

Review Article

Light Hydrocarbon Gas Technology and Its Prospect

Yongqiang Han*, Hui Chang, Zhijun Luo

Petrochemical Institute, Daqing University of Technology, Heilongjiang, China

*Correspondence: Prospect-Yongqiangwqs12@gmail.com

ABSTRACT

Light hydrocarbons are treated as a by-product of the petrochemical industry. They are clean and inexpensive fuels that not only less pollute the environment but also save valuable energy. Through the analysis of light hydrocarbon fuel development status, people now use light hydrocarbon for gasification combustion. This usage requires high quality of light hydrocarbon and strict safety. The feasibility of using light hydrocarbon gas as fuel to replace diesel in oil boilers has been proposed for the current industrial boilers in China, and the sources of light hydrocarbon fuels and the safety of such alternative technologies have been specifically described. We believe such replacement can effectively reduce the dependency of the international oil market.

KEYWORDS: Light hydrocarbon Gas; Green Environmental Protection; Development Prospect

Received: 8th Apr. 2018

Accepted: 4th Aug. 2018

Published Online: 31st Aug. 2018

1. Introduction

At the beginning of the twenty-first century, energy shortages and environmental problems were extensively evaluated by the world. Oil, the non-renewable resource, has become a pillar of national modernization. It is also a strategic resource and its price will have a huge impact to a country's economy. The outbreak of the oil crisis of the 1970s and the Gulf Crisis in the early 1990s proved that oil was a country's political and economic lifeline, and might be one of the important factors leading to military conflict.

Oil and natural gas resources in China are currently facing a critical situation because of the limited domestic oil and natural gas supply and the unstable quality. The insufficient supply and the peaking demand are in great contradiction, so the import of oil and gas will keep increasing year by year. China's oil production has long lagged behind the growing demand: it is predicted that in the next 15 years, China's total oil demand will exceed the total domestic crude oil production, therefore the domestic industrial development will be more and more dependent on the international oil market^[1]. To achieve a sustainable development of national economy, it is necessary to adjust the energy structure, to balance the production and consumption of resources, and to focus on the development of alternative energy. To this end, the relevant state departments have been the development of conservation-oriented resources and the search for alternative fuel oil 'Fifteen-Year' plan^[2]. Light hydrocarbon mixed gas instead of diesel, will be a very good alternative.

2. Brief Introduction of Light Hydrocarbon Gas Technology

2.1. Light hydrocarbon gas formation process

The mixed light hydrocarbon is converted to gas mixture via a gas generating device. Light hydrocarbon gas then goes through a demister and is piped to the costumers' terminal.

2.2. Light hydrocarbon gas supply system

Light hydrocarbon gas (LHG) supply system consists of three parts. First, the LHG station, responsible for the preparation of such LHG, including the host, air, fuel, heat filling, automatic operation, oxygen concentration detection, automatic ventilation alarm and an anti-static system. The closed-fill heat cycling system will provide the latent heat for gas vaporization during the gas generation process. The second part is the transmission and distribution network, from where the gasified light hydrocarbon mixture will be sent to the user terminal. The third part is the terminal application (boilers, cookers, etc.), where the gas mixture is decompressed and eventually burned to generate heat.

2.3. Preparation of light hydrocarbon gas

The gas system used in gas preparation is very simple. It requires low pressure, low temperature and low cost therefore it is safe and economical. The gas system is equipped with a signal source, which is controlled by bit pressure. When gas load is detected, the pressure of the pipe network will be reduced, so the system will automatically switch on the gas equipment to prepare gas. If gas load decreases, the pipe network pressure will rise to a certain extent so the system will automatically terminate the gas installation. The whole system does not store LHG so it is quite safe.

2.4. Light hydrocarbon fuel combustion

Light hydrocarbon air bubble combustion

Light hydrocarbon fuel is mainly used in the gasification combustion, which is roughly divided into two forms. One is the air bubble combustion: air and LHG mixture meet in the stove and get burned. This method is very prone to the quality of light hydrocarbons. There are double olefin contents to ensure the safety during the distillation process. Bubble gas system is generally composed of tanks, carburetors, separation and surplus liquid equipment, piping and control equipment. The gasification unit is the key equipment, responsible for light hydrocarbon gasification and air mixing. Generally, air is blown into a container containing light hydrocarbon fuel. When the air bubbles are in contact with the light hydrocarbon fuel, heat and mass exchange occurs. The liquid surface forms a mixed gas, which contains a certain concentration of gaseous light hydrocarbon. Bubble gas system has a gas pressure limit for security reasons. From the viewpoint of the detection system, it is also necessary to set an oxygen or calorific value monitoring equipment, which will automatically alarm when the gas concentration decreases below the threshold.

Forced gasification of light hydrocarbons

Another way to gasify light hydrocarbon is by heating. For safety reasons, the temperature of heating medium should be no higher than 95 °C and the temperature of light hydrocarbon fuel should be no higher than 45 °C. By this method, the gasification intensity per unit volume is much higher than that of the bubbling gas, and its equipment is relatively small. However, the system is very complicated. In order to meet the safety requirements, its operation and maintenance costs are much higher than the bubble system. This process usually uses water as the heat medium. The light hydrocarbon fuel enters the gasification unit through a constant volume pump and gets gasified by hot water under constant temperature and pressure. Then the gas is separated from the liquid and gets pumped into the gas tank. Air from the air tank and light hydrocarbon fuel gas from the gas tank meet together at constant pressure and constant volume to complete the gasification process. Through the explosion-proof regulator, the mixed gas is finally delivered to the burner for combustion^[3].

2.5. Light hydrocarbon gas characteristics

Advantages of LHG include less investment, fast installation, noise-free when compared with application of artificial gas or natural gas. LHG, along with natural gas and liquefied petroleum gas, are all alkane petroleum products suitable for industrial uses, and can also be used for urban and rural residents.

3. Light hydrocarbon fuel source

3.1. Light hydrocarbon fuel composition

The main components of light hydrocarbons

The raw material of the light hydrocarbon fuel is the mixture of C5-C7 hydrocarbon, which is liquid at room temperature under 1 atm.

The production of light hydrocarbon

The mechanism of light hydrocarbon formation is very complex, mainly including kerogen and crude oil thermal cracking with organic matter catalysis and microbial effects. Microbial action is an important way to generate light hydrocarbons, for example, some C1-C8 hydrocarbons have been detected in fine-grained sediments, indicating that they are generated in situ by microorganisms. Hunt et al. [4] conducted a bacterial culture test on natural terpenes in laboratory and reported for the first time that C4-C7 light hydrocarbon can be produced by microbial activity.

The main mechanism of light hydrocarbon formation is catalysis, and there are two main views on the catalytic origin. Mango [5] believed that the catalyst was transition metal, paraffin and hydrogen. Kerogen was decomposed and the C-C bond was broken and recombined to form light hydrocarbons under the action of the catalyst. Other catalytic cracking was explained by the use of Lewis acid as a catalyst, in which alkanes were cleaved into many low molecular isomeric alkanes. Kissin [6] found that the complexes of clay organic matter under conditions of slow heating were deacidified to alkanes, naphthenes and aromatic hydrocarbons. Therefore, catalytic cracking or thermal cracking of heavy hydrocarbon led the formation of light hydrocarbon at medium (<125 °C) or high temperature (>125 °C), respectively.

Light hydrocarbon presence

Light hydrocarbon is a by-product of the oil extraction and refining process. When light hydrocarbons in the oil and gas reservoirs migrate into the environment, they undergo material and energy exchanges. The former includes: physical adsorption, chemical adsorption, dissolution and hydration, as well as microbial effects and oxidation. From the nature of the interaction between light hydrocarbons and the environment, the existing forms of light hydrocarbons include: free, dissolved and chemically adsorbed, and physical adsorbed states [7-9].

Oil distillation process

According to the whole composition of oil, light hydrocarbons are only a fraction of the oil composition. From the arrangement of petroleum carbon atoms, the first stage is natural gas, whose carbon number is C1. Liquefied petroleum gas is the second paragraph, whose carbon number is C3 to C4. Both natural gas and liquefied petroleum gas are high-quality raw material and gas fuel. The fourth paragraph is the world's most important fuel-gasoline, whose carbon number ranges from C7 to C12.

3.2. Sources of light hydrocarbon feedstocks

Origin of light hydrocarbon feedstock

The source of light hydrocarbon is very broad: oil gas fields, condensate oil gas fields, oil refineries, petrochemical plants and ethylene projects, etc.

Conditions for light hydrocarbon feedstocks

Liquid hydrocarbons can be used as raw materials for gas production as long as (i) the density is in the range of 0.163 to 0.168 kg / L; (ii) the temperature of 50% distillation is below 75°C, (iii) the temperature of 90% distillation range is below 135°C and (iv) the total sulfur content is less than 0.104% [10], such as crude oil, light naphtha in oil refineries, petroleum ether produced in solvent oil plants, light hydrocarbons in oil and gas fields, and natural gasoline, as well as 'bottoms' in natural gas purification plants.

Distribution of light hydrocarbon feedstocks

The data indicate that the total amount of light hydrocarbon that can be used as a raw material for gas at present is at least 5 million tons per year in China, and the total amount of liquefied petroleum gas produced annually is almost the same. It is mostly located in Heilongjiang Province, Liaoning Province, and Inner Mongolia. Because of different extraction is mostly located methods, the amount varies from place to place.

3.3. Widely used in light hydrocarbon feedstocks

It is the use of those chemicals that are not needed in the chemical industry. LHG and other resources have been fully utilized is due to the development of light hydrocarbon technology is very successful, so that it will not be wasted. Light hydrocarbon raw materials and oil, natural gas is coexisting. It is reported that in the 'West- East Gas Pipeline' pipeline project, there will be about a million tons per year of condensed oil and light hydrocarbon production. Although its use is limited, but as a high-quality fuel, making the resources can be integrated, while generating economic, social and environmental benefits.

4. Light hydrocarbon gas to replace other fuels

4.1. Reliability of alternative technologies

Reliability of light hydrocarbon gas in boiler combustion

A diesel-fueled boiler and an LHG-fueled boiler have no difference in structure. Since the furnace and the boiler will not be in contact with other parts, the only requirement is to replace a burner so that the diesel-fueled boiler can be compatible with LHG. Therefore, the safe regulations of diesel boilers will not cause any adverse effects. When the gas source in the LHG is selected, the stable calorific value is ensured and the total amount of gas produced by the gas supply station must also match the load required for the burner^[11].

The core technology of light hydrocarbon gas

For the technology that utilizes LHG as a green alternative energy source for automobiles, its core technology is the addition of trace amounts of 'oil Nuclear magnetic resonance agent' in the light hydrocarbon. For the heavy components of the more light hydrocarbons, can be added by the 'oil' and then directly to the car; and more moderate components of light hydrocarbons, you can add 'oil' after the appropriate proportion of mixed into the gasoline Use; for light components of more light hydrocarbons, you can retain the original structure of the gasoline vehicle in the case of a set of liquid light hydrocarbon fuel supply system installed, so the driver only need to switch the switch and then through the electromagnetic The valve will automatically switch between two sets of fuel systems.

4.2. Advantages of light hydrocarbon gas

Light hydrocarbon gas unique advantages

Light hydrocarbon fuels are more convenient in terms of transport, storage, and vehicle emissions compared to liquefied petroleum gas (LPG) and natural gas, and there is also a significant reduction in emissions from tail gas emissions. Moreover, the cost of cheap hydrocarbon fuels is relatively low and the cost of building light hydrocarbon stations is low. Therefore, it is a good kind of alternative fuel for cars.

Light hydrocarbon as an alternative to clean fuel vehicles, one to safe and convenient, and secondly, is to make the car exhaust gas contains a lot of harmful substances, and more importantly, it can overcome the current widespread use of liquefied petroleum gas, natural gas fuel vehicles The existence of the decline in power, poor performance of the two major shortcomings.

After people tested, light hydrocarbon vehicles in the dynamic, economic stability and acceleration and exhaust emissions and other performance indicators are much better than gasoline cars. Environmental protection experts say that the light hydrocarbon as a green alternative energy is a very unique initiative, this new technology to promote the use of green cars for the open up a new way. Compared to other alternative fuels, LHG has many unique advantages.

Lack of natural gas and liquefied petroleum gas

Now use more of the two alternative fuels are natural gas and liquefied gas, they are all gas, and do not need very sophisticated fuel injection or atomization device, can make the engine structure is relatively simple, and that is the cylinder distribution is very Uniform, this will make the work very smooth. However, due to technical reasons, if a large

number of motor vehicles using natural gas will make the fresh air into the cylinder to reduce the content, resulting in the engine power has declined. Also, natural gas contains a trace of harmful substances, making the engine is corroded; this result is the engine life will quickly shorten.

People in the use of liquefied gas is in the process, often occurs in the evaporator or filter encountered blockage and low temperature conditions, such as poor start and many other issues. More importantly, natural gas and liquefied gas have relatively short mileage, and now the fuel transport and distribution, the sales system cannot be fully utilized, so there is an urgent need to establish a relatively independent storage and distribution network. Especially natural gas, it needs to build a very long transport pipeline, which greatly limits the gas fuel to promote out.

Moreover, the fuel truck converted into LPG car, people want low-emission environmental protection purposes have not been achieved. The reason is that the fuel and gas requirements for the engine is different, the fuel into gas, you must ensure that all aspects of the parameters (such as ignition energy, etc.) with the engine performance to match, but in our current technology, this Kind of optimization will not be achieved for the time being. Therefore, the gas will not be fully burned, so that after the modified dual-fuel vehicle emissions cannot meet the requirements of environmental protection. Moreover, after the modified dual-fuel vehicles, their safety has also aroused people's concerns.

Because now there are only 70 liquefied gas filling stations nationwide, has not yet formed the scale, the LPG car refueling caused inconvenience. Also, because there is no corresponding standard system, making some car modification manufacturers after-sales service system is not perfect, people will face modified cars, their debugging and maintenance difficult to solve the problem. Especially because the dual-fuel vehicle transformation technology is not yet mature, resulting in modified LPG car performance is far from meet the requirements, so its power generally have to drop 5% to 10%.

Advantages and disadvantages of ethanol gasoline

Car ethanol gasoline, according to a certain percentage of ethanol and gasoline will be two kinds of denatured fuel mixed deployment. And because the calorific value of ethanol is relatively low, so the use of ethanol gasoline will make the engine fuel consumption increases. According to the information, mixed gasoline contains 10% ethanol; the engine will make about 5% increases in fuel consumption. There is, ethanol gasoline is not particularly easy to start, will cause the car's drive performance has declined. In terms of environmental protection, the use of ethanol gasoline cars, their CO and HC emissions will be reduced a lot, but nitrogen oxide will rise slightly. In addition, ethanol and gasoline cannot be directly mixed, so according to the traditional process of production, it will make it more cost-effective and very complicated to operate, and its products are not how stable. Ethanol and easy to absorb water, and ethanol after mixing with gasoline will be so that it will make the production, storage and transportation and the use of ethanol gasoline are very difficult.

Although the use of ethanol gasoline will improve the thermal efficiency of the engine, but also to the car's CO and HC emissions have decreased, but it requires the car's engine and other metal parts of the anti-corrosion properties of rubber materials, anti-swelling performance must Very high, in addition to the engine to increase the compression ratio, but also the transformation or replacement of the car's engine and carburetor material, and those who have not yet modified the car or the engine is not suitable for the use of ethanol gasoline. Although the development of various corrosion inhibitors at home and abroad has been successful, but this technology for ethanol gasoline corrosion problem is not completely resolved, but in part to suppress or slow down the occurrence of corrosion, so ethanol is not suitable for gasoline As a substitute for fuel.

Lack of electric vehicles

Electric cars are known as the ideal pollution-free cars, but now its technology is not yet mature, this is the main problem it faces. Its driving range is relatively short, and charging time is relatively long, the other is the price is also very expensive. Its batteries contain lead in the production, use and recycling process of environmental pollution caused by the people should also be given enough attention.

4.3. Reliability of Light Hydrocarbon Gas

According to the above comparison we can see that light hydrocarbon fuel vehicles than diesel and natural gas vehicles and liquefied petroleum gas vehicles and electric cars and ethanol gasoline cars have a good overall effect, and its price is relatively low, the resources are relatively rich, Its production, storage and transportation are very convenient, the other gas station construction costs are relatively low, its promotion plays a great role in promoting.

People have made a lot of attempts to use light hydrocarbons as fuel for cars. The more common way is to mix them directly into gasoline, but because the power is relatively small, the driver feels that it is not so great after joining the car. And the proportion of one-thousandth of a million to two-fifths of the 'oil-based nuclear magnetic resonance agent' added in the heavy components of the light hydrocarbon, it will make its power greatly increased (and for the more light group Light hydrocarbon, then install a set of evaporators on the car). Therefore the addition of 'oil' after the light hydrocarbon as a reliable fuel is to promote the use of the user's warm welcome. And the 'oil nuclear magnetic resonance agent' in accordance with the ratio of one ten thousandth of the two thousand points in the original light hydrocarbon, the fuel consumption can be reduced by more than 18%, power will increase more than 20%, while Exhaust emissions will drop 80%.

4.4. Alternative economy

The use of LHG instead of diesel has many distinct advantages. First of all, in the petroleum products, the increase in the number of carbon atoms, will lead to the gradual reduction of the amount of heat generated by the liquid, the general use of the treatment of gas is C5-based raw materials, its heat is about 48.1kJ / kg, and diesel fuel heat the value is about 42.7 kJ / kg. Two about 5.4kJ / kg difference. Second, the burner for combustion of diesel fuel is slightly different from the burner of the combustion gas, and the thermal efficiency of the diesel burner is about 5% lower than the thermal efficiency of the burner. The use of imported gas burner is the thermal efficiency of the two about 10% to 15% difference. Again, the purchase price of raw materials is not the same. Summer to buy diesel prices is about 3300 yuan / ton, compared with 3600 yuan in winter / ton. But the average purchase price of liquid light hydrocarbons is about 1900 - 2200 yuan / ton. From the economic point of view, to an ordinary Santana sedan, for example, 400km, fuel consumption 40L, oil costs 108 yuan, switch to light hydrocarbon fuel only 34L, 33 yuan a day to save. Compared with liquefied petroleum gas, light hydrocarbons have more promotional value. Because the investment of a liquefied gas filling station to be more than 200 million, and light hydrocarbon filling station can be an ordinary gas station transformation, investment only 20 million. Ordinary car to install a light hydrocarbon dedicated fuel supply system only 4500 yuan, and converted into natural gas, liquefied petroleum gas vehicles need 6,000 yuan^[12]. This can be seen to light hydrocarbon fuel instead of diesel fuel, will produce a very significant economic benefits.

5. Economic, social and environmental advantages

5.1. Economic Policy Advantages

With China's accession to the WTO, to participate in the global economic cycle, the market competition will be more and more intense. The state-owned economy will also make a major adjustment to the strategy. China's state-owned economy has a total of 236 classes, while 148 (62.7%) will let them participate in the market competition, and the government also encourages a variety of economic components coexist. And utilities: water, electricity, gas and warm all year round through a huge financial subsidies to maintain the operation, has long been overwhelmed, but also seriously affected the healthy development of urban infrastructure. Open utilities, cancel financial subsidies, and align it with market prices, which mean that different institutional firms will participate in fair competition on the same starting line. Therefore, state-owned enterprises and private enterprises can participate in the operation of LHG fuel market.

In 2003, the National Development and Reform Commission and the Ministry of Finance and the State Administration of Taxation will light hydrocarbon this fuel included in the 'comprehensive utilization of resources catalog', in 2005 and light hydrocarbon as a key project.

In March 2006, the National Development and Reform Commission, the Ministry of Construction and the Ministry of Public Security Fire Supervision and the State Technical Supervision and the China Urban Gas Association and the State Environmental Protection Administration of LHG officially named 'the fourth generation of urban gas.' Experts agree that LHG in the composition and ignition, etc. has been very consistent with the requirements of urban gas; it can be used as an important city gas supplement.

At present, the mature mixed light hydrocarbon technology has been formed in the country, and in some cities of residential quarters and schools and hotels has been applied very successfully. There are nearly 100 light hydrocarbon mixing stations nationwide, distributed in Guangdong, Sichuan and other provinces.

Light hydrocarbons in the industrial and civilian gas application of the time are relatively short, so there is no large market size. And in order to LHG this technology to carry out large-scale promotion, you must decision-making departments to support. Many industry insiders also called on the relevant departments to make relevant specific incentives as soon as possible, at the same time all levels of government should also clearly plan in the industry and energy in the relevant supporting policies, so that LHG this emerging clean energy can be fast and healthy to grow.

5.2. Energy saving and environmental protection advantages

Protecting the environment is one of China's basic national policies and a very important part of the national economic and social sustainable development strategy. In the Tenth Five-Year Plan, the State made it clear that it was important to pay attention to resource development and conservation at the same time, and to put savings first, rational use of resources and protection according to law, and to improve resource utilization in achieving sustainable use, making the economy with the resources and environment coordinated development.

LHG generally does not have the same secondary pollution as diesel fuel in direct combustion, so the role of this initiative in environmental protection is very obvious. Some experts also believe that if all the domestic light hydrocarbon resources are used up, it is equivalent to the construction of a West-East Gas Pipeline Project. Its significance is no trivial matter.

In the past, light hydrocarbons were not fully exploited and used as a fuel for boilers and industrial furnaces, and some were used for ethylene projects, and most of them left some Petrochemical business point 'daylight' and burned. In the past, light hydrocarbons were burned by the tall chimneys of the refineries, which were a waste of non-renewable resources and would cause serious pollution to the atmosphere.

LHG as a clean energy, its environmental protection in the cause and comprehensive utilization of energy will play an increasingly active role.

5.3. Market demand advantage

At present, China's city gas is the main source of three: artificial gas, liquefied petroleum gas and natural gas. Now, about 20% of our city is using artificial gas. However, because the investment in artificial gas is relatively large, the construction period is long, and pollution is also very serious, its carbon monoxide content is seriously exceeded, so the state has been listed as a restricted development industry.

In China's cities and towns, gas is mainly liquefied petroleum gas. At present, the use of liquefied petroleum gas in China is increasing year by year trend, with the improvement of environmental requirements, the acceleration of small and medium-sized cities and construction of liquefied petroleum gas in other areas of automotive applications more and more widely, resulting in increasing contradiction between supply and demand. Hence, the state must be a lot of imports of liquefied petroleum gas so that this situation has been alleviated.

Everyone recognized as a clean energy is natural gas. With the change of energy in recent years, China has made the natural gas has been rapid development. The state in the overall planning of natural gas development process, to determine the mid-century, the country has nearly 65% of the city all through natural gas. And experts also pointed out that the rapid development of natural gas will certainly make its demand for explosive growth, and this gap is very great. According to the information: it is expected in the next 15 years, natural gas consumption will reach 11% to 13% of the average growth rate, so that its gap will be hundreds of billions of cubic meters, so half must rely on imports. Now, as China's market demand is growing, the supply of three kinds of city gas is far from being met. The development of light air gas can make the light hydrocarbon resources be effectively utilized and gasified into gas, which can be regarded as an important supplement to the city gas in China ^[13].

'Tenth Five-Year Plan' has made clear that China's urbanization development model of the instructions, that is, the focus of small town development, and actively develop the central city, improve the regional central city, mainly play a leading role in the city. There is no doubt that the requirements of environmental protection, the rise of the real estate industry, the major cities to actively promote the blue sky projects, industrial and mining enterprises the urgent needs of energy conservation, national savings and alternative fuel oil '15' strategic approach and people (especially small town farmers Get rich) eager for high-grade clean fuels, so that LHG technology usher in unlimited business opportunities and broad market.

6. Light hydrocarbon new liquid fuel development prospects

An important measure to effectively control the emissions of pollutants in all regions of the country is to prevent air pollution from coal combustion. From the environmental point of view, there is now a lack of energy, the light hydrocarbon mixture as a city, township and rural gas a supplement, use it for cooking, bathing and boiler heating, its development prospects are very great.

It is expected that by 2020, China's population will reach 1.5 billion, while the urbanization process is estimated to last about 20 years. China's urbanization development model in the 'Tenth Five-Year Plan' has been clear. Therefore, we believe that the demand for environmental protection, as well as the rapid rise of the real estate industry and people's desire for efficient energy-saving fuel, the gas industry will bring great potential business opportunities, so that in the gas industry, LHG must get the greatest degree of play!

References

1. World and China's oil energy needs to be predicted [J]. *Fujian Energy Development and Conservation*, 2002, (4).
2. Chen Heping. China's '15' energy-saving plan and countermeasures [J]. *Energy Research and Utilization*, 2001, (1).
3. Tang Yanchun, et al. Design of heat pipe boiler using light hydrocarbon new energy [J]. *Boiler Manufacturing*, 2000, (3): 69-70.
4. Hunt J M, Huc A Y, Whelan J K. Generation of light hydrocarbons in sedimentary rocks. *Nature*, 1980, 288: 688-690.
5. Mango F D. Transition metal catalysis in the generation of petroleum and natural gas. *Geochim Cosmochim Acta*, 1992, 56: 553-555.
6. Kissin Y V. Catagenesis and composition of light cycloalkanes in petroleum. *Org Geochem*, 1990, 15: 575-594.
7. Li Guangzhi, Hu Bin, Yuan Ziyang, et al. Adsorption and analytic model of light hydrocarbon [J]. *Natural Gas Geoscience*, 2006, 17 (4): 552-558.
8. Li Guangzhi, Wang Linzi. Desorption and analysis of adsorbed light hydrocarbons [J]. *Geophysical and Geochemical Exploration*, 2000, 24 (1): 34-42.
9. Li Guangzhi. Formation and characteristics of light hydrocarbon geochemical field [J]. *Petroleum and Natural Gas Geology*, 1999, 20 (1): 66-69.
10. Tian Guansan. Theoretical analysis of air parameters of light hydrocarbon carbon. *Journal of Shandong Institute of Civil Engineering and Architecture*, 2000, 15 (3) 28-32.
11. Jiang Qiuqing. Light hydrocarbon fuel in coal-fired boiler application [J]. *Science and Technology Information Development and Economy*, 2000, 10 (4): 46-47.
12. Ni Jun. Alternative diesel fuel combustion gas combustion technology [J]. *Energy Research and Utilization*, 2003, (3): 41-42.
13. Ma Yanru. C5 light hydrocarbon civil fuel development and utilization [J]. *Energy Research and Utilization*, 2000, (2): 46