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The development of new small-scale processes based on the partial oxidation of hydrocarbon gases.

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Highlights

- New effective low-scale technologies for gas processing and transportation.
- Matrix conversion allows very high productivity and low cost of operation.
- The development of alternative ‘‘without syngas’’ GTL routes via direct partial oxidation or oxy-cracking of hydrocarbons with the subsequent catalytic conversion of oxidation products.

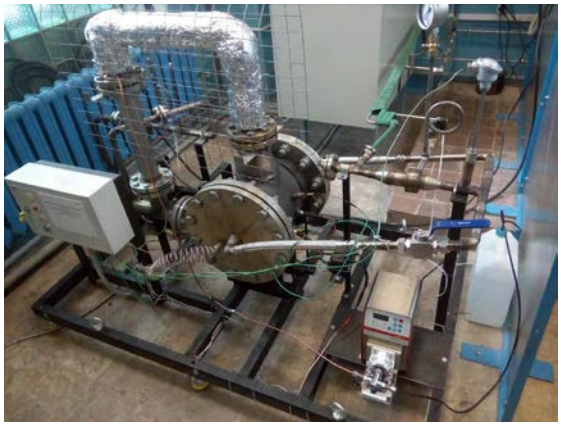
1. Introduction

There are two principal ways to develop more effective natural gas conversion processes. The first one is the elaborating of less expensive and energy consuming methods of natural gas conversion to syngas. The second is the developing of effective methods of direct conversion of hydrocarbon gases into chemicals and liquid fuels. We will consider the both possibilities based on the partial oxidation of light alkanes because this exothermic reaction in both cases let to develop compact and energy effective autothermal processes without additional consumption of external energy.

2. Methods

A very promising way to increase the efficiency and flexibility of the conversion of hydrocarbon gases into syngas is the gas-phase combustion of very rich hydrocarbon-air or hydrocarbon–oxygen mixtures in volumetric permeable matrixes [1–2]. The matrix reformer (Figure 1) has two symmetrically situated matrix units that include flat round matrix with diameter 200 mm and thickness 8 mm fabricated from pressed twisted Chromel wire.

a)



b)

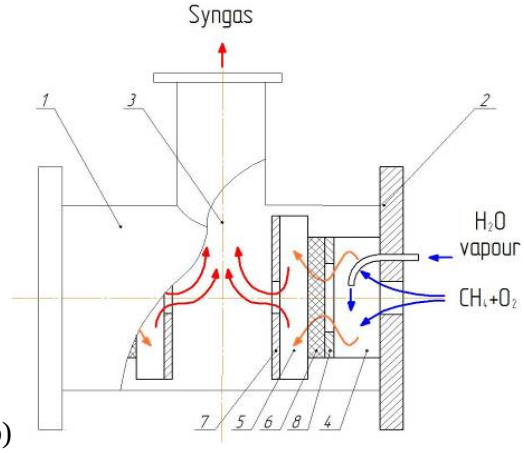


Figure 1. General arrangement (a) and the scheme of inner construction (b) of matrix reformer for natural gas conversion into syngas with enriched air and oxygen. Natural gas flow up to 10 m^3/h. 1 - core vessel; 2 – flange; 3 – discharge nozzle; 4 – mixing chamber; 5 – combustion chamber; 6 – matrix; 7 – radiation screen; 8 – inlet aperture.

The mixture of methane, oxidizer and vapor enters the reformer via one or both side flanges. Approximately 20 mm after exit side of the matrix the perforated stainless steel screen to reflect IR radiation of the flame front back to the matrix was installed.
A general scheme of the new type of GTL-processes without syngas, some of the possible chemicals that can be thus obtained, most effective catalysts, and reaction conditions are presented in Figure 2[3].

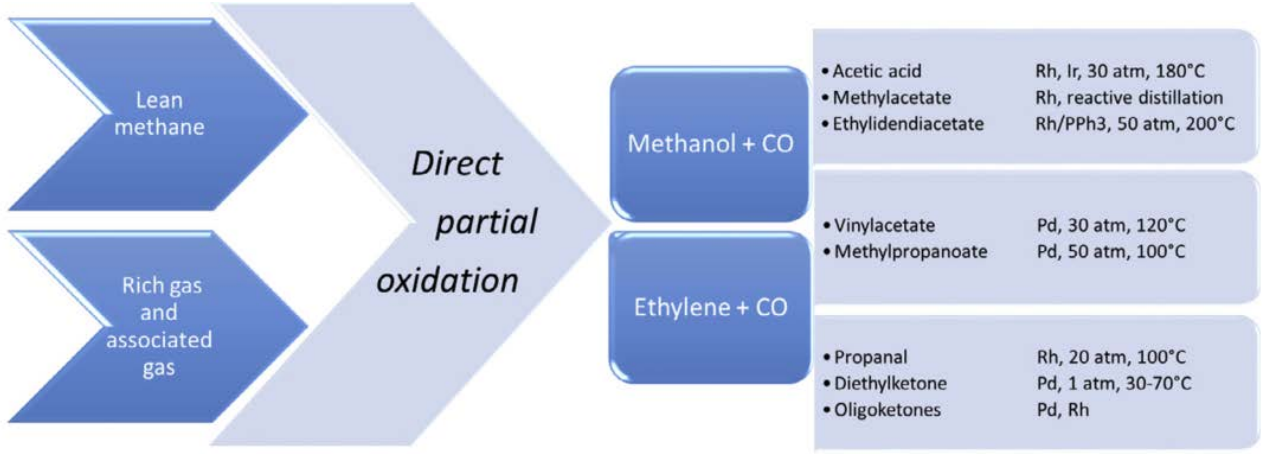


Figure 2. Scheme of new type of GTL-processes based on partial oxidation of natural gas.

The direct partial oxidation and oxy-cracking of hydrocarbon gases give, respectively, mixtures of oxygenates, mainly methanol, with carbon monoxide and light olefins, mainly ethylene, with carbon monoxide. The assortment of chemicals obtained from natural gas by partial oxidation can be significantly enlarged by means of the subsequent catalytic carbonylation and/or oligomerization of the oxidation products, including the co-polymerization of ethylene and CO. It possible to produce a wide variety of valuable GTL products, many of which can be directly used in oil and gas production, transportation, and processing, as well as fuel additives.

3. Results and discussion

Although the process of matrix conversion methane to syngas is only under development, it was already have been shown the possibility to achieve natural gas conversion as high as 90 % with concentration of H_2 up to 54 %, that of CO up to 31 %, and H_2/CO ratio up to 1.8.
We carried out a pilot test of oxy-cracking of modeling associated petroleum gas and identified the main kinetic regularities of partial oxidation of hydrocarbon gases.

4. Conclusions

The principally new type of non-catalytic matrix reformers for the conversion of natural gas into nitrogen-free syngas and hydrogen was developed.
New type of alternative GTL technologies based on the direct partial oxidation of hydrocarbon gases and subsequent carbonylation of products in the presence of platinum group metals catalysts has been proposed. We believe that the absence of the expensive step of syngas production can significantly decrease the capital investment in comparison with traditional GTL.

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Keywords
"Natural gas", "matrix conversion", "partial oxidation", "GTL".

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Education

PhD, Kinetics and catalysis, 2016

Work and research experience:

Development efficient small-scale technologies for hydrocarbons processing - natural gas, associated petroleum gas (APG), biogas, gases of oil refinery and etc. These technologies are based on gas-phase partial oxidation of light alkanes namely:

- matrix conversion of hydrocarbon gases to syngas;
- direct oxidation of methane or heavy alkanes of hydrocarbon gases to methanol;
- oxy-cracking of heavy components of hydrocarbon gases to olefins and CO.

Development and laboratory experimental verification of detailed kinetics schemes of light alkanes C_1-C_5 oxidation. Designed, developed and modeled using detailed kinetics scheme of light alkanes oxidation three pilot installations for matrix producing synthesis gas, capacity 20 m^3/h, 10 m^3/h, 1 m^3/h and one installation of methanol production, capacity of natural gas up 300 m^3/h.

List of publications and talks:

1. Savchenko V.I., Arutyunov V.S., Fokin I.G., Nikitin A.V., Sedov I.V. (2017). Adjustment of the fuel characteristics of wet and associated petroleum gases by partial oxidation of C_{2+} hydrocarbons. Petroleum Chemistry, Vol. 57, No. 2, pp. 177 - 185.
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13. V.S. Arutyunov, V.I. Savchenko, R.N. Magomedov, A.V. Nikitin, I.G Fokin. New conception for low-scale GTL. XXI International Conference on Chemical Reactors "CHEMREACTOR-21", 2014, Delft, The Netherlands.
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15. A.V. Nikitin, V.S. Arutyunov, V.I. Savchenko, I.V. Sedov, V. Shmelev. Small-Scale Production of Syngas from Associated and Natural Petroleum Gases. Digital proceedings of the 8th European Combustion Meeting, 18-21 April 2017, Dubrovnik, Croatia.
16. V.S. Arutyunov, V. Shmelev, V.I. Savchenko, I.V. Sedov, A.V. Nikitin, O.V. Shapovalova, L.N. Strekova. Matrix Conversion of Natural and Associated Oil Gases to Syngas – New Developments and Possibilities EUCASS, The European Conference for Aeronautics and Space Sciences 2017 Italy

List of awards:

1. Scholarship of the President to the PhD-students studying on specialties or areas corresponding to priority directions of modernization and technological development of the Russian economy 2014/2015
2. Diploma IUPAC. Winner of The International Chemical Assembly. Green chemistry-ICA 2014.
3. Diploma and bronze medal of the XIX Moscow international salon of inventions and innovation technologies "Archimedes - 2016". Development: "Device of synthesis gas generating".