

Prospect of Natural Gas Utilization in China

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Abstract

This paper introduces the source and utility circumstance of natural gas in China. The utility circumstance of natural gas is discussed in detail, such as, natural gas as feedstock is produced to acetylene; natural gas is used to cut metal; natural gas is applied to generate ethylene; natural gas instead of heavy oil is fired to produce chromium trioxide. In so doing, the energy demand of China will be better met with least damage to the environment. According to the full utility of natural gas sources, their good economic and social benefits are obtained.

Keywords: Natural Gas, Utilization, China, Environment, Energy Demand

1. Introduction

With the decrease of petroleum energy, it is very important to utilize Chinese traditional energy such as coal and natural gas and improve natural gas as high value production. It has a good economic benefit and society benefit [1]. Chinese economic and social development is limited due to the shortage of natural resource. The output of Chinese petroleum basically keeps at between 1.8×10^8 t per year and 2.5×10^8 t per year [2]. However, Chinese usable petroleum source are reserved at 32.7×10^8 t per year. Chinese petroleum exploration only has 16 years. And 52% petroleum comes from overseas. So Chinese government uses the different policy to decrease the power loss and increase production efficiency and decrease tax for those companies that try to keep the nature source and develop the new source such as wind resource, water resource and natural gas source, and so on.

At present, utilization of natural gas in China is low efficiency and proceeds in a way that quickly degrades the environment and caused serious pollution. The local residents almost depend on natural gas for cooking and space heating. Most of natural gas is directly burnt as fuel for cooking. Due to using outdated stoves, the burning efficiency is very low, utilizing less than 30% of electricity energy.

In conclusion, the overuse of traditional energy (natural gas) as fuel in partial area damages the fragile environment. There exists an urgent need to utilize natural gas in a rational way, which can be done through using

new method to improve production value. This will not only improve energy efficiency, but also reduce pollution and damage the ecological environment. In this paper, the five main methods are introduced. Natural gas as feedstock is produced to acetylene, ethylene and chromium trioxide, respectively; natural gas is used to cut metal and produced to chromium trioxide instead of heavy oil.

2. Natural Gas Utilization in China

2.1. Natural Gas Produced to Acetylene

Zhang Xiangfu [3] introduced that natural gas as feedstock is produced to acetylene with the plasma method. The three methods for acetylene production were compared from the view point of technology and economics. The plasma method for acetylene production has more advantages than the partial oxidation and calcium carbide method. It was effectively used to save energy and decrease production capital and protect environment.

Figure 1 shows the relationship between temperature and free energy of hydrocarbons. When temperature is between 900 K and 1200 K, free energies of hydrocarbon compounds are more than 0 and increase with the increase of temperature. But free energy of acetylene has high value at low temperature and decreases with the increase of temperature. When temperature is more than 1800 K, free energy of acetylene is less than that of others. This proves that acetylene is firstly obtained than others.

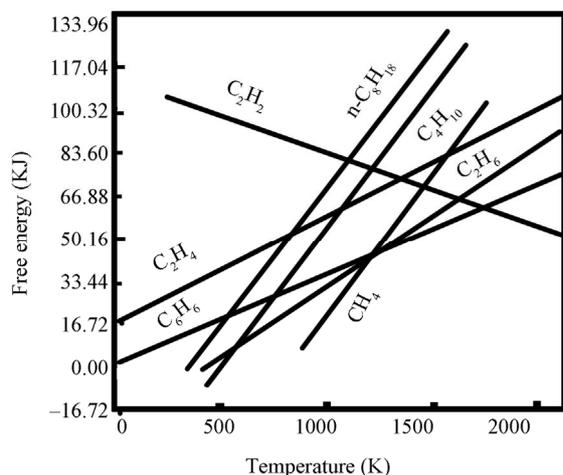


Figure 1. The relationship between temperature and free energy of hydrocarbons.

Natural gas between 3000 K and 5000 K is cracked by using the plasma method and separated to acetylene (main product) and hydrogen (by-product).

Advantages of the plasma method are as follows: 1) this processing is very simple and save investment and low capital. This method doesn't need oxygen and only requires natural gas, water and electricity. **Table 1** shows the comparison of three methods between investment and energy consumption. The plasma method can get more benefits than other methods. 2) Feedstock of the plasma method mainly is natural gas or cheap petroleum gas which is easily obtained. 3) The crack gas is easily separated and purified.

2.2. Natural Gas Used to Cut Metal

Gong Yanwu [4] introduced that natural gas is used to cut metal. Natural gas as cutting gas gradually takes the place of propane and acetylene because high investment and high energy consumption. It limits to the development of propane and acetylene, such as, the feedstock of acetylene (calcium carbide) is one of high energy consumption product, 1 t calcium carbide is got with the consumption of 3000 KWh - 5000 KWh electricity and 0.5 t standard coals. 3.5 t calcium carbide residual and some harmful gas (CO, H₂S and SO₂) are discharged; on the other hand propane's price quickly increases due to no more propane. So the appliance of natural gas instead of propane and acetylene has some advantages at the aspects of economic and environment and safety.

2.2.1. Natural Gas' Characteristics

Table 2 presents comparison about natural gas, propane and acetylene. Natural gas' explosion limit and burning point and burning speed are very low and slow, respect-

Table 1. The comparison of three methods between investment and energy consumption.

Method	plasma	partial oxidation	calcium carbide
Ratio of investment and income	1	3	2
Amount	600 t/y	2.87 million t/y	> 0.67 million t/y
Natural gas (\$0.98/m ³)	\$2248	\$6419	
Oxygen (\$0.8/m ³)			\$2736
Hydrogen (\$0.3/m ³)	900		
Coal (\$500/t)			\$825
Electricity (\$0.464/KWh)	\$4872		\$5564
Feedstock	\$8020	\$9155	\$7950

Table 2. Characteristics of three gases (natural gas, propane and acetylene).

Gas	Natural gas	Propane	Acetylene
Volume (%)	0.75	2.0	1.2
Explosion limit (%)	5 - 15	2.1 - 9.5	2.5 - 80
The lowest heat value (kcal/m ³)	8800	22256	12600
Theoretical oxygen consumption (m ³ /m ³)	2	5	2.5
Burning speed (m/s)	4.6	3.7	6.9
Burning point (°C)	1850 - 2540	2832	3100 - 3350

tively. So natural gas isn't easily explored and burnt than acetylene and has high safety performance. It has high efficiency and clean and doesn't produce calcium carbide residual. Its price is lower than that LPG, gasoline and diesel. Its utilization not only effectively decreases energy loss and reduces equipment corrosion and environmental pollution, but also improves the factory's competition, with great benefits reached by the industry.

2.2.2. Service Method of Natural Gas

Service methods of natural gas include piping natural gas (PNG) and compressing natural gas (CNG) and liquefying natural gas (LNG). **Table 3** indicates characteristics

Table 3. Comparison of three methods of natural gas provided.

Providing method	PNG	CNG	LNG
Providing condition	Piping arrives at place	No piping, CNG exists	Any area
Storage condition	No	25 Mpa	-162°C and 0.1 - 0.3 Mpa
Storage equipment	-	High compressed bottle	Low temperature tank
Price unit (Yin)	3.0 - 4.0 Yin/m ³	3.0 - 4.0 Yin/m ³	4.0 - 5.0 Yin/m ³
Note	Low investment	Transportation	LNG gas station or LNG tank

of three service methods. LNG has high price due to complicated processing and higher investment. So its sale prices are more than that of PNG and CNG. But LNG can be compressed into bottle and is good for personal requirement.

1 kg acetylene and 1 kg natural gas' prices are 16 Chinese Yin and 12 Chinese Yin, respectively. Using natural gas as fuel instead of acetylene can save 4000 Yin per day and decrease oxygen consumption. It can reduce capital investments about 2 millions Chinese Yin per year.

2.3. Natural Gas Used to Cut Metal

Tang Hongqing [5] introduced how to synthesize ethylene with natural gas. Three methods, which include three steps, two steps and one step, were discussed in detail. Three steps method, two steps method and one step method mean natural gas-synthetic gas-methanol-ethylene, natural gas-methanol-ethylene and natural gas-ethylene, respectively.

0.5 t per year unit is established by Norsk Hydro Company with three steps method in 1995. This unit was continually operated at 90 days. The experimental results showed that unit was very stable and catalyst performance was well and high yield of ethylene and propylene were obtained.

Table 4 shows product yield of MTO (Methanol-To-Olefins) unit (500 t per year ethylene). 2370 kt methanol coming from 20 billions natural gases was required to produce to 500 t per year ethylene. At the same time 345 kt propylene and 100 kt butylenes were obtained.

Table 5 presents evaluation of naphtha and natural gas as feedstock to produce ethylene. The investment of using natural gas method is more than 43.6% that of using naphtha method, while the operating cost of using natural gas method is only 20% that of using naphtha method.

Natural gas is oxidized to methanol and then produced to ethylene with MTO method. This is two steps method. It is seldom used because it is very difficult to control the first step (oxidation reaction) and a lot of by-products are

Table 4. Product yield of MTO (Methanol-To-Olefins) unit (500 t/y ethylene).

Name	Quantity, kt	Yield, %
Ethylene	500	48.0
Propylene	345	33.0
Butylenes	100	9.6
C ₅ ⁺	25	2.4
H ₂ , C ₁ , C ₂ , C ₃ paraffin	37	3.5
CO ₂	5	0.5
Coke	30	3.0
Water	1328	0.0
Total	2370	100

Table 5. Evaluation of naphtha and natural gas as feedstock to produce ethylene.

	naphtha	natural gas
Investment, billion Yin	5.5	7.9
Operating cost, billion Yin	549	247
By-product recycle	-447	-379
Net feedstock capital	102	-132
Interest, %	25.9	29.9

got. At the same time the separation processing is very complicated and has high requirement for reactor's material.

Natural gas is hydrogenated to produce ethylene. A lot of researcher studied on this method (OCM). And the good results were obtained. **Table 6** shows the different catalysts having an effect on OCM method. Reaction temperature and conversion of ethylene are above 870°C and 36%, respectively.

2.4. Natural Gas Instead of Heavy Oil Fired to Produce Chromium Trioxide

Song Ying [6] introduced that natural gas took the place of heavy oil as fuel to produce chromium trioxide. Disadvantages of heavy oil was used as fuel, such as, chromium trioxide processing is no continuing operation, heavy oil can't be fully burnt at the beginning and is discharged black flue and pollute environment; heavy oil's viscosity and freezing point are high. The heating systems are required due to storing and transporting and burning heavy oil; the quality of chromium trioxide has relationship with melting point; chromium trioxide is cracked with the increase of reaction temperature.

The composition of natural gas was shown in **Table 7**.

Advantages of heavy oil was used as fuel, such as, unit is very simple and easily operated; no more black flue is discharged and environment is protected; heat efficiency is improved in **Table 8**, heat efficiency increases 45%

Table 6. An effect of the different catalysts on OCM method.

Catalyst	Temperature (°C)	CH ₄ /O ₂	Conversion, %
Li-Mn-Ti	1073	2.5	43.9
Li-Mn	1023	1.7	47.3
Li-Na-Mn	1073	3.0	38.3
Na-W-Mn/SiO ₂	1073	2.6	38.1
Li-Na-Sn	1073	2.0	41.2
Li-Mn-Ti	1073	2.5	37.3
SnO ₂	953	1.5	44.9
Li-Mg	998	1.7	47.3
Li-Mg-Nd	1003	2.0	57.1
Li-Re	873 - 1073		41.3
Li-Mg-Mn	973		44.35
Na-Mg-B	1013		36.4

Table 7. Composition of natural gas, v%.

Composition	Volume, v%
CH ₄	95.86
C ₂ H ₆	1.54
C ₃ H ₈	0.17
C ₄ H ₁₀	0.62
C ₅ H ₁₂	0.06
C ₆ H ₁₄	0.03
N ₂	1.13
CO ₂	1.19

Table 8. Comparing consumption of natural gas and heavy oil.

Project	Natural gas	Heavy oil
Consumption	106.9 Nm ³	150 kg
Total input heat energy, kJ	380.2 * 10 ⁴	627.4 * 10 ⁴
O ₂ consumption, Nm ³	212.410	334.138
CO ₂ , Nm ³	110.748	242.4
H ₂ O, Nm ³	214.516	205.2
N ₂ , Nm ³	800.253	1294.8
SO ₂ , Nm ³	0	0.158

while amount of flue is decreased to 35.41%; operating cost can be decreased, its equipment is very cheap and a lot of electricity and water and steam are saved.

Economic benefits are listed as follows:

1) Amount of chromium trioxide is 7000 t per year, prices of heavy oil and natural gas are 1500/t and 1.6/m³, respectively, consumption of heavy oil and natural gas are 0.15 t/CrO₃ and 106.9 Nm³/tCrO₃, respectively, Costs of heavy oil per year 1500 * 0.15 * 7000 = 1.575 millions dollars Costs of natural gas per year 106.9 * 1.6 * 7000 = 1.197 millions dollars Saving cost = 1.575 millions dollars – 1.197 millions dollars = 0.378 millions dollars.

2) The equipment of water circulation for heavy oil is easily fragile and about 20 parts needs to be replaced. The price of one part is 2000 Chinese Yin. Factory can

save 40000 Chinese Yin per year.

The energy consumption of the natural gas system is reduced, such as, cooling water, steam and electricity.

3. Conclusions

In a word, using natural gas as high value production is promising option for energy reserve in China. Benefits of natural gas are listed as follow:

1) Displace the traditional energy (coal) and protect the local fragile environment, substitute for fossil fuel consumption transported from at least 1000 km and avoid pollutions emissions, such as SO₂, NO, Total Suspended Particles and CO₂.

2) Make good benefits for public and factory in the south and east of China cost-effectively.

3) Facilitate the local sustainable development and increase the local income and job opportunity.

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