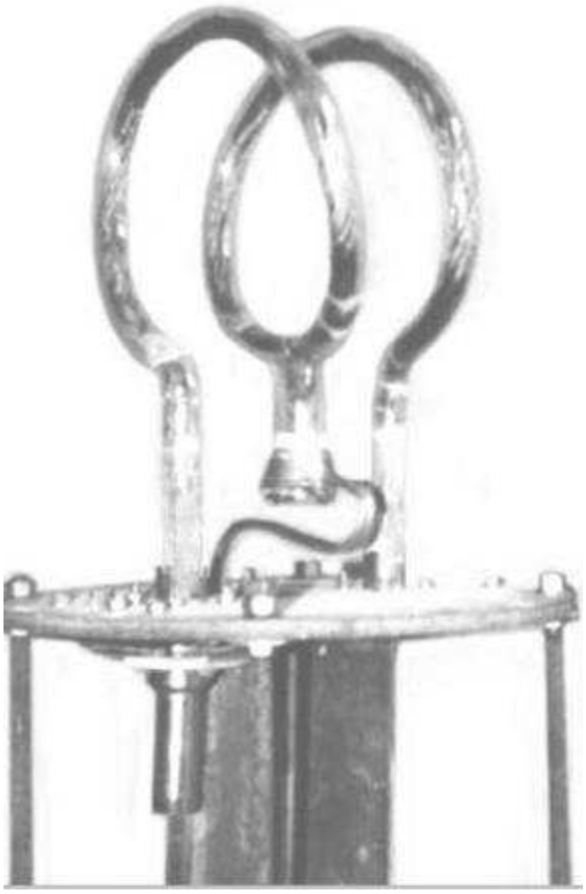


Figure 3 - General view of litz inductor [3]

In this case single conductor (tube) of inductor is replaced by a multi-conductor system consisting of a large number of parallel thin wires intertwined to ensure flow of current across the entire cross-section of each conductor.Calculations and tests of inductor have shown that the ohmic losses are reduced to 7 times or more as compared to an inductor made of a copper pipe [3]. Difficulties encountered when creating litz inductor is to choose a dielectric material for water-cooled cover, which current carrying is lived in. Shaped quartz was used in the made inductor. On plasma-chemical unit of Orenburg stand the interaction of individual basic units and stand together were worked, was confirmed low level of energy consumption for plasma-chemical conversion process of hydrogen sulfide gases as using UHF and HF plasma equipment at 1 kW·h for a 1 m^3 of hydrogen and 1.4 kg sulfur [3].

Conclusion

Currently, hydrogen sulfide is considered useless component of crude oil which is not used. However, the depletion of oil and the switching to hydrogen fuel is a matter of time only. This method of hydrogen production is energy efficient and suitable for engraining, also a sulfur by-product may be used in civil engineering as the additive to concrete. The method needs to be working out to search for optimal parameters of plasma and hydrogen sulfide flow, but now it is suitable for use.

REFERENCES

1. Verzhichinskaya S. V. Khimiya i tekhnologiya nefti i gaza. – M.: FORUM, 2009. – 400 s.
2. Murin V. I. Tekhnologiya pererabotki prirodnogo gaza i kondensata. – M.: OOO «Nedra-Biznestsentr», 2002. – CH. 1. – 517 s.
3. Vysokoeffektivnyye plazmennyye tekhnologii dlya neftyanoy i gazovoy promyshlennosti / V.N. Ivanov, B.M. Nikitin // Ekspozitsiya neft' gaz. – 2010. - №7. – S. 13-17.
4. Neorganika (Tom 2) / L. Koldits, G. Blyumental', Engel's Z.
5. Khimicheskiy demonstratsionnyy eksperiment - M.: Vysshaya shkola, 1969. - 248 s / Ivanova MA, Kokonova MA
6. Vvedeniye v vodorodnuyu energetiku / E. E. Shpil'rayn, S. P. Malyshenko, G. G. Kuleshov
7. Okislitel'nyye protsessy otchistki prirodnykh sernykh gazov i uglevodorodnykh kondensatov / G. A. Agayev V.I. Nasteka, Z. D. Seidov.