Catalytic Combustion of Natural Gas Dehydrator Emissions

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Introduction

Natural gas as it comes from the reservoir contains water that needs to be removed before transportation and use. Water is removed using triethylene glycol as an absorbent, however, in addition to water some methane and other hydrocarbons such as Benzene, Toluene, Xylene and Ethyl benzene (BTEX) are also absorbed. These compounds are emitted during the glycol regeneration step. Natural gas dehydration effluent is the third largest methane emission source in the natural gas industry. After CO_2, methane is considered the second largest contributor to greenhouse gas (GHG) emissions [1-3] and BTEX compounds are known to be carcinogenic. The conventional method to control these emissions is homogeneous combustion which has drawbacks, including formation of NO_x compounds due to high operating temperatures [4-5]. In this study catalytic combustion was used for treatment of simulated natural gas dehydration effluent using a counter-diffusive radiant heater. In this type of design, fuel is introduced in the back and the combustion air diffuses from the front and combustion takes place on catalyst surface. The catalyst was Pt deposited on Al_2O_3 fibre pad. The effect of methane feed rate on its conversion was studied at different methane flow rates. The role of oxygen deficiency on methane conversion was verified by installation of a fan on top of the funneling hood which was used to capture the exhaust gas. In the next step pentane, toluene and water were added to the reactor feed to study the performance of the unit for treatment of natural gas dehydration effluent.

Materials and Methods

The commercial counter-diffusive radiant heater used in the experiments was a 30 cm × 30 cm unit. It consisted of a catalyst pad, an insulation blanket, an empty space in the back for fuel injection and an electrical heating element. The thickness of the catalyst pad was about 1 cm. The electrical heating element was used to raise the catalyst pad temperature and when the temperature was high enough to sustain the combustion, methane was introduced and electrical heater was unplugged. The sample of the exhaust gas was analyzed using an HP 5890 gas chromatograph. Methane conversion was calculated based on the relative concentration of methane and CO_2 in the exhaust gas. Pentane used in the experiments was anhydrous pentane of 99+% purity and toluene was HPLC grade. These compounds were added to the reactor feed to simulate the real natural gas dehydration effluent. A syringe pump was used to transfer the mixture of pentane and toluene into the back of the heater through a small injection port added to the unit and a digital pump was used to pump the water. The molar concentrations of methane, water and hydrocarbons mixture were 40%, 40% and 20%, respectively. These two streams joined together shortly before the injection port. Temperature distribution across the catalyst pad was monitored using three thermocouples placed diagonally at 5 mm depth inside the pad and the temperature in the back space where fuel is injected was monitored by the forth thermocouple. The fan used in some of the experiments was a 12 V DC fan with adjustable speed. For data acquisition, Labview software package was used.

Results and Discussion

In base case operation of the unit with methane, it was observed that the temperature was higher at the bottom of the catalyst pad which can be explained by the effect of boundary layer development in front of the catalyst pad. Conversion of methane was decreased at high methane flow rates with more methane detected in the exhaust gas. Methane conversion at different flow rates is shown in Figure 1. In fact at high flow rate there is not enough oxygen to satisfy the oxidation demand. When the fan was turned on to increase the air circulation in front of the pad, complete conversion of methane was achieved.

Addition of water into the reactor did not significantly affect the methane conversion at low flow rate. However at high water flow rates, temperature at the bottom of the catalyst pad was significantly lower and bottom of the pad was wet, and conversion was observed to decrease. When toluene and pentane mixture were introduced into the unit, significant decrease of methane conversion was observed since these hydrocarbons are combusted preferably before methane. Even in presence of hydrocarbons, complete methane conversion can be achieved if the oxygen demand is satisfied.

Significance

Controlling the emission of GHGs is a challenge for different industries and effective technologies are required to meet the governmental regulations. By application of these units, not only methane and BTEX are combusted efficiently, the generated thermal energy can be used for several applications and significant savings in energy can be achieved.

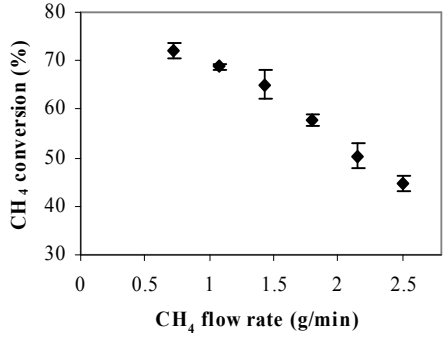

Figure 1. The effect of methane flow rate on its conversion

References

1. Su S. and Agnew J., Fuel 85 9 (2006).
2. Solomons S., Hayes R.E., Poirier M. and Sapoundjiev H., Catal. Today, 83 1-4 (2003).
3. Jorgenson A.K., Soc. Forces, 84 3 (2006).
4. Kiwi-Minsker L., Yuranov I., Siebenhaar B. and Renken A., Catal. Today, 54 1 (1999).
5. Kiwi-Minsker L., Yuranov I., Slavinskaia E., Zaikovskii V. and Renken A., Catal. Today, 59 1-2 (2000).