Innovative Approaches to CO2 Emission Reduction and Application

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This article discribes how limestone and iron ore can become raw materials for energy production by relying on carbon gasification reaction (C+CO2=2CO). Converting a lime calcining kiln into an electric gas producer is the most economical-effective emission reduction, achieving "0" capture cost.

The total CO2 discharged from the two industries of cement and steel is 3.664 billion tons, which can produce 3729.952 billion m3CO, equivalent to 1,376.4 billion m3 of natural gas, equivalent to the energy transported by 25 Nord Stream 2 lines annually. Unfortunately, it is currently wasted。

The water-gas instead of the direct combustion of coal should be a feasible technical route. A profitable water-gas technology route should be more welcome. The technical route of Emission Reduction-ER is much better than the CCS technical route.

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I. INTRODUCTION

Climate warming and frequent extreme climate events pose a serious threat to human life and survival. Scientists primaly attribute this to the greenhouse gas- CO_2; So many methods of capturing CO_2 have emerged.

According to a report in the People's Daily CHina on October 10, 2021, the 26 CCS units have been put into operation worldwide in 2020, capturing a total of 40 million tons of CO_2. The CCS technology is difficult to promote, because of the expensive of capture and storage.

This paper proposes that using coal directly to capture the CO_2 eleased in the production of lime and iron should be an economical and feasible method, which can fully utilize the natural resources and open up a new way of energy production. The use of water-gas as power plant fuel has remarkable emission reduction effect and reduced coal consumption.

The author has written an article, 《The Technology of Producing Sponge Iron, Lime, and Nitrogen-Free Type Gas Simultaneous with Encloseed Heating Furnace.》[1], The paper is complementary and expanded.

II. THE COAL IS USED TO DIRECTLY CAPTURE CO_2 RELEASED DURING CALCINATION OF LIMESTONE.

2.1 An Argument Question

The author once wrote an article titled《A chemical reaction can save mankind》[2,3]. Discribing the carbon gasification reaction ($C+CO_2=2CO$). but didn't receive the attention it deserved. Some scholars argue that neither Emission Reduction-ER nor energy enhancement occurs before and after the carbon gasification reaction. Furthermore; they assert that heat lose may result in more to lose than gain. For the carbon-water reaction ($C+H_2O=CO+H_2$), the same problem exists.

But the author believes that the source of question is that some scholars do not take into account the results of "after used" of CO gas. The Consequence on relying on the carbon gasification reaction is described later in this paper, limestone becomes raw material for producing energy. opening up a new way of energy production. So this result seems like a strong proof that the statement of《carbon gasification reaction can save the earth and mankind》is not wrong.

2,2 The lime calciner should be transformed into an electric heat gas generator

Achieving 'o' capture costs。

The chemical equation associated with calcination of limestone is as follows:

$$CaCO_3=CaO+CO_2 \qquad \Delta H^{o}_{298k}=177.4kj/mol\ [4] \tag{1}$$

$$C+CO_2=2CO \qquad \Delta H^{o}_{298k}=162.297kj/mol\ \ ZN=3.48^{***} \tag{2}$$

$$CaCO_3+C=CaO+2CO \qquad \Delta H^{o}_{298k}=339.697kj/mol\ \ ZN=1.67 \tag{3}$$

$$2CO+O_2=2CO_2 \qquad \Delta H^{o}_{298k}=-566kj/mol \tag{4}$$

$$C_{(graphite)}+CO_{2\,(g)}=2CO_{(g)} \quad \Delta H^{o}_{298k}=172.53kj/mol \tag{5}$$

Stored energy index ZN= stored energy/consumed energy. The stored energy is the energy released after the gas is completely burned. The energy consumed includes the energy absorbed by the reaction, heat loss (including furnace gas, furnace wall, slag, product).

Equation (1), (2) is a well-known old equation that has been used in industrial production for a long time. The Lime produce depends on the equation (1).

The blast furnace ironmaking, sponge iron production, producing gas in generator ,surface carburizing of steel parts, sintered steel production, cemented carbide production, vacuum deoxidation of alloy powder etc. These are totally dependent on this reactions (2). To metallurgists, they are very familiar with this reaction. Therefore, I do not want to say more here.

Reaction (3) is endothermic reaction, or energy storage reaction. It is the result of adding the two equations (1)+(2)=(3).

The theoretical storage energy index ZN=566/339.69=1.67, including 10% heat loss, storage energy index ZN*==566/339. 697X1.1=1.51. The energy storage index is greater than 1, which means that the energy consumption of production process is zero for producing lime and CO gas at same time.

According to the calculation of equation (1), we can get:

A. To produce 1 ton of lime, the limestone decomposes and releases $400M^3CO_2$ or 785.7 kg CO_2.
B. To Produce 1 ton of lime, 3167857kj of heat was absorbed. Equivalent to 880 kwh of electricity.

According to the calculation of equation (3), it can be obtained that:

To produce 1 ton of lime, while 800M³ of CO gas (without nitrogen) can be produced. The Nitrogen free type CO gas comes from a closed furnace body or hearth.

C. To produce 1 ton of lime, absorbed 6066018kj heat. Converted into electrical power is1572kwh. Thereinto; 880kwh is heat absobed by limestone decomposition, account for 55.97%。692kwh is heat absobed by carbon gasification, account for 44%.
D. The production of 1M³ nitrogen-free type CO gas requires 2.1 KWh of electricity, factor in 20% heat loss, it is 2.5 kwh of electricity.

Due to the slow burning rate of limestone, large heat loss is caused by calcination,

According to the calculation of the reaction formula(2),_the production of 1m³ gas requires 1.08 kwh of electricity and 0.27 kg of carbon. The calorific value of 1m³ CO gas is 3045kcal, the caloricity of 1kwh is 860 kcal, the selling price about is 3 yuan, the use of valley power production, the cost is 0.3 yuan。 After the comparison in regard to the economy and energy consumption,it can be found that there is a large profit space. There is no "more harm than good".

The (0) capture cost is achieved because the production of lime also produces gas at same time, and the price of gas is much greater than the price of lime, and lime becomes a by-product.

The rough calculation shows that unprofitable situations seem unlikely.

Fortunately, the making temperature required for limestone calcination and producing gas is the consistent of 1050°C.. In addition; The carbon gasification reaction rate is much greater than the calcinate rate of limestone, the former is measured in seconds, but the calcination of limestone is measured in hours, the heat transfer of the porous lime layer is slow, The burn-through rate of limestone at 1100°C, is 1.6cm/h, and the burn-through rate becomes the control step or slowest step of the lime produce process. The rate of carbon gasification reaction does not affect the lime produce。

It is worth mentioning that the use of carbon capture CO_2 has the potential to increase lime productivity and reduce production costs. Because the condition of limestone decomposition is that the decomposition pressure (P_{CO2})of calcium carbonate must be greater than the partial pressure of CO_2(p^*_{co2}) in the furnace gas. At 1050°C, when the carbon gasification reaction reaches equilibrium, the CO_2 content in the gas phase is almost zero, $P_{CO2}>>>P^*_{CO2.}$ The P^*_{CO2} in the furnace gas is almost zero, so it is conducive to the decomposition of calcium carbonate and improve the decomposition rate of limestone。 So increasing productivity.

At present; The steel heat treatment furnaces and powder metallurgy sintering furnaces were used extensively in industrial production, these furnace bodies are closed all and can be used to produce gas and lime, Only the stock box is filled with limestone and carbon powder.

Of course, if a supplementary gasification chamber with a cross-sectional area 5-10 times larger than that of the furnace hearth and about 1 m long is added at the tail of the furnace, the CO_2 in the gas is reduced to less than 1%, which may be a complete gas producer. As for the combined furnace type, it remains to be practiced.

In addition, it is necessary to increase the gas washing device and gas storage tank.

According to the Internet, the production of 1 ton of lime in the calcination furnace requires 600-900 kg of coal***, the equivalent carbon content is 516-774 kg, take the middle value of 645 kg, 645 kg of carbon after burning to produce 2365 kg(645x3.67=2365)of CO_2. adding 785.7 kg of CO_2 released by limestone decomposition. that is to say to produce 1 ton of lime, the total CO_2 emission is 3150 kg(2365+786=3151).

The production of 1 ton of lime, the release of 3.151 tons of CO2, of which 2.365 tons of CO2 from coal combustion, accounting for75% of emissions.

With electric heating instead of carbon heat has a significant emission reduction effect, especially the use of valley electricity, it is more economical. Therefore, it is the most effective and economical technical route to transform lime kiln into electric gas producer. The CCS route simply doesn't compare.

In 2016, the consumption of lime is 3.248 billion tons, and the amount of CO_2 emitted should be 10.2 billion tons, accounting for 31% of the global total emissions of 33 billion tons, which is a large emitter. The authors argue that capturing CO_2 focus should be the lime kiln.

To sum up, the transformation of lime calciner into gas producer and the

production of lime and gas at the same time is an economical and effective emission reduction technical route, and there is no difficult technical problem.

***:The data quoted on the Internet differs greatly from the theoretical data of 122.3 kg/ton lime.required for carbon, which is estimated to be the data of calcination in round kilns。

2.3 CO gas is produced to use limestone, Open up new ways of producing energy

According to online data, in 2016, the global production of cement is 5 billion tons, with China accounting for 2.5 billion tons. It is calculated that the consumption of limestone used to produce cement should be 5.8 billion tons.Based on the CaO content of cement being approximately 65%, this equats to a limestone consumption of 5.8 billion. The amount of CO_2 released from the calcination of this limestone is 2.552 billion tons, Thereinto; the content of carbon is 696 million tons, and the content of oxygen is 1.856 billion tons. The 2,552 billion tons is 7.73% of the total global CO_2 emissions of 33 billion tons。

If carbon gasification reaction $C+CO_2=2CO$ is used, the CO_2 is converted into CO gas. According to the equation(2); One ton of carbon can converts 3.67 tons of CO_2 into CO. 2.552 billion tons of CO_2 would require 696 million tons of carbon or 770 million tons of standard coal. Of the 2.552 billion tons of CO_2, the carbon content is 696 million tons, which is 809 million tons of standard coal, which is larger than the annual extraction of the United States or India.

According to equation (3), 1 ton of CO_2 can produce 1018 M^3 of CO, 2.552 billion tons of CO_2 can produce 2,600 billion M^3 of CO,

The calorific value of natural gas is 8000-8500kcal/m^3, and the median value is 8250kcal/m^3. The calorific value of CO is 3045kcal/m^3, and the calorific value of natural gas is 2.71 times that of CO gas. 2,600 billion cubic meters of CO gas is equivalent to 959.4 billion cubic meters of natural gas. It is equivalent to the annual transport capacity of 17.4 pipelines of the Nord Stream 2 line. (The design transport capacity of Nord Stream Line 2 is 55 billion m^3 per year). Europe needs 570 billion m^3 of gas per year, and 959.4 billion cubic meters of gas is almost enough to meet the annual gas demand of two European countries.

People celebrate the discovery of 100 billion cubic meters of natural gas fields, while every year 10 PCs 100 billion gas fields are wasted and ignored. They are to go to war for one natunal gas pipeline, killing each other, giving the lives of many, young men, war is the most stupid act of mankind. If the expense of the war is used for technological transformation and the lime kiln is transformed into an electric gas producer, mankind can enjoy a peaceful and happy life forever.

Three-quarters of carbon and oxygen element in gas come from limestone, which has become a raw material for energy production, opening up a new way of energy production.

If limestone can be recycled to use, there is no need to worry about energy depletion. When the coal runs out, the wood carbon can be used in gasification reaction instead of coal.

III. THE USE OF COAL TO DIRECTLY CAPTURE THE CO_2 RELEASED DURING THE PRODUCTION OF SPONGE IRON

The formula for carbon reduction of iron oxide is:

$$Fe_2O_3+3C=2Fe+3CO \quad \Delta H^{o}_{298k}=447.4kj/mol \tag{6}$$

The actual carbon reduction of iron oxide is carried out in steps, that is:

$Fe_2O_3 \rightarrow Fe_3O_4 \rightarrow FeO \rightarrow Fe$. The longest reduction process is FeO reduction.

The reaction is endothermic, and the theoretical storage energy index ZN=844/447.4=1.89. After accounting for 10% heat loss, the storage energy index ZN*= 1.70. The ZN is greater than 1, which means that the energy consumption of the production process is zero.

According to the calculation of the reaction formula, the production of one ton of sponge iron while producing 600 M^3 of nitrogen-free type CO gas requires 0.321 tons of reducing agent carbon or standard coal 357 kg. From the results of our repeated determination of the reduction gas phase composition, in the reduction stage of FeO, For thermodynamic and kinetic reasons, the reduction gas phase always contains about 25% CO_2, which must be converted to carbon monoxide with carbon outside the reduction reaction zone.That is just to put some carbon powder at the top of the reaction tank.

From the formula of Fe_2O_3, the content of iron is 70% and the content of oxygen is 30%. According to the network, in 2023, the global crude steel production is 1,888.2 million tons, (China's crude steel production is 1,019 million tons, accounting for 53.97% of the world).

According to the crude steel production, the application amount of refined iron ore should be 2.697 billion tons, of which the oxygen content should be 809 million tons, and these Oxygen with carbon combine to produce CO_2,. Its weight is 1.112 billion tons.

When we add the CO_2 released by the decomposition of limestone and the CO_2 released by the production of ironmaking, and we get 3.664 billion tons of CO_2 (25.52+11.12= 3.664 billion tons), if it is converted into CO rely on carbon gasification reaction, it is 3,729.95 billion m^3 CO gas, this value equivalent to 1,376.36 billion $m^3$of natural gas, and that`s equivalent of 25 Nord Stream 2 lines energy delivered in a year。

At present; So much energy is thrown away。

We used a sealed small iron box (120x60mm)[6], which was filled with iron ore powder and carbon. The carbon powder was added with Fe, Co, Ni, Cu Ag, S etc. catalysts or poisons to study their catalytic and poison effects on carbon reduction of iron oxide. The catalytic activity was determined according to the flow rate of the reduction gas release, the composition and the carbon content in the sponge iron. The CO content in the released reducing gas fluctuates at 75%, and there is about 25% CO2, which is the CO2 we need to add carbon to converte to CO.

IV. USING WATER TO REDUCE CO_2 EMISSIONS

Using water to reduce CO_2 emissions is based on the reaction equation:

$$H_2O+C=H_2+CO \quad \Delta H^{\circ}_{298k}=39488 \text{ kcal/kgmol.(liquid)} \quad (6)$$

$$28380 \text{ kcal/kgmol.(vapour)}$$

This is an old reaction that everyone knows. The equation clearly tells you that gas contains 50% hydrogen. Using this water-gas gas as a power plant fuel, the CO_2 content of the flue gas can be reduced remarkable.

The carbon in the equation can be any kind of carbon, such as; plastic, rubber, paper, cloth, bituminous coal, peat, firewood, wood chips, feces, animal carcasses, and so on. Different raw materials have different hydrogen content in the gas.

4.1 Carbon

Carbon reacts with water:

$$C_{(graphite)}+H_2O_{(g)}=H_{2(g)}+CO_{(g)} \quad \Delta H^{\circ}_{298k}=+131.382kj/mol[6], \quad ZN=4.35 \quad (7)$$

This reaction is endothermic reaction, or energy storage reaction, the theoretical energy storage index of the reaction ZN=4.35, if the 20% heat loss is included, ZN*= 3.62, the energy storage index is greater than 1, This means that the production process uses zero energy.The gains and losses feared by some scholars are unlikely to materialize.

According to the reaction calculation, 1 ton of carbon requires 1.5 tons of water to produce 3733 m^3 of nitrogen-free type water-gas, and the calorific value of water-gas is 3048 kcal/m^3.

4.2 Plastic

$$\text{PE type plastic; } C_2H_4+2H_2O=4H_2+2CO \quad (8)$$

$$\text{PP type plastic; } C_3H_6+3H_2O=6H_2+3CO \quad (9)$$

According to equation (8), (9), a ton of PE or PP type plastic and 1.3 tons of water can produce 4800 m^3 of nitrogen-free type gas, the content of hydrogen in the gas is 67%. Once this water-gas is used as fuel for power plants, CO_2 emissions can be reduced by 67%

People are very worried about white pollution. Her Majesty the Queen has called on scientists to save the planet .Because the sea is also seriously pollute The author believes that the white pollution can be eliminated by using water and electricity, and the plastic islands floating in the Pacific Ocean can be a good raw material for the production of gas. The energy storage index of these two reactions is estimated to be higher than 4.35, so it is unlikely that the gains will outweigh the losses. In a strongly reducing atmosphere, toxic dioxin gases are unlikely to occur.

Thankfully; In the lab we have done experiments and got beautiful blue flames.

4.3, Rubber

$$C_5H_8+5H_2O=9H_2+5CO \quad (10)$$

According to equation (10), a ton of waste rubber and 1.32 tons of water can produce 4600 m^3 of nitrogen-free type gas, and the content of hydrogen in the gas is 64%.

4.4. Starch (C_6H_{1005})

$$2C_6H_{1005}+12H_2O=1017H_2+12CO \quad (11)$$

According to equation (11), a ton of starch plus 0.1 tons of water can produce 10700 M^3 of nitrogen-free type gas, and the hydrogen content in the gas is 98.83%, almost all hydrogen.

4.5 Starch

$$2C_6H_{1005}+12H_2O=1017H_2+12CO \quad (12)$$

According to equation (12), a ton of starch plus 0.1 tons of water can produce 10700 m^3 of nitrogen-free type gas, and the hydrogen content in the gas is 98.83&, almost all hydrogen.

4.6. fat ($C_{57}H_{11006}$)

$$C_{57}H_{11006}+57H_2O=5560H_2+57CO \quad (13)$$

According to equation (13), a ton of fat plus 0.087 tons of water can produce 10760 M^3 of nitrogen-free type gas, and the hydrogen content in the gas is 98.98%, almost all hydrogen.

As can be seen from the above, using water to produce water-gas, the minimum hydrogen content of gas is 50%. If animal carcasses are used as raw materials, the hydrogen content is almost 100%. The emission reduction effect is even more significant.

According to online data, power plants account for about 70 percent of global CO_2 emissions of 33 billion tons per year. That is, 330x0.7= 23.1 billion tons, if all the world's thermal power plants are converted to water-gas as fuel, 50% emissions reduction is 11.55 billion tons, an astonishing figure. Therefore, using water to reduce CO_2 emissions is also the very effective and economical way.

Using water to reduce CO_2 emissions has many advantages;

One of the biggest advantages is that resources are abundant, the price is cheap, and the production cost of gas is low.

Another advantage is that an infinite number of Bioenergy is utilized and It is easy to realize coal gasification in rural areas, while protecting the environment. Once the global rural coal gasification, energy depletion, environmental pollution, climate warming three problems troubling mankind should be solved.

Fortunately, the laboratory research on the production of water-gas using plastic, waste paper, wood chips, pig skin and pig manure as raw materials has been basically completed. There's video to prove it.

The author holds that the use of water and biological energy to produce water-gas is the only way for human beings, because the resources are rich and continuous, both to provide energy, but also to protect the environment, protect the climate, conducive to human survival.

V. CONCLUSION

The three technical schemes share several commonalities; Firstly, a closed furnace body or hearth; Secondly, a consistent operating temperature of 1050°C; Thirdly, the complete utilizztion of natural resources. Fourth, the direction of the flow of gas and furnace charge must be the same, from low to high temperature.

Fiveth, the emissions reduction, reducing emissions at the source. It is more cost-effective than capture.

The author believes that the most economical and effective emission reduction is the replacement of carbon heat by electric heating, The limestone calcining kiln must be transformed into electric gas generator. the simultaneous production of lime and gas, and the realization of '0' capture cost.

The author holds that; Using carbon gasification reaction, limestone becomes raw material of energy production, opening up a new way of energy production, which is of great significance. The author considers that "A chemical reaction can save mankind" is not wrong。

Using coal to capture the carbon dioxide released by the production of sponge iron, the production cost of iron is reduced, and the oxygen in the iron oxide is fully utilized. Once sponge iron becomes raw material of steelmaking; blast furnaces, sintering furnaces, coke ovens, converter will be eliminated, there will be a technological revolution in the metallurgical industry.

Using water and bioenergy to produce water gas, it should be a feasible technical route to change direct combustion to indirect combustion. It is the technological route that human beings must take. It is also the technical route to realize coal gasification in rural areas. In particular, the use of valley power to produce gas, there is a large profit space.

Any of the above three technologies are more economical - efficient - than the CCS technology route。

Finally; The authors argue that the $C+CO_2=2CO$ and $C+H_2O=H_2+CO$ reactions could save the earth and humanity. One is the use of limestone, the other is the use of bioenergy, both resources are rich, the source of constant.

Electricity, cement, steel are the three pillars of the national economy, both energy consumption, but also large carbon dioxide emissions, relying on electricity, water, coal; Relying on carbon gasification reaction and carbon water gas reaction, the author believes that it can economically and effectively solve the three major problems of energy exhaustion, environmental pollution and climate warming. Let mankind live in peaceful and happy life forever.

Finally；To compare the two technical routes of ER and CCS, it is obvious; The ER technological route has great advantages.

The author is shallow knowledge, not self-evident, talking on paper, a brick to attract jade, expectations of insightful criticism and correction.

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