Matrix conversion of natural gas to nitrogen-free syngas.

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Highlights

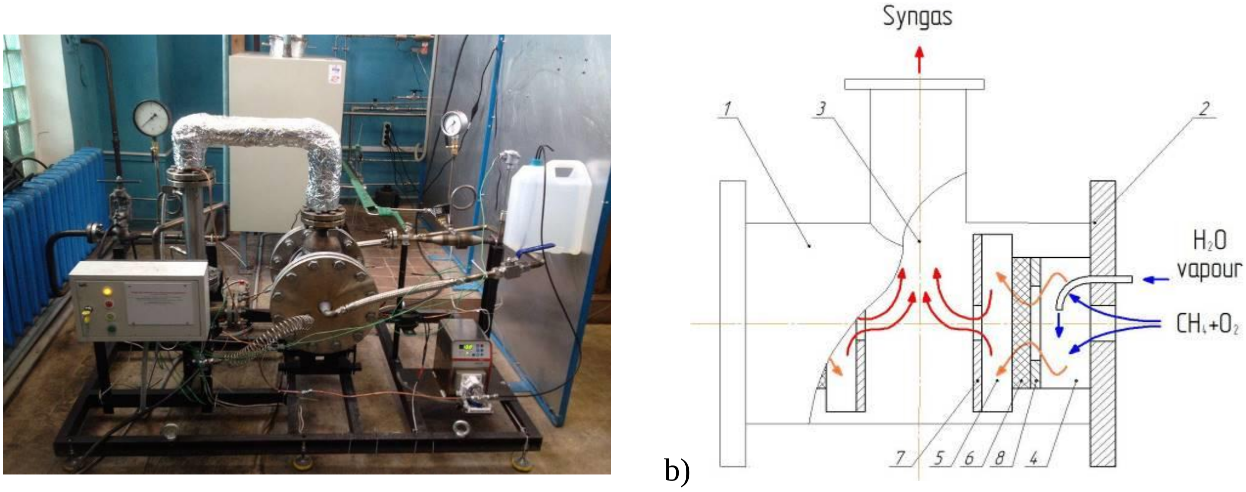
- Matrix conversion allows very high productivity and low cost of operation.
- Any type of oxidizer can be used including air, enriched air and oxygen.
- Oxidizing by oxygen allows obtaining nitrogen-free syngas.
- Addition of steam allows mitigating process conditions and stabilizing matrix temperature.

1. Introduction

Practically all existing large-tonnage gas-chemical processes for production of such chemicals as ammonia, hydrogen, methanol, and synthetic liquid hydrocarbons (GTL-products) use a two-stage technology with preliminary natural gas conversion into syngas. The step of syngas production is power-consuming and requires large capital expenditure. Therefore, at modern crude oil prices even giant world-class gas-chemical GTL enterprises appear to be uncompetitive compared to traditional petrochemical plants [1]. These technologies can't be used as a base for profitable distributed production of hydrogen, which is the main reason that restrains the development of clean "hydrogen energy". For the development of gas chemistry and "hydrogen energy" based on ecologically clean hydrogen vehicles and fuel cell power plants more efficient technologies for conversion of hydrocarbon gases to syngas are urgently needed.
Recently we have suggested principally new non-catalytic method for the conversion of hydrocarbon gases into syngas. It is based on the flameless surface combustion of natural gas in the vicinity of the surface of gas-penetrable matrixes [2-5]. This auto-thermal process allows very high specific volume capacity, at any rate ten times higher than that of traditional technologies, thus providing the possibility for profitable operation of not only large-scale but as well small-scale reformers. It allows stable conversion of very rich hydrocarbon gas – oxidant mixtures with value of oxygen excess coefficient $\alpha = [O_2]/2[CH_4]$ as low as 0.32-0.36. This technology was previously tested at pilot level for the conversion of methane by air with input gas flow up to 20 m^3/h and has shown very promising results [5]. It was possible to achieve methane conversion above 95% with concentration of H_2 up to 24%, that of CO up to 14%, and H_2/CO ratio up to 1.7. The possibility to operate at enhanced pressures (up to 5 atm) has been also demonstrated. Now we present more recent results on the oxidation with enriched air and oxygen which show the possibility to obtain at matrix conversion nitrogen-free syngas, more valuable and convenient for production of chemicals and hydrogen.

2. Methods

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. The mixture of methane, oxygen and nitrogen enters the reformer via one or both side flanges. Before the entrance side of the each matrix apertures with diameter 150 mm were installed to restrict the gas flow trough peripheral part of the matrix with lower temperature. 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. In both sides of the matrix and in volume before and after the matrix thermocouples were installed. The conversion products were removed through a side socket athwart to the entrance flow. The composition of products was determined by gas chromatography.



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.

3. Results and discussion

One of the main findings was that the addition of steam with the steam/CH_4 ratio up 1.4 lets to stabilize matrix temperature and allows operating in a wide range of conditions. Addition of steam reduces as well the yield of acetylene - one of the main precursors of soot formation. The reduction of acetylene in the syngas is very important for subsequent catalytic synthesis. Although the process 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.

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. It was shown that the addition of steam allows stabilizing matrix temperature, decreases the yield of acetylene and makes process more stable.

The main advantages of matrix conversion are: auto-thermal and non-catalytic nature of the process which excludes the necessity of introduction of additional heat and deep purification of feed gas; very high specific capacity increasing that of traditional technologies at any rate in 10 times; the possibility to convert without separation and deep pretreatment hydrocarbon gases of practically any origin and composition.

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Keywords
"Natural gas", "syngas", "matrix conversion", "gas chemistry".