

and CO are close to equilibrium values. For example, experimentally obtained concentration of H_2 reached 20% and that of CO 13% while equilibrium values are $\sim 25\%$ and 14% , respectively.

3.4 Volumetric Matrix with the Recuperation of Heat

To provide more stable operation at low values of α , the recuperation of heat from outlet gases to inlet gas mixture was organized. The air–gas mixture was introduced in the burner through crimped metallic tube situated coaxially along the burner axis. For matrix made of metallic mesh, the heating of inlet gas by hot outlet gas and thus increasing of the initial temperature of mixture let to decrease the stable conversion limit from $\alpha = 0.48$ to 0.39. Some additional measures to optimize burner construction and thermal insulation of the external shell let to decrease the stable operation limit for converter with matrix made of metallic foam down to $\alpha = 0.35$ (Fig. 9). But at such low values of α , the formation of soot observes. It worth to note that for both matrix made of metallic foam (see Fig. 8) and metallic mesh, the dependences of matrix temperature from thermal load are very similar that indicates approximately the same matrix temperatures at equal thermal load.

It is evident (see Fig. 8) that specific thermal load is the determining factor for the extinction of flame. Besides, the limit of stable operation can be widening to lower values α by increasing of heat recuperation, i. e., by increasing the temperature of inlet gas (Fig. 10).

In the converter made of metallic foam, the recuperation of heat provides stable combustion of mixtures with α down to 0.35. In this case, concentrations of H_2 and CO attain their highest values at the highest specific thermal load, which in the present experiments did not exceed 15 W/cm^2 (see Fig. 10). So, it can be supposed that the further increasing of specific thermal load up to possible value 60 W/cm^2 will increase not only the capacity of this device but as well, alongside with the increasing of the temperature of matrix, the yield of H_2 and CO.

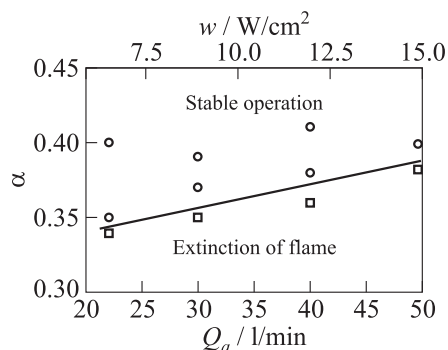


Figure 9 The boundary of stable operation and extinction of flame for the converter with matrix made from Chromel–nickel foam (with the recuperation of heat)

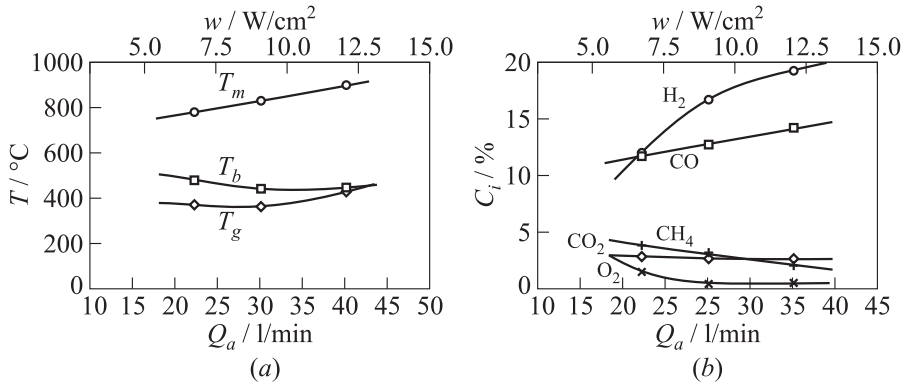


Figure 10 Experimental dependences of temperature of matrix working (inner) T_m and outer T_b surfaces (a) and concentrations of products (b) vs. air flow Q_a (specific stoichiometric thermal load w) at methane conversion in the burner made of Chromel–nickel foam (recuperation of heat, $\alpha = 0.37$, stable mode)

3.5 Volumetric Matrix with Catalytic Active Surface

Previously, it was supposed that matrix does not cause any other influence on gas–fuel mixture except its heating. Of course, at temperature above 600°C (see Figs. 8 and 10), practically any surface exhibits some catalytic properties. Besides, a treatment of the matrix walls with active catalytic components can lead to a widening of the combustion limit for methane-rich mixtures. At last, as it can be seen from Fig. 3, at low values of α , the decreasing of flame front temperature also rapidly decreases the conversion of fuel thus decreasing syngas yield. So, it is possible to expect that the catalytic pretreatment of gas–fuel mixture during its interaction with heated matrix will not only enhance the stability of flame at low α but as well will increase syngas yield.

Investigation of different types of matrix materials was performed in a cylindrical volumetric matrix with inner diameter 50 mm and height of about 100 mm made of alundum. The permeable bottom that serves as a matrix was made of 15-millimeter-thick perforated ceramic plate with cylindrical channels of 1.2-millimeter diameter.

As it was expected, the treatment of ceramic plate with Pt catalyst led to significant enhancing of rich combustion limit (Fig. 11). But although Pt catalyst widening conversion limits, it simultaneously enhances the yield of products of deep oxidation (CO_2 and H_2O) thus decreasing the yield of goal products — H_2 and CO . So, it is necessary to find milder catalysts capable to convert methane and other hydrocarbon fuels at typical matrix temperatures and contact times

into some intermediates, e. g., oxygenates, that can be more easily transformed into syngas.

Besides perforated ceramic, several other types of matrix materials, e. g., metallic foams made of Nichrome and Ni with different porosity (from 60 to 80 ppi) were tried. But with the exception of Pt catalyst, the matrix material and the noted difference in porosity had insignificant effect on burner operation and the yield of products.

Taking into account the positive influence of hydrogen addition to fuel on performance of different types of power engines, the yield of hydrogen can be enhanced at the expense of CO by its conversion to hydrogen in a water-gas-shift (WGS) reaction [6]. Some experimental sets were also performed with hydrocarbons heavier than methane-propane-butane mixture and evaporated straight-run gasoil. They showed prospective results and well possibility to convert heavier and even liquid hydrocarbons into syngas in such type of converter. This work is under investigation now as well as the investigation of conversion of biogas and some other gases with low heating value.

4 CONCLUDING REMARKS

Thus, the combustion of natural gas (methane) and heavier hydrocarbons in volumetric permeable matrix burners in the conditions of locked IR radiation can be considered as a high-productive, adaptable, and rather simple way of syngas or hydrogen (with the use of WGS) production for various low-scale applications including enhancing the performance characteristics of power engines. Due to continuous operation, it is more convenient than filtration combustion in porous media. It is important that the absence of interaction of products with the surface of matrix and very short time of fuel conversion in the flame front let to avoid such serious problem as soot formation. The use of enriched air or oxygen as oxidant and enhanced pressures can further widen the limits of stable operation and fuel conversion thus making such type of converter convenient for many other applications.

There is another global problem to which the use of volumetric permeable matrix burners can be addressed. Due to existing estimates, about 150 billion

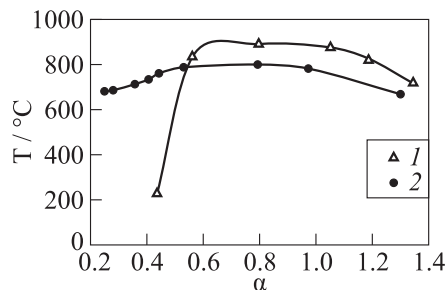


Figure 11 Dependence of outgoing gas temperature vs. oxygen excess coefficient α for methane-air mixture for perforated ceramic matrix (1) and that treated with Pt catalyst (2) (total gas flow — 6.2 l/min)

cubic meters of associated oil gas is flared annually worldwide [7]. The main reason is that it is very difficult to use raw associated gas as a fuel in modern types of power engines. Due to high content of heavier hydrocarbons, such gases are very incline to detonation as well as soot and tar formation. Modern technologies of gas treatment are too complex and costly to be applied for usually low fluxes of associated oil gas which makes their flaring economically preferable. But simple enough volumetric permeable matrix burners can effectively convert such low gas fluxes into syngas or hydrogen thus making them more attractive for low-scale and ecologically clean local power supply including use of fuel sells.

REFERENCES

1. BONG-HY. 2007. Parallel application of blends of natural gas and hydrogen in internal combustion engines and fuel cells. Final Report.
2. Chiesa, P., G. Lozza, and L. Mazzocchi. 2005. Using hydrogen as gas turbine fuel. *J. Engng. Gas Turbines Power* 127:73–80.
3. Shmelev, V. M., and A. D. Margolin. 2000. On gas mixture burning above the surface of perforated matrix. *Russ. J. Chem. Phys.* 19(5):36–42.
4. Arutyunov, V. S., V. M. Shmelev, I. N. Lobanov, and G. G. Politenkova. 2010. A generator of synthesis gas and hydrogen based on a radiation burner. *Theor. Found. Chem. Engng.* 44(1):20–29.
5. Basevich, V. Ya., V. I. Vedeneev, and V. S. Arutyunov. 1996. Study of partial oxidation of hydrocarbons with reference production of synthetic gas. *Theor. Found. Chem. Eng.* 30(5):456–60.
6. Ratnasamy, C., and J. P. Wagner. 2009. Water gas shift catalysis. *Catalysis Reviews* 51:325–440.
7. Elvidge, C. D., K. E. Baugh, D. W. Pack, and C. Milesi. 2007. Satellite data estimate worldwide flared gas volumes. *Oil Gas J.* 12:50–58.