BBChina

Master Program
on Bio-Based Circular Economy

Course of Renewable Energy Technologies

Waste to energy in China

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Summary

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Chapter 1 Background

1.1 The Amount of Municipal Solid Waste in China

Since the 21st century, with the rapid development of China's economy, science and technology, people's living standards have been improved continuously. At the same time, the amount of municipal solid waste is also increasing. According to the statistics of China Association of urban environmental health, the annual output of municipal solid waste in China has reached 150 million tons, with an annual growth rate of 10%. Over 6 billion tons of waste has been accumulated over the years, covering an area of more than 5000 square kilometres. More than 1.5 million tons of urban domestic waste are produced every year in China, increasing by 8%-10% every year; 2/3 of large and medium-sized cities in China suffer from waste problems, and the annual resource loss value caused by waste is nearly 30 billion yuan [1].

However, the per capita daily output of domestic waste in different provinces and towns fluctuates widely. On the whole, the waste productivity is related to the level of regional economic development, residents' living habits and the main fuel used. The per capita daily output of domestic waste in all provinces (cities) and autonomous regions in China shows the characteristics of high in the south, high in the north and low in the East and low in the West. The output of domestic waste in villages and towns in the more developed areas in the Middle East is higher than that in the less developed areas in the West. In the same area, the output of MSW in villages and towns is related to the source of domestic fuel, per capita annual income, types of breeding and types of farmers (pure farmers, agribusinesses, non-agribusinesses and non-farmers). The household with large population and high per capita income will produce more domestic waste, while the household with coal as the main domestic fuel will produce less domestic waste. In addition, the output of domestic waste in different seasons in the same area will also change, especially in Zhejiang, Guangdong, Liaoning and Yunnan, the output of domestic waste in different months fluctuates greatly. This is because the residents in these areas will choose to go out to work during the slack period, which will reduce the production of domestic waste to a certain extent; during the slack period, the production of domestic waste will increase due to the increase of agricultural waste bottles sprayed with pesticides. [2]

1.2 Main Treatment Methods of Municipal Solid Waste in China

The main ways of waste treatment are sanitary landfill, incineration, composting and comprehensive utilization. By the end of 2015, statistics showed that the collection scale of municipal and county-level cities in China had reached 840000 T/D of domestic waste, with 2077 harmless treatment facilities, including 1748 sanitary landfills, 257 waste incineration plants, 72 other treatment facilities, and a total of 758000 T / D of domestic waste, with a harmless treatment rate of 90.2%. In the process of harmless treatment, 31% of the domestic waste is treated by incineration, of which 48% is burned in the eastern part, and most of the domestic waste is still treated by sanitary

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landfill. According to the latest "13th five years plan" for the construction of harmless treatment facilities for urban domestic waste, the overall application of landfill is not ideal, and environmental pollution is prominent. By the end of 2020, realize "zero landfill" of primary waste. [3]

1.3 Main Waste-to-energy Technologies in China

The main method of waste-to-energy technology is thermal treatment technology, namely waste is converted into other forms of energy at high temperature. thermal treatment technology is the most important and effective means to reduce and recycle waste, which mainly includes three ways: incineration, pyrolysis and gasification.

Incineration has the advantages of high reduction rate, high utilization rate and small space requirements, and has the highest market share of thermal treatment technology for waste in the world. However, the secondary pollution problems such as dioxins and heavy metals caused by incineration have become increasingly serious. Pyrolysis is a process based on the thermal instability of organic matter. Without oxygen, the thermal energy is used to transform the organic matter in waste into combustible gas, tar and coke. Compared with incineration, the amount of flue gas and fly ash in pyrolysis technology is less and dioxins are not easily generated. Gasification is a process, in which the organic components in waste react with gasification agent under hypoxia to produce combustible gas and ash residue. Gasification is more conducive to high efficiency of energy utilization and strict pollution control. The post-treatment system of gasification is simple and the investment is low, which not only guarantees good environmental protection effect, but also can be used for power generation or heating.

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Chapter 2 Incineration Technologies

Waste incineration is a process of reducing the volume of waste by oxidation at high temperature through proper thermal decomposition, combustion, melting and other reactions, and becoming residue or molten solid material.

2.1 Incinerator and its Process

Waste incineration technology is based on decades of application and development. At present, there are many types of incinerators that can meet environmental protection, applicability, economy, and recyclability. According to the furnace body composition, heat transfer and combustion methods, it can be summarized into three types: mechanical grate type, fluidized bed type and rotary kiln type.

2.1.1 Mechanical grate furnace incinerator [4-5]

The core of the grate type incinerator lies in the mechanical grate, which has a long history of use. After long-term research and development and practical application, the technology is mature, the operation is reliable, the area is small, and the thermal efficiency is high. The general grate furnace can be divided into three sections according to the different functions and combustion degree of each part: drying zone, combustion zone and ash zone. The domestic waste sorted and piled up is pushed into the drying area by the feeder pusher, and then preheated, dried and gasified. After preheating, with the mechanical action of the grate, the garbage moves forward on the grate to the combustion area for full incineration, and finally to the ash area, where it is burned multiple times until the remaining refractory solid waste. The mechanical grate is driven by hydraulic linkage mechanism to perform reciprocating motion. The relative movement between the grate allows domestic garbage to move, roll, and advance in the furnace body, ensuring its full combustion and the smooth discharge of waste. The advantage of the mechanical grate type incinerator is that it does not require strict pretreatment of the garbage entering the furnace. During the movement of the grate, the garbage is cut, turned and stirred, and the garbage can be uniformly mixed, which is conducive to ignition and combustion. All domestic garbage incineration can be run on the grate, so the treatment is fast and the degree of automation is high.

2.1.2 Fluidized bed incinerator [6]

The furnace body of a fluidized bed incinerator is usually a container with refractory material as the inner wall, which is arranged vertically. The bottom of the furnace is provided with porous distribution plates, and domestic waste is sent into the furnace from the upper or side of the fluidized bed, accompanied by inert particles as a fluidized carrier, and enters the furnace body at a certain ratio at the same time. The air enters the furnace through the ventilation device at the bottom of the

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incinerator, and the vertically rising air flow blows the mixed particulate matter in the furnace, causing intense tumbling combustion and continuous circulation flow, which has the characteristics of fluid. The fluidized bed incinerator has the advantages of high burnout rate, wide load adjustment range, low pollutant emissions, high heat intensity, suitable for burning low calorific value materials, etc. It has great development prospects in small and medium-sized cities and towns, especially for relatively low calorific value Incineration of garbage. However, due to the violent tumbling and circulating flow of domestic waste during the combustion process, the requirements for its particle size and density are high, so it is necessary to carry out strict pretreatments such as crushing and stirring to ensure small differences. This makes the pretreatment steps of domestic waste before entering the fluidized bed incinerator more cumbersome, which greatly affects its development and use.

2.1.3 Fluidized bed incinerator [7]

Rotary kiln incinerator refers to an incinerator equipped with a refractory lining furnace inside a cylindrical body made of steel plate. Its structure and composition usually include: domestic garbage stacking area, garbage feed inlet, incinerator furnace body, thermal energy Recycling device, secondary combustion chamber, waste recycling and pollution control. The kiln body is a one-dimensionally inclined, low-speed rotating cylinder. After the garbage enters, it slowly rotates while transferring the waste supplied from the upper part to the lower part. Air is supplied from the front or rear until the ash is discharged from the lower end. Generally, a secondary combustion chamber is provided after the rotary kiln, so that the toxic and harmful gases that have not been completely burned in the previous section can be completely burned at a higher temperature. Rotary kiln incinerator is a mature technology, which has strong adaptability to the change of incineration materials, can burn wastes with different properties, and has the advantages of long residence time and good heat insulation. At the same time, because of the turning effect, the waste material layer is fully turned over, which is more suitable for garbage containing a variety of incombustible substances. In addition, the situation where the moisture in the garbage is large is also suitable. Because of its stable combustion state and good safety performance, rotary kiln incinerators are currently mainly used in waste disposal projects with less waste and greater risk, such as medical waste and hazardous waste. However, when the calorific value of domestic waste is low, there will be insufficient combustion and excessive pressure, which makes combustion difficult. In addition, the furnace of the rotary kiln rotates slowly, and the uneven combustion for a long time makes the refractory lining seriously damaged, requiring frequent repair and replacement. At the same time, the equipment has high sealing requirements and high maintenance costs, which makes it difficult to adapt to the actual needs of waste disposal and power generation, and is rarely used in current waste incineration power generation.

2.2 Development of China's Domestic Waste Incineration Plant

During the "Twelfth Five-Year Plan" period, my country's urban domestic waste incineration industry has developed rapidly. According to the relevant requirements of the "Notice on Accelerating the Promotion of Domestic Waste Classification in Some Key Cities" of the Ministry of Housing and Urban-Rural Development, the number of waste incineration plants in operation has increased year by year. Before 2000, there were only two waste incineration power plants in China. As of the end of 2017, there were about 303 domestic waste incineration power plants built and put into operation in China, with a total processing capacity of 304,000 t/d and a total installed capacity of about 6280MW. Among them, there are 220 incineration power plants using grate furnaces, with a total treatment capacity of 228,000 t/d and an installed capacity of 4380MW, accounting for about 50% of the harmless treatment capacity [8]. The disposal capacity of domestic waste has been greatly improved. According to the current situation, affected by the economic environment, domestic waste incineration power plants are mainly distributed in the southeast coastal area, especially around the large cities around Jiangsu, Zhejiang and Shanghai, and the construction progress of their waste treatment facilities is far ahead. With the economic development, more and more cities in China have chosen to build domestic waste incineration power plants, but the overall progress is relatively slow compared to coastal areas.

2.3 Impact of Waste Incineration

2.3.1 Environmental advantages of household waste incineration

In terms of waste disposal methods, the incineration of municipal solid waste has obvious advantages, and has become an important solution to the problem of waste in many cities. The main advantages are as follows:

First, the requirements for environmentally friendly emissions have been increased. When it comes to garbage incineration, the primary consideration is the emission of dioxins in the flue gas. Dioxins aromatic compounds have a great impact on the ecological environment and have a strong carcinogenic effect. How to deal with dioxin has become an unavoidable topic in the research of waste incineration technology. Its research progress directly affects the development of waste incineration technology. Dioxins aromatic compounds in the environment mainly come from industrial incineration, pesticide abuse, paper bleaching and other activities. In recent years, incinerators developed by countries around the world have first fundamentally solved the generation of dioxins, and secondly focused on the secondary combustion of waste. And exhaust gas purification. Under various government controls, incineration of waste incinerators is no longer the source of dioxin emissions.

Second, it reduces greenhouse gas emissions. Compared with other treatment methods, waste incineration technology has many advantages, especially in terms of energy saving and emission

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reduction: (1) Compared with traditional landfill treatment, full incineration greatly reduces the greenhouse gas emissions of landfills; (2) Waste incineration can provide a large amount of heat energy for industrial production, thereby significantly reducing the use of fossil fuels and the production of greenhouse gases; (3) The carbon content of waste incineration waste residue is less than 1%, which makes full use of carbon resources[8].

Third, it provides new energy. Although compared with developed countries, China's domestic waste is "absolutely poor mine", its calorific value content is less than 50% of developed countries, but waste incineration can still provide a lot of energy. According to statistics, China's waste incineration power generation project generates an average of 250kWh of electricity per ton of domestic waste, and the process requires 50kWh of electricity, which is a net output of 200kWh. This data (the amount of electricity generated per ton of domestic waste) is as high as 520kWh in the United States. As early as 2004, the output value of the waste incineration power plant in the United States reached as high as 10 billion yuan, which can be called "wealth in waste". Waste incineration power generation is the smallest environmental impact of all combustion power generation [9].

2.3.2 Problems in the application of domestic waste incineration

Although domestic waste incineration has significant advantages, there are still many problems in practical application. In China, disputes over location selection and supervision are endless, and many places even face strong opposition from public opinion. In the process of implementing the waste incineration treatment method, the current main problems are as follows:

First, the lack of in-depth understanding of the garbage incineration project by the masses makes it still controversial. Social groups panic about pollutants such as dioxin, fly ash, and leachate from garbage incineration. Residents in many places refused to build the incineration plant around their residences, and opposition voices became the biggest obstacle to the implementation of the policy.

Second, the effectiveness of corporate processing is insufficient, and government supervision is difficult. Although the waste incineration plant relies on regional monopolies, government subsidies, waste disposal fees, and revenue from renewable power resources to ensure a high return on the project, it has quickly become a hot investment spot for domestic and foreign companies. However, in actual operation, there are still many bad behaviors. For example, in order to reduce costs, some companies have greatly reduced exhaust gas purification consumables and lowered emission standards. In December 2016, according to incomplete monitoring by private environmental protection organizations, there were 27 waste incineration plants that emitted smoke 2533 times in excess of the standard for 25 days [8]. In the process of government supervision, many over-standard problems have not been effectively punished and rectified, which has reduced the credibility of the local government, triggered the resistance of the people, and caused the dilemma of being unable to communicate.

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Chapter 3 Pyrolysis Technologies

Pyrolysis refers to the process of decomposing objects under high temperature conditions under the conditions of anaerobic or anoxic conditions. Pyrolysis treatment methods are more inclusive of materials and can handle a variety of complex mixed wastes, including those containing high alkali metals, heavy metals and acid gases. And the pyrolysis process is in an inert atmosphere, which can avoid the discharge of various polluting gases. Compared with the incineration method, its processing temperature is lower. After pyrolysis, there are less residual residues, which can achieve a larger volume reduction ratio, and the remaining residues are relatively stable, which is easy for later storage treatment[10].

In the 1920s, the pyrolysis mechanism of coal was relatively mature, and industrial implementation has been successful. The application of pyrolysis technology to the disposal of solid waste was a matter of the 1960s. At that time, European countries were studying the incineration method for the final treatment of waste, while the relevant scientific workers in the United States were exploring a waste treatment method-pyrolysis method that is safer for the environment and can recover energy than the incineration process. In the 1960s and 1970s, the use has been greatly developed. For example, United Carbide Corporation, Occidenting Petroleum, Monsanto, Torrax, etc. have researched and developed a set of unique pyrolysis systems, which have been put into use in the United States. At the same time, people of insight in some European countries and Japan realized the unfavorable factors of waste disposal by incineration, and in turn strengthened the research on pyrolysis technology. China has only conducted systematic research on pyrolysis technology of solid organic waste since the 1980s. Tongji University, Chongqing University, Shanghai University of Technology, etc. are carrying out similar pyrolysis gasification research, but there is no industrialization yet. The device is put into operation. It can be considered that internationally, solid organic waste pyrolysis treatment technology has entered the stage of industrialization and gradually updated. China has also made great progress in solid waste pyrolysis. At present, China adopts pyrolysis treatment of waste tires, biomass, urban Domestic garbage, etc.[11] Reactions take place in a recognized pyrolysis process can be expressed as:

$$C_xH_yO_z + Q \rightarrow Char + Liquid + Gas + H2O \quad (1)$$

where Q is the heat that needs to be input to the reactor for the reactions to take place.

3.1 Configuration Characteristics

3.1.1 Combined technologies

Existing industrial pyrolysis technologies rarely use gas, tar, and char as the final products to operate alone, and most of them are combined with gasification, combustion, and smelting; combined with gasification, they produce medium calorific value gas, which has been incinerated in recent years.

The process is still receiving widespread attention, and it will be a competitive choice in the future[12]. But at the same time, combined technologies are expensive and may not be available where pyrolysis technology is needed.

3.1.2 Fed with pre-treated materials

All urban domestic waste pyrolysis technology replaces the original urban domestic waste with pre-treated urban domestic waste, indicating that pretreatment is a necessary step of urban domestic waste pyrolysis technology. Pretreatment generally includes separating undesired materials and reducing particle size; sometimes a drying step is required before the pyrolysis reactor to reduce the water content of the materials fed to the reactor. However, preparing the input waste stream to match the process may be too expensive to exceed profitability. A process with flexible waste input is more practical. The combination of pyrolysis and gasification stages and the independent use of pyrolysis products serve the necessity of process flexibility.

3.1.3 Installed with secondary treatment of products

In those technologies that export pyrolysis gas to gas engines, gasification is treated as a primary treatment, and gas scrubbing is followed to ensure the quality of the syngas. When sold as industrial carbon-rich materials, char should have secondary treatment measures such as quenching, screening, and metal separation. Sometimes, the secondary treatment of pyrolysis products may be very strict, depending on the feed and the way the product is used. In order to avoid extensive secondary treatment of the product, high-temperature combustion inside the system is a suitable choice.

3.1.4 Equipped with emission abatement devices

All commercial pyrolysis processes are equipped with emission reduction devices similar to incineration plants to ensure that the pyrolysis process is clean. Typical exhaust emission control devices include particulate filters, cooling towers, wet scrubbers, etc., but the size is reduced compared to the devices used in incineration plants. In addition to commercial and semi-commercial pyrolysis technologies, some pilot or demonstration technologies have been developed to simplify the pyrolysis system of municipal solid waste by applying pyrolysis technology alone.

3.2 Typical Pyrolysis Equipment

The reported reactors for MSW pyrolysis include fixed-bed reactors, rotary kilns, fluidized bed reactors and some innovative reactors. In regards to the reaction conditions, most pyrolysis processes have been conducted at atmospheric pressure. Vacuum pyrolysis has only been reported in studies of special wastes such as printed circuit board disposal (Peng et al., 2006; Li et al., 2009) , But achieving

vacuum pyrolysis is difficult in practice. Therefore, all of the following discussions in this review are based on atmospheric pressure. The reactors used in studies and at industrial scale are summarized.

3.2.1 Fixed-bed reactor

Due to the low heat transfer coefficient, the fixed bed reactor has the characteristics of low heat consumption. Therefore, when testing a larger sample mass, the temperature inside the sample is not uniform [13], and the raw materials decompose at different temperatures at the same time. Fixed-bed reactors are mainly used to determine the control parameters that affect pyrolysis products. Due to low efficiency, such reactors are rarely used in scale-up facilities.

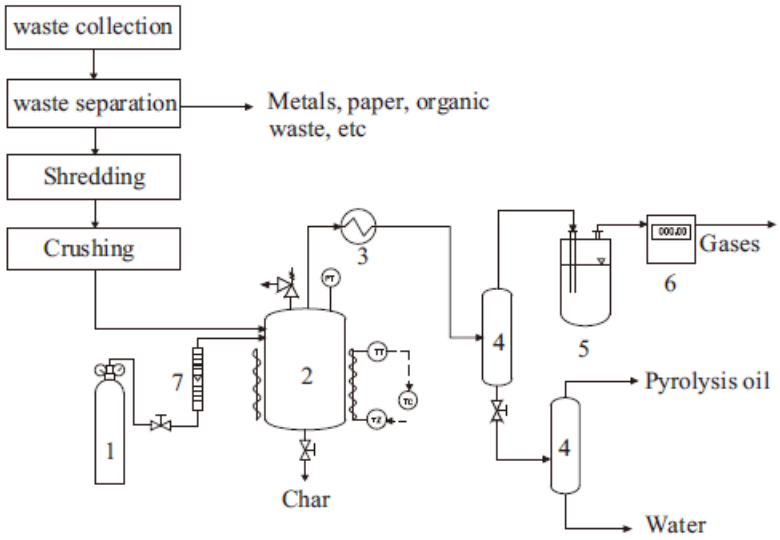

Fig. 1. Fixed-bed reactor and pyrolysis system (1-N2 bottle; 2-reactor; 3-heat exchanger; 4-separation unit, 5-water trap; 6-gas flow meter; 7-rotameter)[14]

3.2.2 Rotary kiln reactors and their systems

The rotary kiln is more efficient than the fixed-bed reactor in heating up the feedstock. The slow rotation of an inclined kiln enables good mixing of wastes. The rotary kiln reactors are widely used, but they are typical reactors used for conventional pyrolysis (slow pyrolysis), which proceeds under a slow HR with significant product portions of char, liquid and gas. HR is not higher than 100°Cmin^{-1}. The residence time is up to 1h. This is because in the pyrolysis process, only the reactor wall plays the role of transferring heat from the outside to the particles. The small wall surface is distributed on the unit mass of the raw material, and the coarse particles result in a low Hr. However, most reported domestic waste pyrolysis technologies are based on rotary kiln pyrolyzers because rotary kiln reactors have many unique advantages over other types of reactors. In addition to good waste mixing, flexible residence time adjustments and large waste flow channels allow the feeding of heterogeneous materials, so extensive pretreatment of waste is not required and maintenance is simple.

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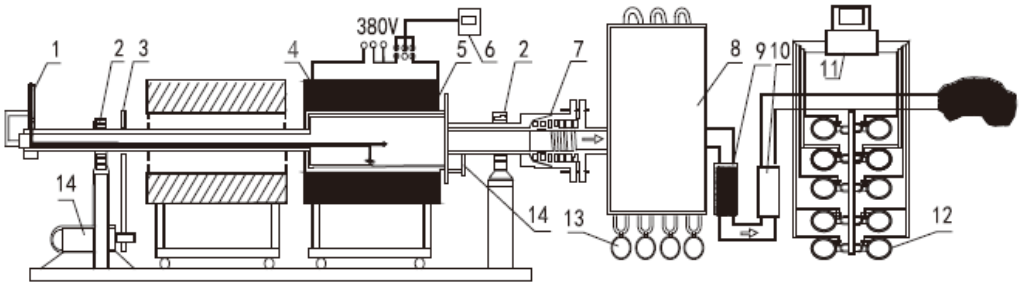

Fig. 2. Rotary kiln pyrolysis system (1-thermometer; 2-bearing; 3-gear transmission; 4-electrical furnace; 5-rotary kiln; 6-temperature controller; 7-seal; 8-two-steps condenser; 9-filter; 10-accumulative flowmeter; 11-computer; 12-gas sampling device; 13-feed and discharge opening; 14-speed adjustable electrical machinery)[15]

3.2.3 Fluidised-bed reactors

The characteristics of fluidized-bed reactor are high ratio of material to liquid and good mixing effect. Therefore, this reactor is more often used to describe the effects of temperature and residence time on pyrolysis behavior and products [16]. Generally, fluidized bed reactor is used to study the fast pyrolysis (or flash pyrolysis) behavior, and to explore the secondary cracking of tar under a long residence time. Although fluidized-bed reactors have been extensively adopted in laboratory studies, their industrial application is not common for MSW pyrolysis. The reason is that the separation of bed mate- rial from coke, along with its external heating and recirculation, is complicated.

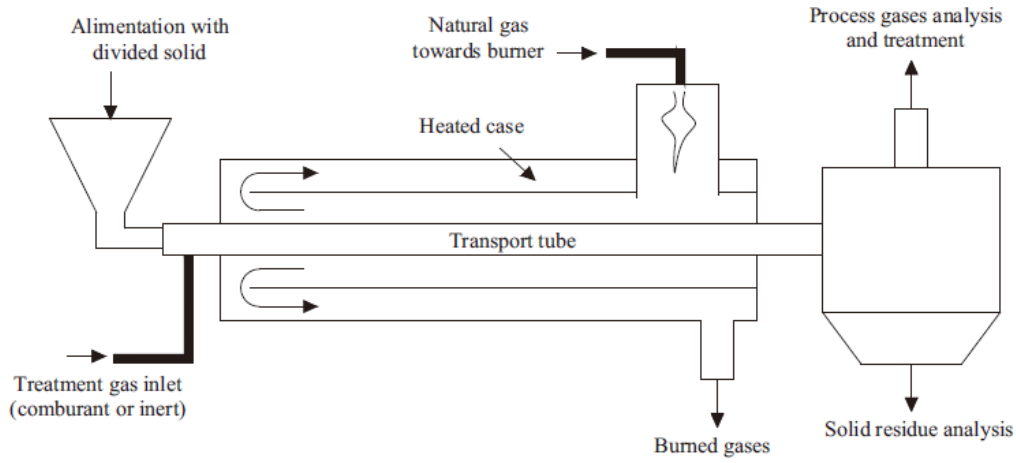

Fig. 3. Fluidised-bed pyrolysis system[17]

3.3 Pyrolysis Application

3.3.1 Pilot pyrolysis process in Tianjin

According to the characteristics of non screened MSW and the characteristics of various existing MSW pyrolysis devices, the external heat source and internal heat source are combined organically to realize the utilization of energy generated by MSW pyrolysis, This equipment is composed of main pyrolysis furnace, auxiliary pyrolysis furnace, combustible gas cooler, tar distillation tower, combustible gas filter, gas storage tank and garbage ash processor. The process flow chart of the

equipment is as follows: Figure 4 shows the pilot municipal solid waste pyrolysis facility developed in Tianjin, China[18], with a daily treatment capacity of 5 tons. When dealing with unsorted waste, it consists of a main reactor and a sub-reactor. The main pyrolysis reactor is a tubular reactor with a screw inside to push the municipal solid waste forward; the tube is heated from the outside by burning solid fuel (such as coal or charcoal produced during pyrolysis). The hot flue gas leaving the main reactor is transported to the sub-reactor, after cooling in the radiant tube, it is mixed with the pyrolysis gas, directly contacts the municipal solid waste, and heats the municipal solid waste for decomposition and gasification.

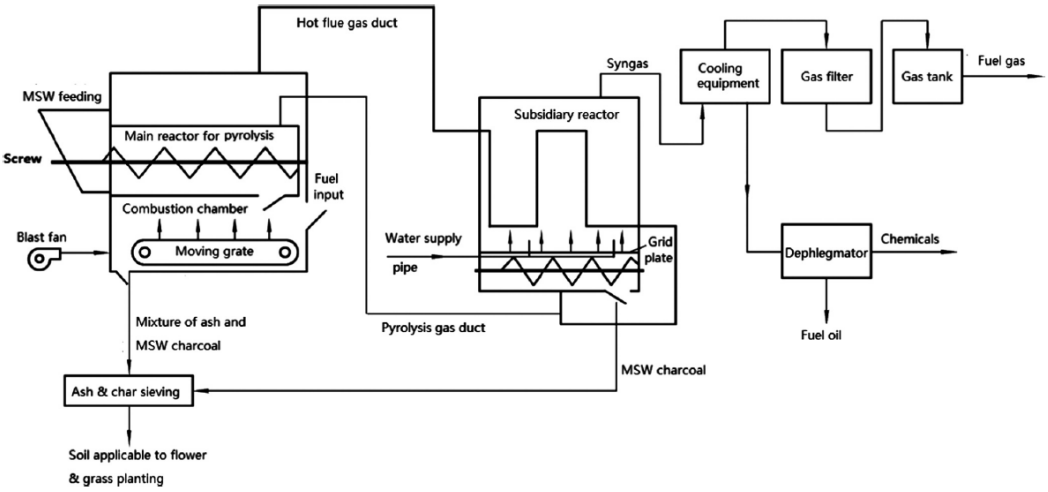

Fig. 4. Schematic of the pilot MSW pyrolysis plant in Tianjin, China

3.3.2 Pyrolysis of hazardous waste

Zhengzhou Hanyang Tianchen Hazardous Waste Disposal Co., Ltd. uses a vertical rotary pyrolysis gasifier for the treatment of medical wastes → secondary combustion chamber → waste heat boiler → quenching boiler → acid removal tower → activated carbon adsorption → bag filter → induced draft fan → chimney. The medical waste enters the vertical rotary pyrolysis gasification furnace through the feeding device, and is cracked and gasified by the air supply combustion. Under the action of the induced draft fan, the cracked combustible gas is introduced into the second combustion chamber, and further burned completely by the air supply, and then the high temperature flue gas After cooling by the waste heat boiler and quenching boiler, it is deacidified by the acid removal tower, the activated carbon absorbs dioxins and the dust is removed by the bag filter, and it is evacuated through the chimney through the induced draft fan. The incineration line of Zhengzhou Hanyang Tianchen Hazardous Waste Disposal Co., Ltd. is designed to dispose of 30t/d. Except for the necessary shutdown of the furnace for ash and slag cleaning or the replacement of refractory and thermal insulation materials, it can be operated continuously and stably, with an annual operating

time of more than 340d. The treatment of medical waste by this process will not produce wastewater. Solid wastes mainly include incineration residues and fly ash.[19]

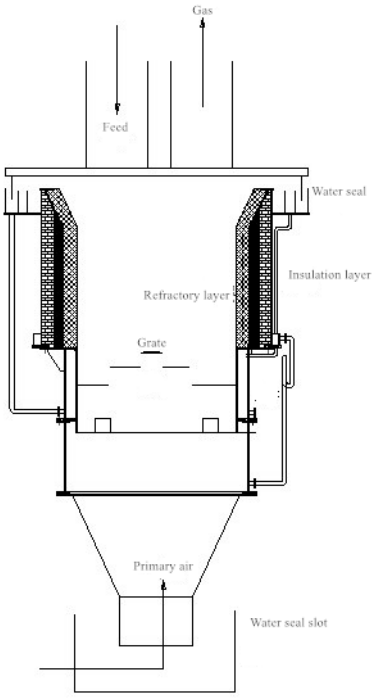

Fig. 4. Incinerator structures[19]

3.4 Advantages of Pyrolysis

The thermal degradation process of waste produces recyclable products including coal char, oil/wax and combustible gases. When applied to waste management, municipal solid waste can be converted into fuel and safe disposable materials (coal char, metal, etc.), and the pyrolysis process conditions can be optimized to produce solid coal char, gas, or liquid/petroleum products, ie heat The solution reactor acts as an effective waste energy converter. Compared with the traditional incineration plant with a daily processing capacity of 1,000 tons, the pyrolysis plant is more flexible. In recent years, the thermal decomposition of municipal solid waste has attracted more and more attention from small towns because it is not conducive to long-distance transportation. Distributed urban domestic waste treatment method. Due to the limitation of capital cost, it is difficult to ensure the environmental safety of generally distributed urban domestic waste treatment facilities; and when the quality of coal tar, oil/wax and combustible gas is well controlled, pyrolysis with appropriate capacity and output of energy products Device is a suitable substitute

Chapter 4 Gasification Technologies

4.1 Introduction of Gasification Technologies

Gasification technology is the process of converting organic matter and producing mixed gases at high temperatures (usually 550~1000℃) with insufficient oxygen. The produced gas (Syngas) is mainly composed of carbon dioxide (CO_2), carbon monoxide (CO), hydrogen (H_2), methane (CH_4) and other gases. Gasification agent mainly include air, oxygen-rich air, water vapor, carbon dioxide and so on.

In traditional waste incineration technologies, excessive air is used to ensure the complete combustion of waste. While in gasification technologies, the needed amount of air is usually 1/3 ~ 1/5 of that required for complete incineration [20]. In the gasifier, thermochemical reactions occur between waste and gasification agent to produce combustible gases such as CO, H_2 and CH_4. Gasification process includes two phases: the first stage is the thermal decomposition and gasification stage. Under the condition of below 600 ℃, waste is dried and volatile is released. The reaction products mainly include various hydrocarbons, fixed carbon and ash. The second stage is the reduction reaction between fixed carbon and gasification agent and combustion reaction between carbon and oxygen.

4.2 Typical Waste Gasification Technologies Processes

Gasification technology, as a new means of harmless and resource utilization of waste, has been widely applied and rapidly developed all over the world. The technology is becoming more and more mature, and many mainstream waste gasification technologies have been produced. Generally speaking, the gasification technology can be divided into gasification-incineration technology and gasification-melting technology, which have many different applications.

4.2.1 Gasification-incineration technology

Gasification-incineration technology means that the waste is gasified under the reducing atmosphere of 400℃ ~ 700℃ to generate combustible gas for combustion and semi-coke. Gasification-incineration system includes gasification chamber and combustion chamber. Combustion reaction between gasification products and air takes place in the combustion chamber. The air coefficient in the gasification chamber is relatively small, so is the total amount of smoke, and the cost of flue gas purification equipment is low. The quantity of volatile organic compounds (VOCs) such as benzene and phenol in gasification products is low. Meanwhile, the high temperature of the combustion chamber can decompose the dioxin precursor and reduce the emission of dioxin. At present, there are three types of gasification-incineration technologies that have been put into commercial operation, namely fixed bed type, fluidized bed type and rotary kiln type.

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According to the type of furnace, fixed-bed gasification-combustion system can be divided into vertical type and horizontal type. The structure of vertical type is simple, and the cost is low. The waste drying, pyrolysis, oxidation and reduction processes are carried out in a fixed vertical bed, and the gasification products are gas of low heat value and char. The furnace is sensitive to the mechanical properties of waste and requires homogeneous materials, so it is usually used to treat RDF with higher density or other wastes with more uniform density [21]. The horizontal fixed-bed gasifier is CAO furnace. The system is divided into two chambers: one chamber ensures enough time for the waste to be heated, and then partly gasified, partly decomposed and partly burned. The produced syngas goes into the second chamber and is then combined with air to make it burn up. CAO technology has high efficiency, is suitable for waste of low heat value, but the initial investment is large.

The rotary kiln gasification incineration process is an external-heat gasification process. After the waste is broken, it is first dried in an external-heat rotary kiln and pyrolyzed. Then the products go into an independent combustion chamber for incineration at high temperature.

In fluidized-bed gasification-incineration process, the particle size of the material needs to meet the conditions, that gas-solid contact is good and heat and mass transfer is easy. And in order to prevent slagging, the bed temperature control requirements are strict. It is a gasification process with wide adaptability, high conversion rate and high gasification intensity. At present, many companies have developed the fluidized-bed gasification-incineration process, and some of them have been put into commercial use.

4.2.2 Introduction of gasification technologies

Gasification-melting system is a new type of harmless waste-utilization technology, which combines gasification in low temperature with melting at high temperature. First gasification takes place under the reducing atmosphere at 400℃ ~ 700℃, and combustible gas and easily recycled metal are produced. Then combustible gas is fully burned, and the ash is melted at about 1300℃, the molten ash can be used as building material. Gasification-melting technology has become a new generation of gasification technology with the high development potential due to its excellent environmental benefits and higher resource recycling utilization rate [22]. At present, the typical gasification-melting technologies are blast furnace type, vertical furnace type and fluidized-bed type.

Blast furnace type gasification-melting technology comes from direct gasification-melting system in blast furnace of Nippon steel company [23], it combines pyrolysis gasification with melting, by controlling the furnace temperature and oxygen supply conditions, makes the waste in the same furnace dried, pyrolyzed, burned and melted. The combustible gas is taken into the second chamber to generate power, usually coke is added to provide heat to melt ash in the first chamber.

There are many kinds of vertical furnace type gasification-melting processes, including Torrax process developed by EPA of the United States, Purox process developed by UUC of the United States

and FLK process of Germany. The heat required for waste drying and pyrolysis gasification of Torrax system is provided by air at 1000 ℃ from the bottom of the furnace and carbon black combustion. 35% of the heat value of waste in Torrax system is used for heating combustion air and power supply of the system, and 57% is provided to waste heat boiler.

The fluidized bed type gasification-melting process is based on fly ash melting and is developed on advanced fluidized bed incinerators. Ebara corporation is the first one to research and develop this technology and has promoted more than 20 municipal solid waste gasification-melting devices.

4.3 Applications of Waste Gasification Technologies in China

In the late 1980s fixed-bed and fluidized-bed reactor were used in Tongji University to research the pyrolysis, air gasification and steam gasification, and a technical and economic analysis for the comprehensive utilization of waste gasification process in Shanghai was also given. The scheme of making combustible gas from organic matter and making brick from inorganic matter in the waste is put forward [24]. Experimental studies on the treatment of domestic waste in a downdraft gasifier were carried out in Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, and the gasification agent is air [25]. Zhejiang University has carried out a series of research on biomass waste gasification and designed a 75t/h circulating fluidized-bed gas-steam combined power generation process system using coal and biomass as fuel [26]. A 3 t/d thermal test system has been designed and built in Southeast University for the research and development gasification at low temperature and melting at high temperature technology in CFB [27]. Kunming University of Science and Technology, learning from Nippon's blast furnace gasification-melting technology, uses pulverized coal injection instead of coke for heating to reduce costs, and develops the "Kunming municipal solid waste direct gasification-melting incineration system" [28].

In general, there isn't many research results about gasification in China. although several universities and institutes has successfully developed some gasification technology processing through a number of experimental researches for many years, these results lay particular stress on mechanism and basic research, can only reflect certain features of gasification. The most achievements have not been put into industrialization application because of the lack of systematism. At present, only some parts of China have used relatively advanced gasification-incineration technology to treat domestic waste, and the scale is limited. While gasification-melting technology has not been applied in industry in China. Some applications of waste gasification technologies in China is as follows:

(1) CAO waste gasification-incineration power generation system. In 1997, Guangzhou Jinma Power Equipment Group Introduced CAO power generation technology and built a 2×150 t/d waste power plant in Longgang, Shenzhen [29]. CAO furnace is based on the characteristics of classified collection of foreign household waste and high heat value. However, due to the lack of domestic

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waste classification, low heat value and high moisture content in waste in China, the total annual power generation of the CAO incinerator and the ash heat loss rate can not meet the original design requirement.

(2)LXRF vertical rotary pyrolysis gasification power generation system. The core device of LXRF vertical rotating pyrolysis gasification power generator system is LXRF series vertical rotating pyrolytic incinerator, which is developed by Shenzhen Han's solid waste company and Tsinghua university jointly [30]. This technology application in China has invested projects, a waste power plant (2x100 t/d) was established in 2002 in Jinan, and a medical waste incineration center of 30 t/d was established in 2003 in Zhengzhou.

(3)Pyrolysis Type CAPS waste incineration power generation system. Pyrolysis Type CAPS waste incineration power generation system is a new solid waste treatment technology developed by Richway based on CAO technology [31]. This process does not require pre-sorting of waste, and glass and metal substances do not change in any property, and can be completely recycled. In 2005, Shenzhen Longgang Pinghu Garbage power Plant (3×225 t/d) and Huizhou waste incineration power plant (4×200 t/d) were built using CAPS pyrolysis incineration technology, and have been put into operation. However, the actual operation has not been revealed.

4.4 Evaluations of Waste Gasification Technologies

Gasification technology is a new kind of waste disposal technology, compared with the conventional methods, gasification has many advantages: high energy recovery rate, little secondary pollution, small smoke amount and simple post-processing equipment. And the combination of gasification and melting technology makes it possible, to make the best of the organic composition of waste, at the same time to utilize the inorganic components stably, harmlessly and resourcefully. As a result, the secondary pollution problem such as dioxins and heavy metals can be fundamentally solved. Gasification technology has broad prospects for development.

But at present the mainstream of the gasification technology is designed for the waste through effective classification and with high heat value. Without auxiliary fuel and combustion air, the heat value of waste needs to be higher than 6500 kJ/kg. For the sake of the whole system running safely and reliably, the heat value requires to be higher than 8500 kJ/kg, otherwise auxiliary fuel, oxygen or oxygen-enriched is needed, in order to maintain the thermal balance of the whole system. The gasification technology is not suitable for waste with low heat value and effective classification. In addition, the gasification technology has some other shortcomings. The waste gasification scale isn't larger than 300 t /d, which is relatively small compared with conventional incineration power generation scale. Gasification-melting technology requires auxiliary fuel or rich oxygen to maintain the combustion chamber temperature of 1300 ℃, and the operating costs are high. The rotary kiln gasifier adopts the external heating method with poor heat transfer efficiency, which leads to large

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furnace size and increased investment cost.

In general, gasification technology has great potential, but it still needs further development.

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Chapter 5 Conclusions

Incineration, pyrolysis and gasification technologies have their own advantages and disadvantages. In practical application, many influencing factors, including economic factors, environmental factors and the characteristics of waste, must be considered comprehensively. Only in this way can we choose the appropriate technology.

Based on the actual situations in China, the characteristics of waste treatment systems are shown in Table 5.1:

Table 5.1 Comparison of different waste treatment systems

Furnace type	Large incinerator	Small incinerator	Gasifier incinerator	Gasifier	Pyrolysis incinerator
Maximum quantity of single furnace	>150 tons/day	< 30 tons/day	5-30 tons/day	< 8 tons/day	5-30 tons/day
Investment cost	350-650 thousand yuan/t	70-100 thousand yuan/t	200-400 thousand yuan/t	200-400 thousand yuan/t	15-30 thousand yuan/t
Feed material	heat value > 5000 kJ/kg; moisture content < 50%	heat value > 5000 kJ/kg; moisture content < 30%	heat value > 3000kJ/kg; moisture content < 30%	heat value > 3000kJ/kg; moisture content < 30%	heat value > 3000 kJ/kg; moisture content < 50%
Working hours	24 Hours/day	6-10 Hours/day	6-10 Hours/day	24 Hours/day	24 Hours/day
Waste reduction rate	70-90%	70-90%	70-90%	70-90%	70-90%
Waste residue	Bottom ash belongs to general waste, with a heat reduction rate of 5%; fly ash has the highest amount, which belongs to hazardous waste and needs to be stabilized.	Bottom ash is a kind of general waste, with a reduction rate of 5%.	Bottom ash is a kind of general waste, with a reduction rate of 5%; fly ash ratio incineration. The process produces a small amount of hazardous waste, which needs to be landfilled after stabilization.	Bottom ash is a kind of general waste, with a reduction rate of 5%; no fly ash is produced.	Bottom ash is a kind of general waste, with a reduction rate of 5%; fly ash ratio incineration. Less process production belongs to hazardous waste, which needs to be landfilled after stabilization.
Waste gas	The investment cost of processing technology is relatively high, accounting for 30% of the total construction cost	Simple flue gas treatment Facilities and pollutants are difficult to reach the discharge standard	Less particles and NOx in flue gas, easier flue gas treatment	The content of particulate matter and nitrogen oxide in flue gas is low, but the content of tar is high.	Less particles and NOx in flue gas, easier flue gas treatment
Waste water	Landfill leachate needs to be treated by a sewage treatment plant.	Generally, there is no waste percolation Liquid generation; however, flue gas washing will generate washing wastewater	Generally, there is no waste percolation Liquid generation; however, flue gas washing will generate washing wastewater	Generally, there is no landfill leachate; however, flue gas washing will produce washing wastewater.	Generally, there is no waste percolation Liquid generation; however, flue gas washing will generate washing wastewater

In spite of the rapid development of waste energy technology as well as some practical applications in China, sanitary landfill is still the main waste treatment. On the one hand, the steps of sanitary landfill are simple, and the cost is low; on the other hand, it is also related to the complex composition and low heat value of waste in China. Waste classification can effectively make the situation better in China.

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Waste classification refers to the classification, storage, delivery and handling of waste according to its properties, and the classification of waste for resource utilization. The purpose of waste classification is to classify waste according to its attributes to improve its resource value and economic value. waste classification system can effectively reduce the amount of domestic waste, more importantly, waste classification can be more conducive to recycling and utilization of important resources, meet the requirements of domestic waste recycling, and at the same time, in the process of waste composition identification, cultivate the awareness of resources and environment of the whole society and improve the overall quality of civilization. However, with the improvement of people's living standards and the acceleration of urbanization, the supporting collection, transportation and treatment facilities can not keep up with the amount of waste generated, and the increasingly complex components of waste make classification difficult. The current situation of waste classification in China has not achieved the expected results. Generally speaking, the development level of domestic waste classification in China is still at a low level, facing many difficulties. It is mainly reflected in the following aspects:

1. The laws and regulations related to the classification of domestic waste are not perfect.

2. Urban residents generally lack the consciousness and ability of classification of domestic waste. Although domestic waste classification has been implemented in China more than ten years ago, urban residents generally lack the awareness and knowledge of classification of domestic waste, which leads to urban residents rarely take the initiative to complete the classification work, and the overall effect of domestic waste classification is not good.

3. The installation of domestic waste classification facilities is insufficient, and the domestic waste treatment system is not perfect. At present, in China, recyclable and non recyclable signs are widely used in waste classification. The definition of the boundary is vague, which fails to realize the effective classification of domestic waste. Due to the different characteristics of food and beverage life in China, the main difference between domestic waste and other countries is the content of kitchen waste, which results in the high water content, high oil content and high organic content of domestic waste in China, which also seriously affects the classification of waste.

From July 1, 2019, the regulations of Shanghai Municipality on the administration of domestic waste has been formally implemented. At present, it has achieved initial results, and the classification of household waste has been basically realized, especially in residential areas. However, in some public places (such as supermarkets, shopping malls, etc.), although there are three types of waste bins: dry waste, wet waste and hazardous waste, due to the lack of supervision and guidance, some consumers, especially tourists, are still difficult to do the correct classification[32]

References

[1] Xu Yanping, Huang Lihua, Cui Fangna. Present Situation of the Application and Development of Municipal Domestic Waste Incineration Technology[J]. Guangdong Chemical Industry,2015,42(12):140-141+134.
[2] Yang Junfeng. Characteristics and treatment status of domestic garbage in Villages and towns in China[J]. Resources Economization & Environmental Protection,2019(04):181+195.
[3] Luo Honglin, Hu Hui, Zhang Min, Zhang Jiangang. Present situation and Trend of Municipal Solid Waste Treatment Technology[J]. Pollution Control Technology,2018,31(03):22-25.
[4] A summary of the development of my country's urban domestic waste treatment industry in 2011 [J]. China Environmental Protection Industry, 2012(10): 20-26.
[5] Zhao Xuping, Li Zhibo, Li Xuan. Research on the technology of mechanical grate type household garbage incinerator [J]. Comprehensive Utilization of Resources in China, 2017, 35(09): 135-138.
[6] Mao Yuru, Ma Xiaofeng, Yao Jianjun, Nie Hao. Fluidized bed garbage incineration power generation technology[J]. Boiler Manufacturing, 2000(02): 3-6.
[7] Pei Zhaotang, Wu Weixiang. Application of rotary kiln incinerator in medical waste treatment[J]. Environmental Engineering,2007(02):55-57+4.
[8] Wu Jianye. Overview of municipal solid waste incineration technology[J]. Gansu Science and Technology, 2020, 36(05): 22-26.
[9] Wang Yinan. Current situation and development of domestic waste incineration power generation in large cities in my country [J]. Macroeconomic Research, 2010(11): 12-23.
[10] Hu Dehao. Experimental study on pyrolysis characteristics of typical solid waste[D]. Beijing Jiaotong University, 2019.
[11] Wan Yun. Research on pyrolysis technology of solid waste[D]. Chongqing University, 2004.
[12] OHMUKAI Y, HASEGAWA I, MAE K. Pyrolysis of the mixture of biomass and plastics in countercurrent flow reactor Part I: Experimental analysis and modeling of kinetics[J]. Fuel, 2008,87(13-14): 3105-3111.
[13] Wang Lihua, Zhang Yuan, Song Lina. Experimental Study on the Process of Catalytic Cracking of Waste Rubber to Produce Raw Oil[J]. Journal of Liaoning Technical University, 2006,25(3): 336-338.
[14] MISKOLCZI N, ATEŞ F, BORSODI N. Comparison of real waste (MSW and MPW) pyrolysis in batch reactor over different catalysts. Part II: Contaminants, char and pyrolysis oil properties[J]. Bioresource Technology, 2013,144: 370-379.
[15] LI Shuiqing, Li Aimin, Yan Jianhua. Pyrolysis of biomass waste in rotary kiln Ⅰ. Effect of pyrolysis conditions on the distribution of pyrolysis products[J]. Acta Energiae Solaris Sinica, 2000(04): 333-340.
[16] MASTRAL F J, ESPERANZA E, GARCíA P, et al. Pyrolysis of high-density polyethylene in a fluidised bed reactor. Influence of the temperature and residence time[J]. Journal of Analytical and Applied Pyrolysis, 2002,63(1): 1-15.
[17] MARCULESCU C, ANTONINI G, BADEA A, et al. Pilot installation for the thermo-chemical characterisation of solid wastes[J]. Waste Management, 2006,27(3).
[18] Li Xinyu, Zhang Yufeng, Niu Baolian. Research on Urban Solid Waste Pyrolysis Equipment and Characteristics.[J]. Journal of Huazhong University of Science and Technology(Nature Science Edition), 2007,35(12): 99-102
[19] Li Qingya, Lu Xiaotao, Liu Hui. Application Research of Vertical Rotary Pyrolysis Incinerator Technology in Medical Waste Treatment[J]. Henan Science and Technology, 2019(22): 40-42.
[20] Ren Yifeng. New Technology of Garbage Disposal Power Generation and its Application[J]. Power Equipment,2011,25(05):370-373.
[21] Xiong Guang, Liu Yusan. Incinerating Mechanism and Pollutant Control of Incinerator with LXRF Vertical Rotary, Thermal Decomposition and Gasification[J]. China Environmental Protection Industry,2004(S1):97-100.
[22] Li Rundong, Chi Yong, Li Shuiqing, Yan Jianhua, Wang Lei, Cen Kefa. Discussion on the Gasification and Melting Technology of MSW[J]. Power System Engineering,2002(02):45-48+50.
[23] Hu Jianhang, Wang Hua, Liu Huili, Zhang Fengxia, Ma Xudong. Gasification-melting Technology of Municipal Solid Waste[J]. Environmental Science & Technology,2008(11):78-81.
[24] Wu Jiazheng, Wen Wang, Wang Baosheng, Chen Chunxiang. Influence of the Properties of Municipal Solid Waste Raw Materials on the Process of Distillation and Gasification[J]. Journal of Tongji University,1989(01):113-122.
[25] Xiong Zuhong, Li Haibin, Wu Chuangzhi, Chen Yong. Treatment of Municipal Solid Waste in a Down-draft Gasifier[J]. Techniques and Equipment for Environmental Pollution Control,2005(08):75-78.
[26] Chen Qipeng, Zeng Xianhua, Hu Linshun, Yin Lisong. Biomass Gasification Technology and its

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Development[J].Guangdong Chemical Industry,2011,38(03):26-27.
[27] Zhu Ying, Jin Baosheng, Xiao Gang, Wang Xiaohua. Experimental Study and Simulation of Low-Temperature Gasification of Municipal Solid Waste in Circulated Fluidized Bed[J]. Journal of Combustion Science and Technology,2009,15(02):161-166.
[28] Wang Hua, Hu Jianhang, He Fang, Ma Wenhui, Bao Guirong. Experimental Research on Harmless Technology of Municipal Solid Waste Incineration with Direct Gasification and Ash Melting[J]. Industrial Heating,2004(03):16-19.
[29] Zhang Shuting, Huang Lianqing, Mai Qizhou. Discussion on Technique Reform of CAO Air Control Waste Incinerator[J]. Environmental Sanitation Engineering,2006(02):48-50.
[30] Yuan Hongwei, Shen Kai, Chang Peng, Li Zhenghua, Liu Gang. LXRF Vertical Pyrolysis Gasification Incinerator Technology and Municipal Solid Waste Incineration System[J]. Boiler Technology,2004(06):71-76.
[31] Cheng Baohua, Hu Yaxin, He Gang, Sun Shiwen. The Structure and Technology of CAPS Waste Incineration Treatment System[J]. Environmental Engineering,2008(04):48-50+4.
[32] Bi Zhujie, Tai Jun. A Brief Analysis of China's wet waste treatment process types and Supporting Policies - A case study of Shanghai[J]. Environment and Sustainable Development,2019,44(04):54-58.

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Master Program on Bio-Based Circular Economy

Course of Renewable Energy Technologies

Waste to energy in China

Students:PAN Wei, ZHANG Qian, HU Tingting ,LI Zhihao ,HE Jinglong

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Contents

Background

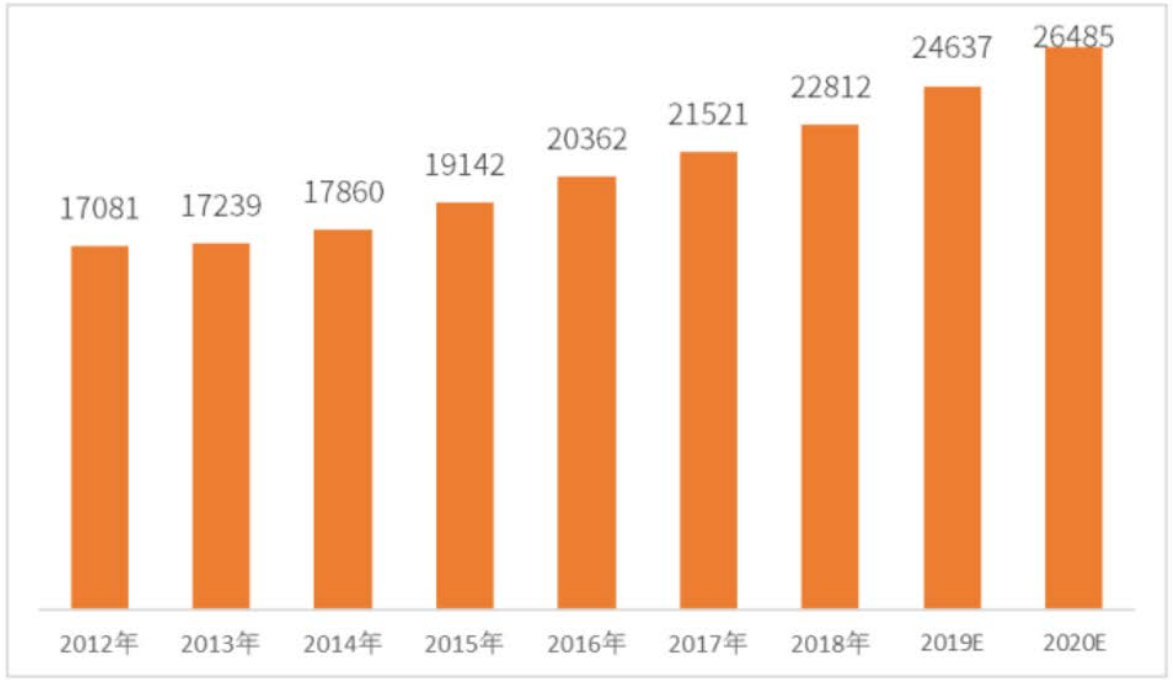
Waste production

Waste classification

Main treatment methods of domestic waste in China

Waste production

China's domestic waste removal and transportation volume and forecast [2]
2012-2020 （10000 tons）



According to the statistics of China Association of urban environmental health, the annual output of municipal solid waste in China has reached 150 million tons, with an annual growth rate of 10%. Over 6 billion tons of waste has been accumulated over the years, covering an area of more than 5000 square kilometers. More than 1.5 million tons of urban domestic waste are produced every year in China, increasing by 8%-10% every year;

2/3 of large and medium-sized cities in China suffer from waste problems, and the annual resource loss value caused by waste is nearly 30 billion yuan[1]

Waste classification

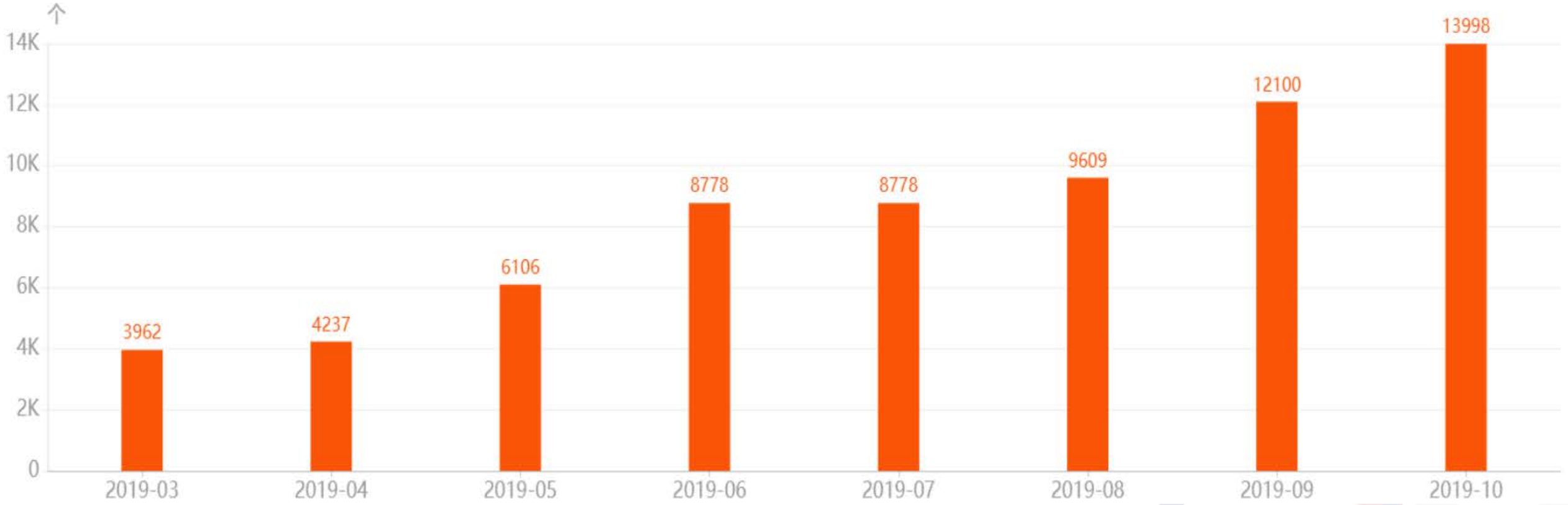
From July 1, 2019, the regulations of Shanghai Municipality on the administration of domestic waste has been formally implemented. At present, it has achieved initial results, and the classification of household waste has been basically realized, especially in residential areas.

The development level of domestic waste classification in China is still at a low level

1. The laws and regulations related to the classification of domestic waste are not perfect.
2. Urban residents generally lack the consciousness and ability of classification of domestic waste.
3. The definition of the boundary is vague, which fails to realize the effective classification of domestic waste. Due to the different characteristics of food and beverage life in China, the main difference between domestic waste and other countries is the content of kitchen waste, which results in the high water content, high oil content and high organic content of domestic waste in China, which also seriously affects the classification of waste. [3]

Waste classification

Number of waste sorting and recycling service points in Shanghai, China [4]
2019.03-2019.10



Main treatment methods of waste in China

Statistics by the end of 2015 showed that the collection scale of municipal and county-level cities in China had reached 840000 T / D of domestic waste, with 2077 harmless treatment facilities including 1748 sanitary landfills, 257 wasteincineration plants, 72 other treatment facilities, and a total of 758000 T / D of domestic waste, with a harmless treatment rate of 90.2%. In the process of harmless treatment 31% of the domestic waste is treated by incineration, of which 48% is burned in the eastern part, and most of the domestic waste is still treated by sanitary landfill. According to the latest "13th five year plan" for the construction of harmless treatment facilities for urban domestic waste, the overall application of landfill is not ideal, and environmental pollution is prominent. By the end of 2020, realize "zero landfill" of primary waste.[3]

Main treatment methods of waste in China

Incineration has become the mainstream technology of domestic waste treatment in large and medium-sized cities in ChinaIt can be considered as the most suitable treatment technology for the current situation of domestic waste in China.

However, in small and medium-sized cities and counties with a population of less than 300000 and a waste removal capacity of less than 300t / D, the harmless treatment of garbage mainly depends on sanitary landfill, and there is a large gap in the demand for efficient treatment of domestic garbage and facilities. The municipal solid waste disposal industry is exploring other processes that can meet the needs of small volume waste disposal, have small investment, and the pollution emission level is equal to that of incineration technology, so as to effectively supplement and realize clean, efficient and energy-efficient treatment of domestic waste. Pyrolysis and gasification technology fill the gap.

Incineration technology

Application in municipal solid waste in china

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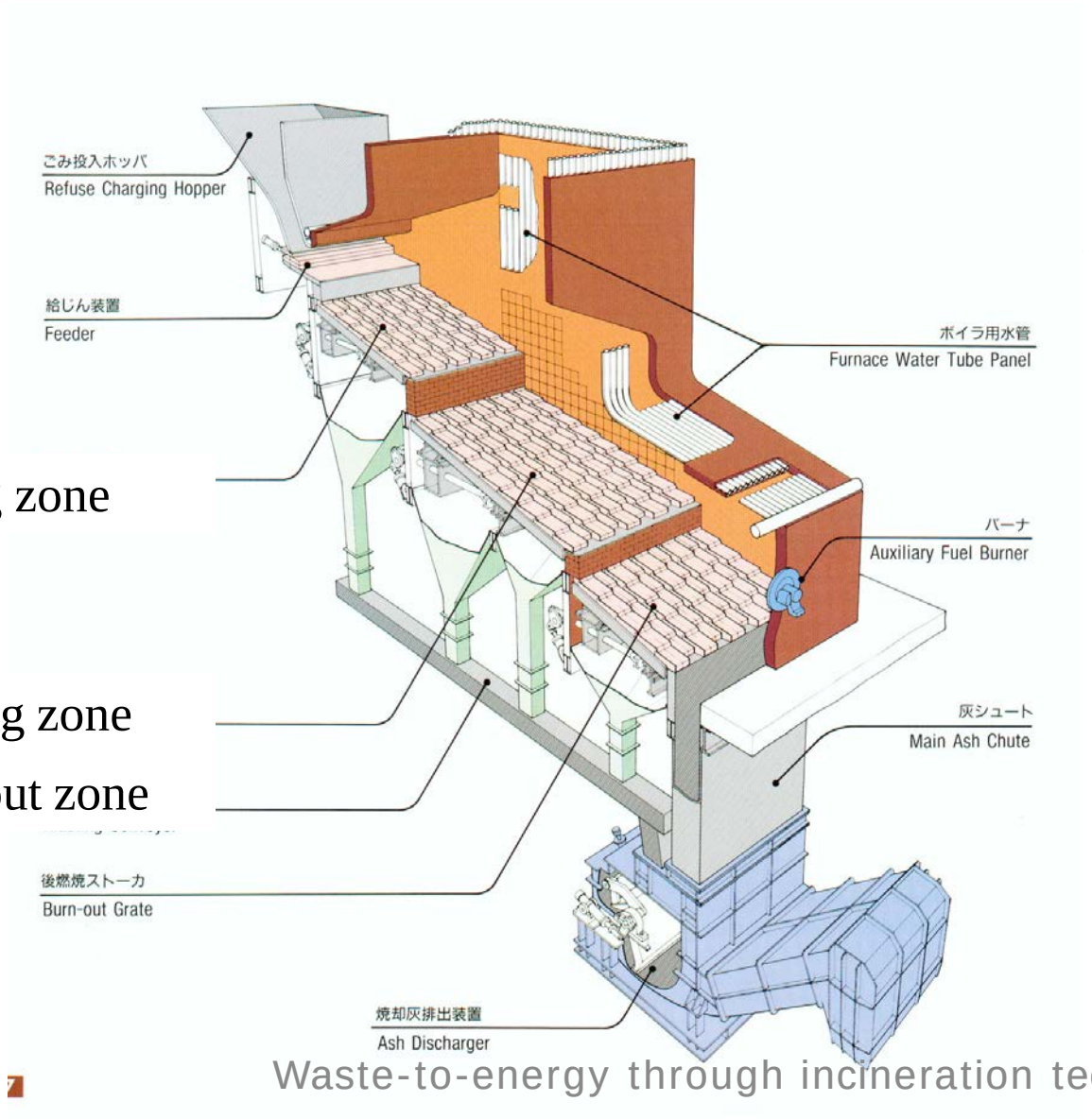
Incineration technology

Garbage incineration is a process of reducing the volume of waste by oxidation at high temperature through proper thermal decomposition, combustion, melting and other reactions, and becoming residue or molten solid material.

Mechanical grate furnace incinerator



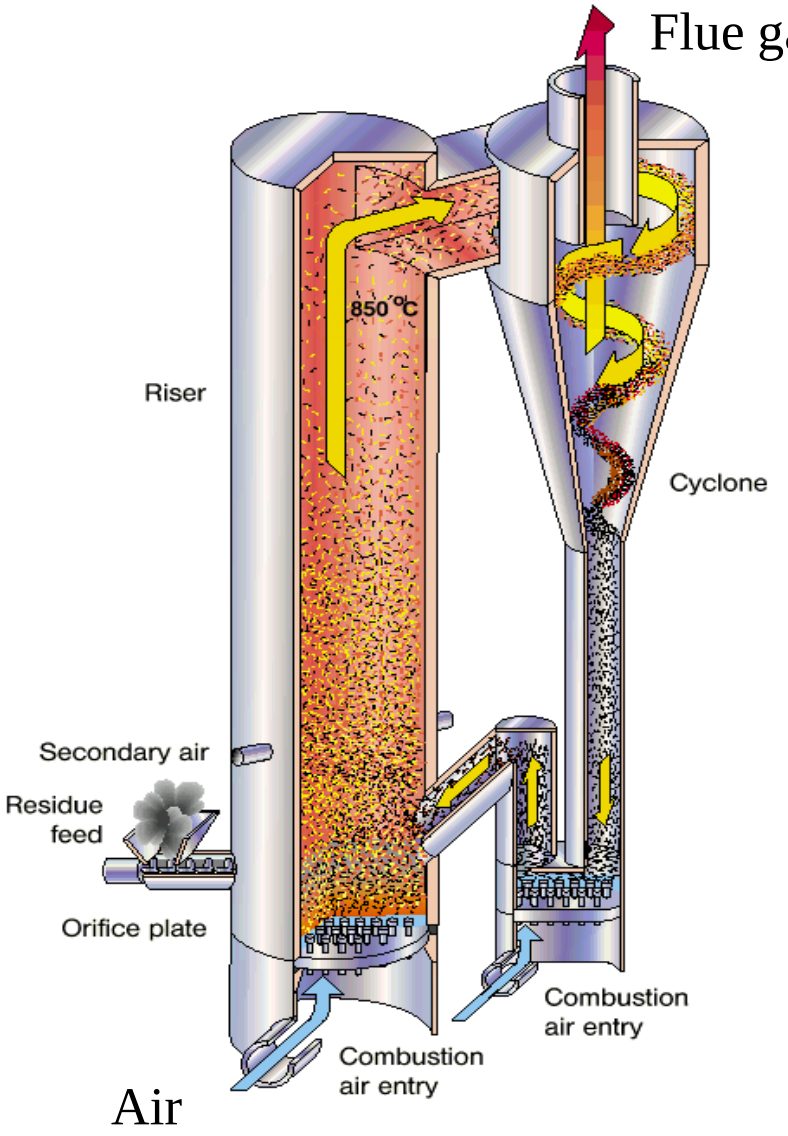
Drying zone

Burning zone

Burn-out zone

Reliable operation,
mature technology,
high thermal efficiency
...

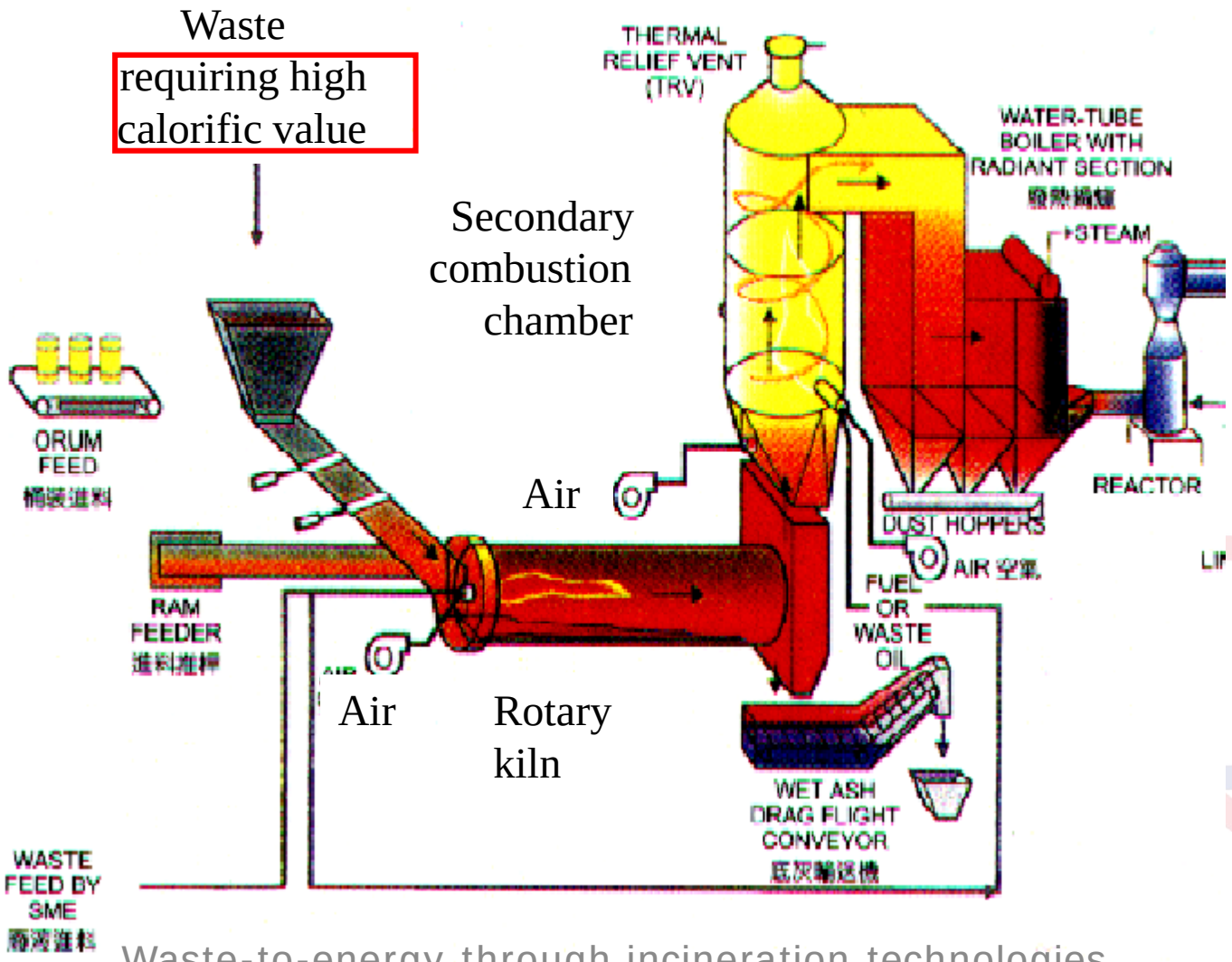
Fluidized bed incinerator



Incombustible bed material took more than 95% of the solid particles in furnace

- High fuel adaptability
- Mild combustion with low discharge of NOx

Rotary kiln incinerator



Impact

Environmental advantages:

- **increase the requirements for environmentally friendly emissions**
- **reduces greenhouse gas emissions**
- **provides new energy**

Problems in the application:

- **the lack of in-depth understanding by the masses**
- **the effectiveness of corporate processing is insufficient**
- **government supervision is difficult**

Pyrolysis technology

Application in municipal solid waste in china

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The oldest application of pyrolysis: wood to charcoal

Pyrolysis technology

- The most classical definition of pyrolysis is proposed by **Stanford Research Institute, Sri's J. Jones**, that is, under the condition of not introducing oxygen, water vapor or heated CO2 into the reactor, through indirect heating, the carbonaceous organic matter will undergo thermochemical decomposition and generate fuel (gas, liquid and carbon black).

  Reactions take place in a recognized pyrolysis process can be expressed as:

  $C_xH_yO_z + Q \rightarrow Char + Liquid + Gas + H2O$

Typical pyrolysis equipment

- Fixed-bed reactor

Wide range of processing objects

But small capacity

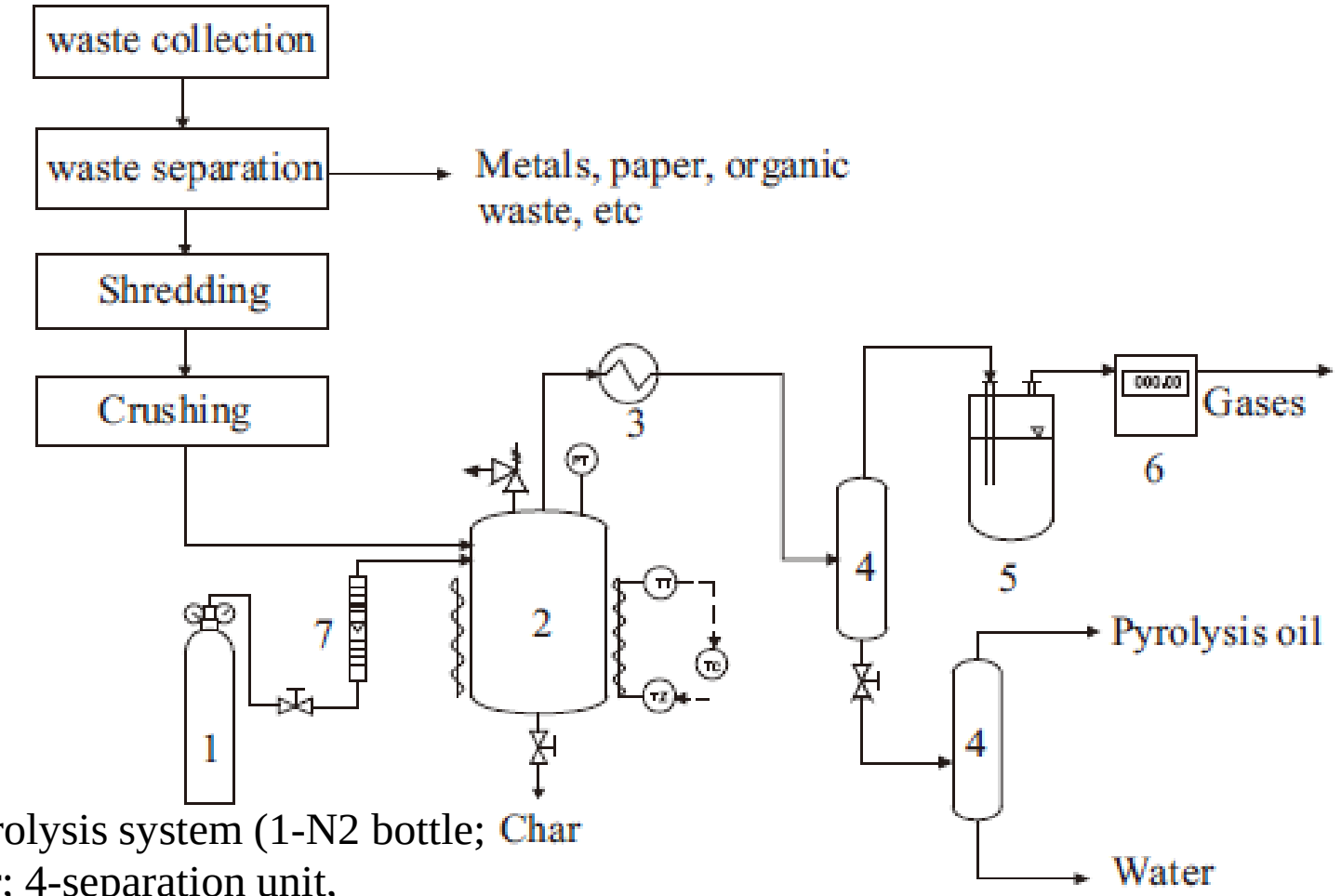


Fig. 1. Fixed-bed reactor and pyrolysis system (1-N2 bottle; 2-reactor; 3-heat exchanger; 4-separation unit, 5-water trap; 6-gas flow meter; 7-rotameter) ---- [5]

Typical pyrolysis equipment

- Rotary kiln reactors and their systems

  - The waste is well mixed
  - Flexible residence time
  - Large waste flow channel

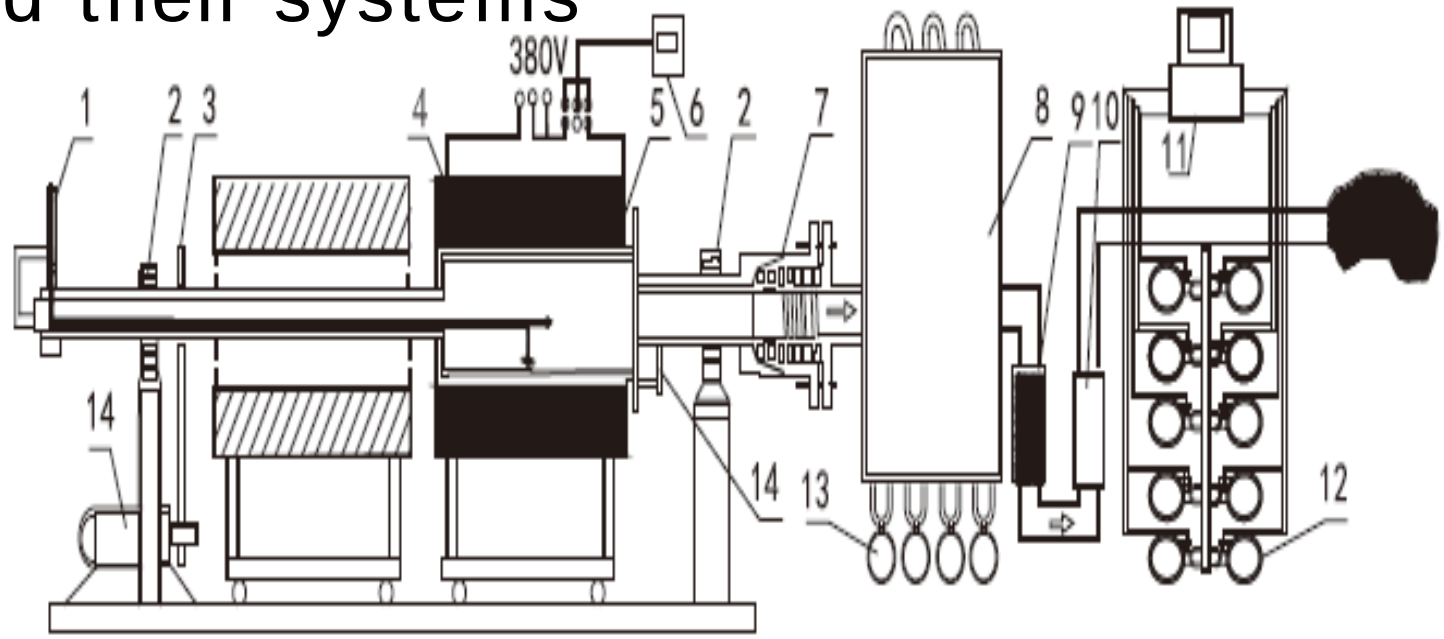


Fig. 2. Rotary kiln pyrolysis system (1-thermometer; 2-bearing; 3-gear transmission; 4-electrical furnace;5-rotary kiln; 6-temperature controller; 7-seal; 8-two-steps condenser; 9-filter; 10-accumulative flowmeter; 11-computer; 12-gas sampling device; 13-feed and discharge opening; 14-speed adjustable electrical machinery) ---- [6]

Typical pyrolysis equipment

- Fluidized-bed reactors

Good temperature controllability
Fast heat transfer and large processing capacity
But it is necessary to pre prepare the materials handle

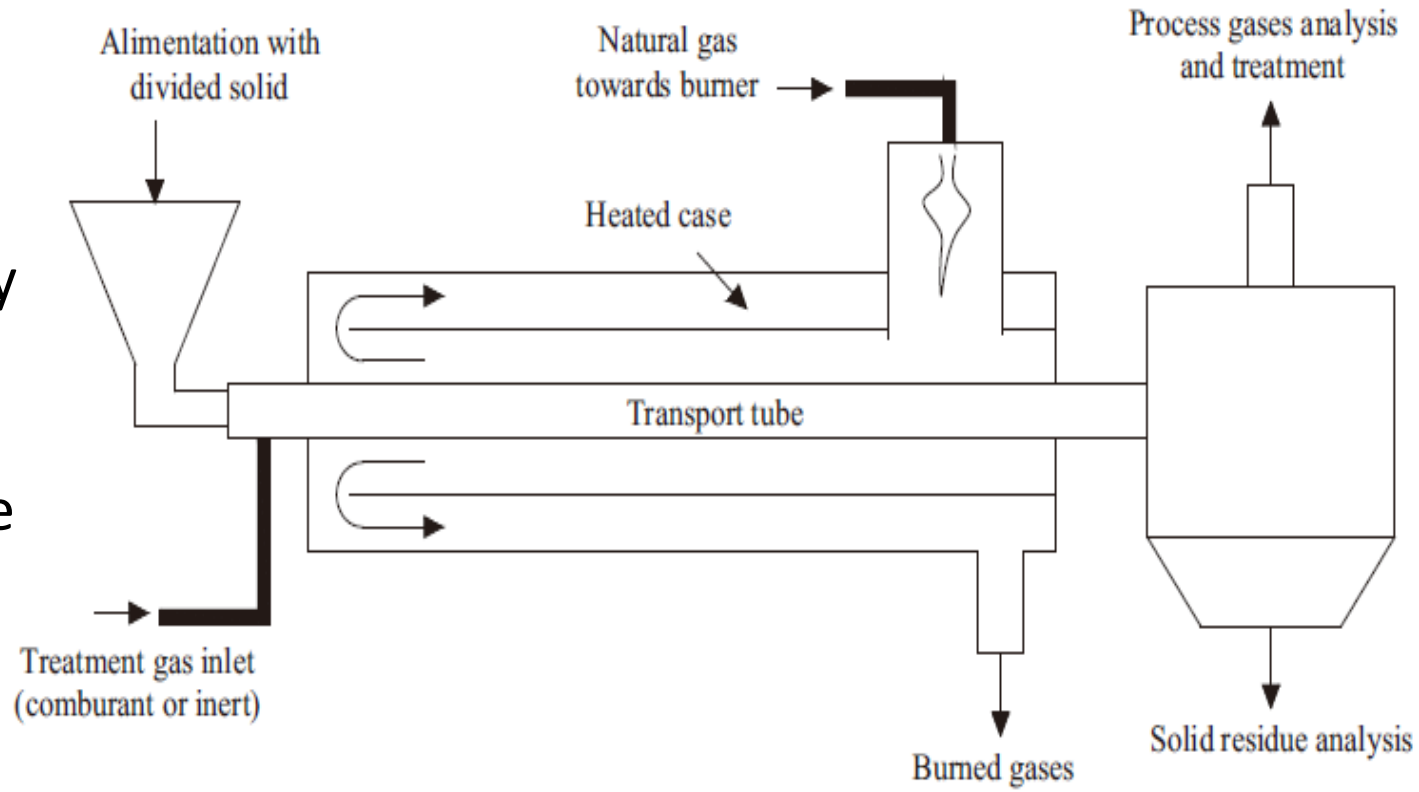


Fig. 3. Fluidized-bed pyrolysis system ----[7]

Example of pyrolysis treatment

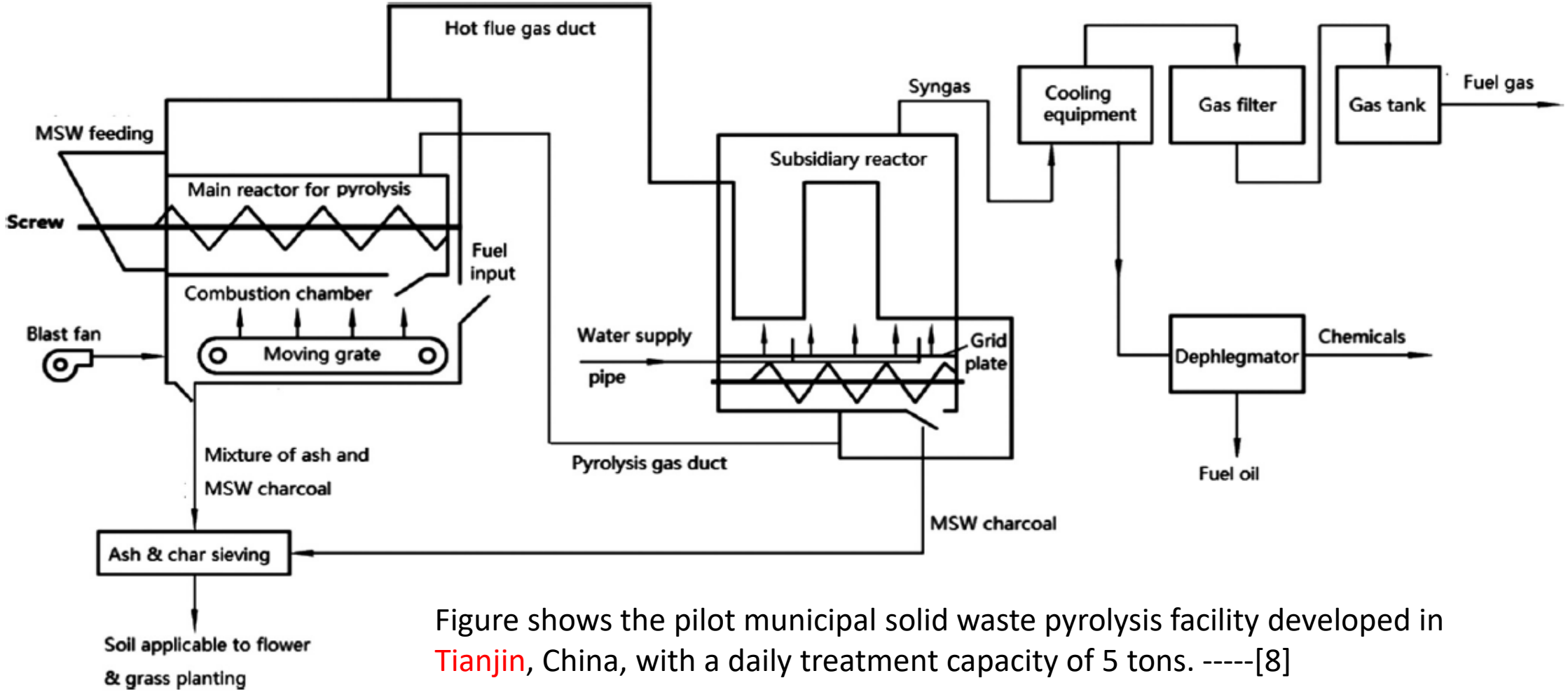
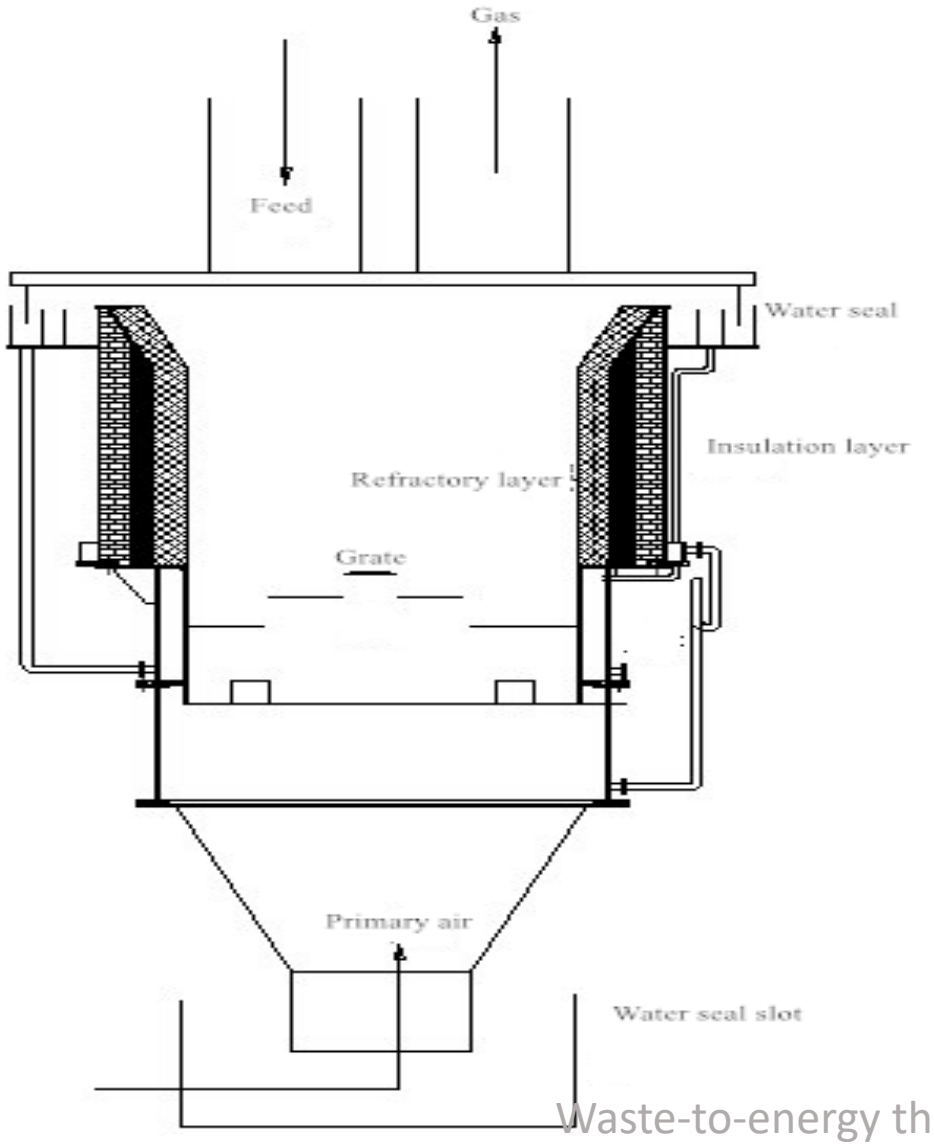


Figure shows the pilot municipal solid waste pyrolysis facility developed in Tianjin, China, with a daily treatment capacity of 5 tons. -----[8]

Example of pyrolysis treatment



Zhengzhou Hanyang Tianchen Hazardous Waste Disposal Co., Ltd. uses a vertical rotary pyrolysis gasifier for the treatment of medical wastes . The incineration line of Zhengzhou Hanyang Tianchen Hazardous Waste Disposal Co., Ltd. is designed to dispose of 30t/d. with an annual operating time of more than 340d. The treatment of medical waste by this process will not produce wastewater. [9]

Evaluations

- pros

- The organic matter in solid waste can be converted into storage energy mainly composed of fuel gas, fuel oil and carbon black;
- Because of the lack of oxygen decomposition and the small amount of exhaust gas, it is beneficial to reduce the secondary pollution to the atmospheric environment;
- Most of the harmful components such as sulfur and heavy metal in the waste are fixed in char;
- NOx production is low.

- cons

- The yield and composition of pyrolysis products are greatly influenced by raw materials, pyrolysis temperature, heating rate and the type of reactor used, especially oil and gas.
- The char produced by pyrolysis of waste has high calorific value and is a potential solid fuel resource, but it will be polluted by heavy metals and organic pollutants.

Gasification technology

Application in municipal solid waste in china

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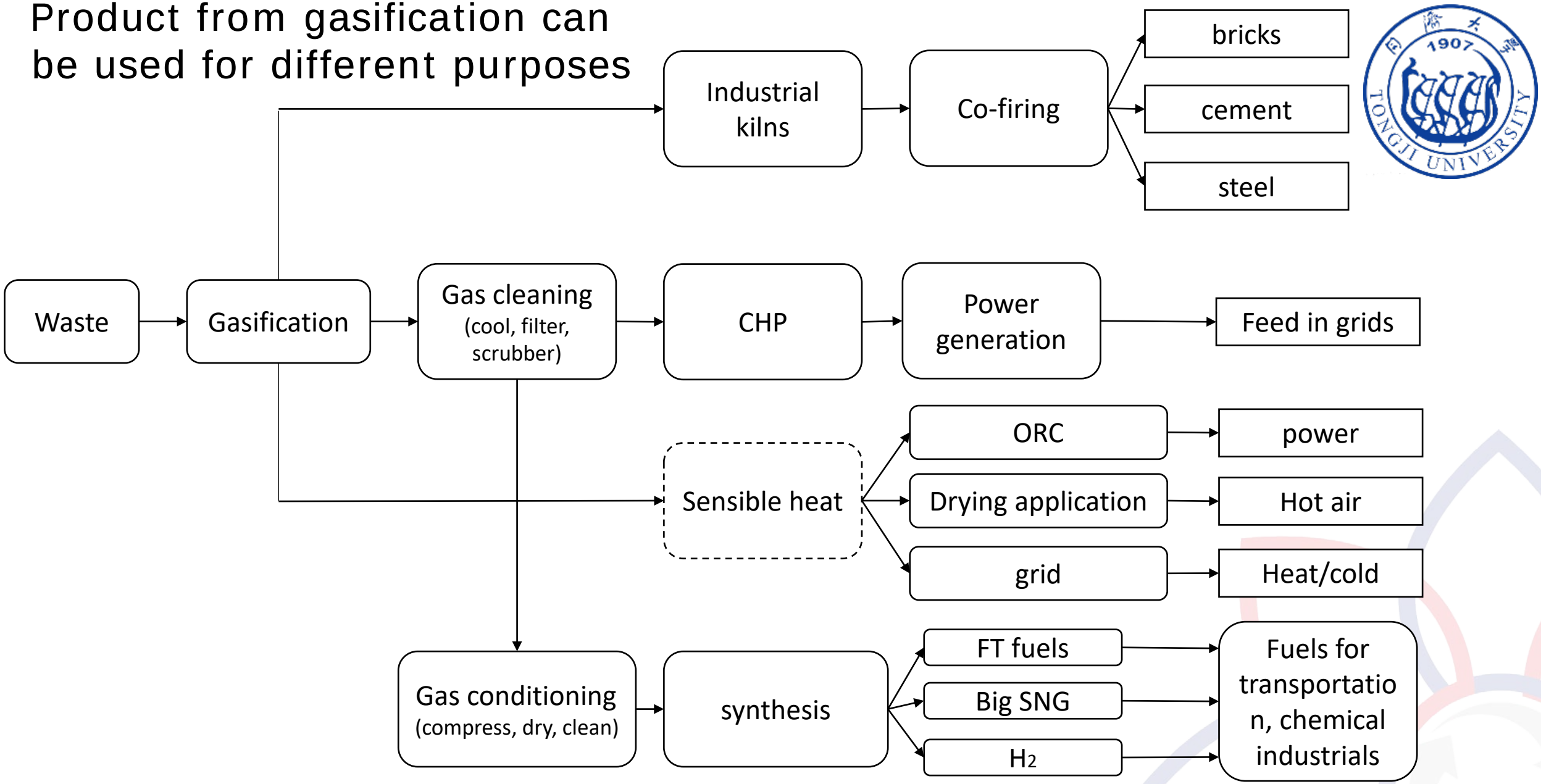
Gasification technology

- Gasification technology is the process of converting organic matter and producing mixed gases at high temperatures (usually 550~1000℃) with insufficient oxygen. The produced gas (Syngas) is mainly composed of carbon dioxide (CO_2), carbon monoxide (CO), hydrogen (H_2), methane (CH_4) and other gases. Gasification agent mainly include air, oxygen-rich air, water vapor, carbon dioxide and so on.

Product from gasification can be used for different purposes

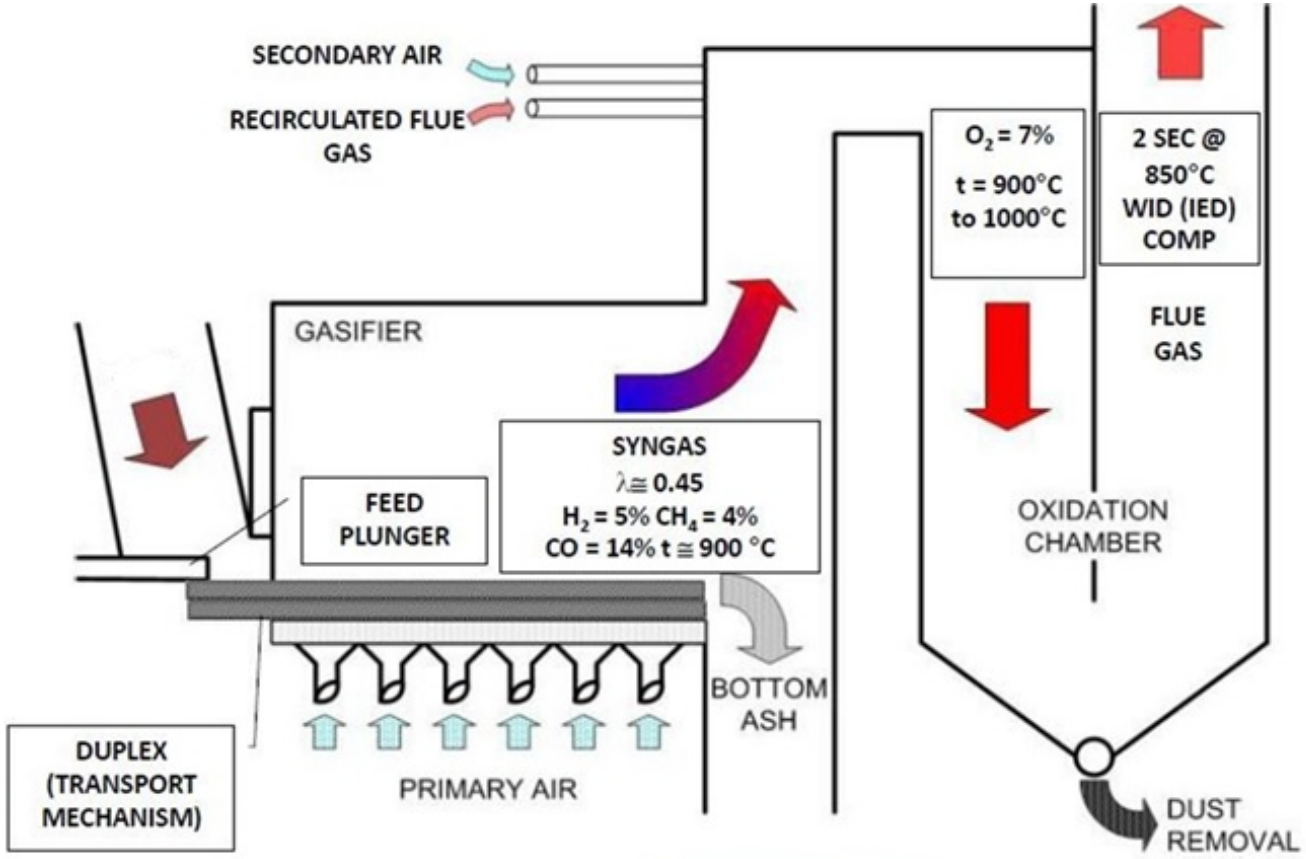


Typical waste gasification technologies processes

- Gasification-incineration technology

Gasification-incineration technology means that the waste is gasified under the reducing atmosphere of 400℃~ 700℃ to generate combustible gas for combustion and semi-coke.

At present, there are three types of gasification-incineration technologies that have been put into commercial operation, namely fixed bed type, fluidized bed type and rotary kiln type.

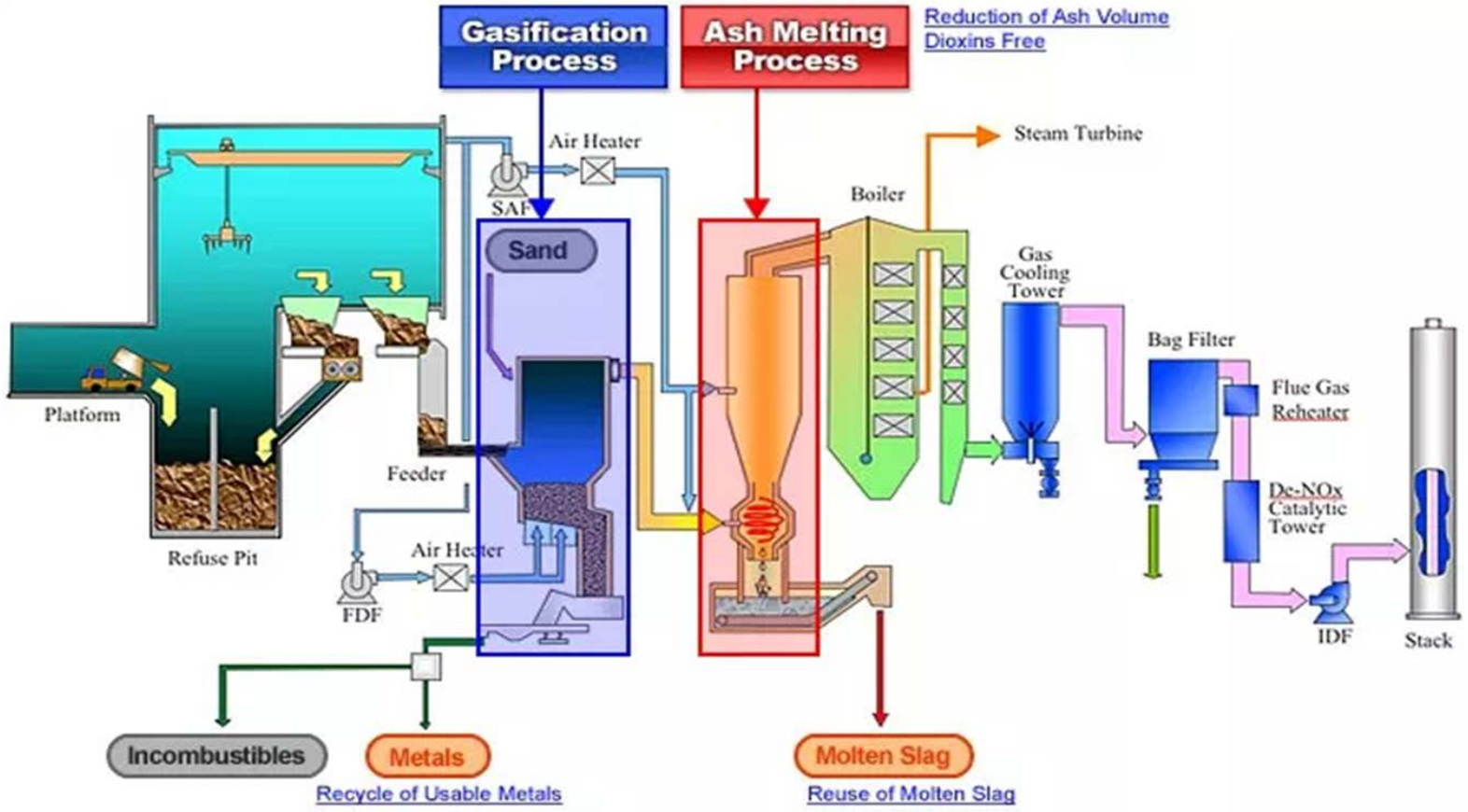


Typical waste gasification technologies processes

- Gasification-melting technology

First gasification takes place under the reducing atmosphere at 400℃ ~ 700℃, and combustible gas and easily recycled metal are produced. Then combustible gas is fully burned, and the ash is melted at about 1300℃, the molten ash can be used as building material.

At present, the typical gasification-melting technologies are blast furnace type, vertical furnace type and fluidized-bed type.



Applications of Gasification Technologies in China

(1) In 1997, Guangzhou Jinma Power Equipment Group Introduced CAO power generation technology and built a 2×150 t/d waste power plant in Longgang, Shenzhen.[10]

(2) LXRF vertical rotary pyrolysis gasification power generation system has also applications in China, a waste power plant (2x100t/d) was established in 2002 in Jinan, and a medical waste incineration center of 30 t/d was established in 2003 in Zhengzhou.[11]

(3) In 2005, Shenzhen Longgang Pinghu Garbage power Plant (3 × 225t /d) and Huizhou waste incineration power plant (4 × 200t /d) were built using CAPS pyrolysis incineration technology, and have been put into operation.[12]

Evaluations

- pros

➢high energy recovery rate

➢small smoke amount and simple post-processing equipment（combination of gasification and melting technology makes it possible）

➢make the best of the organic composition of waste, at the same time to utilize the inorganic components stably, harmlessly and resourcefully

➢the secondary pollution problem such as dioxins and heavy metals can be fundamentally solved.

- cons

➢Without auxiliary fuel and combustion air, the heat value of waste needs to be higher than 6500 kJ/kg.

➢Small scale : The waste gasification scale isn't larger than 300 t /d, which is relatively small compared with conventional incineration power generation scale.

➢Gasification-melting technology requires auxiliary fuel or rich oxygen to maintain the combustion chamber temperature of 1300 °C

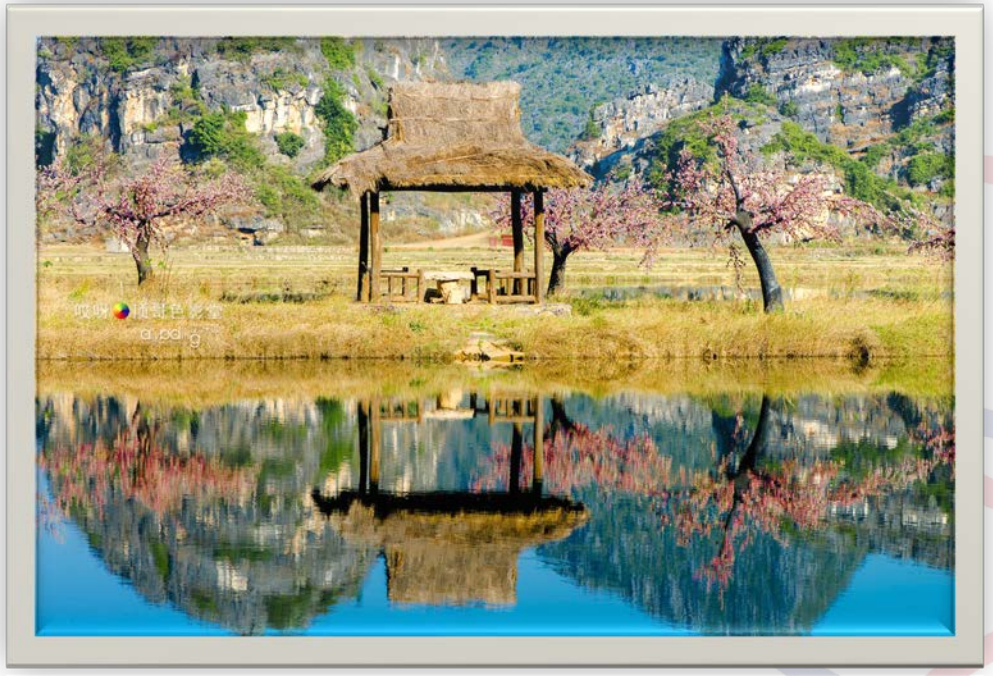
➢ The operating costs are high. The rotary kiln gasifier adopts the external heating method with poor heat transfer efficiency, which leads to large furnace size and increased investment cost.

Conclusion

Comparison of three typical waste heat treatment methods

Central transportation: economic development, relatively flat terrain, convenient rural areas, such as Beijing, Shanghai, Guangzhou, Shenzhen, Zhejiang and other parts of the countryside. Because transportation costs are relatively high.

Decentralized treatment: economically underdeveloped mountainous areas, hilly areas, poor transportation conditions of villages and towns, can use small rural household waste heat treatment facilities such as pyrolysis gasification furnaces.



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Comparison of different waste treatment systems

Furnace type	Large incinerator	Small incinerator	Gasifier incinerator	Gasifier	Pyrolysis incinerator
Maximum quantity of single furnace	>150 tons/day	< 30 tons/day	5-30 tons/day	< 8 tons/day	5-30 tons/day
Investment cost	350-650 thousand yuan/t	70-100 thousand yuan/t	200-400 thousand yuan/t	200-400 thousand yuan/t	15-30 thousand yuan/t
Feed material	heat value > 5000 kJ/kg; moisture content < 50%	heat value > 5000 kJ/kg; moisture content < 30%	heat value > 3000kJ/kg; moisture content < 30%	heat value > 3000kJ/kg; moisture content < 30%	heat value > 3000 kJ/kg; moisture content < 50%
Working hours	24 Hours/day	6-10 Hours/day	6-10 Hours/day	24 Hours/day	24 Hours/day
Waste reduction rate	70-90%	70-90%	70-90%	70-90%	70-90%

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Comparison of three typical waste heat treatment methods

Furnace type	Large incinerator	Small incinerator	Gasifier incinerator	Gasifier	Pyrolysis incinerator
Waste residue	Bottom ash belongs to general waste, with a heat reduction rate of 5%; fly ash has the highest amount, which belongs to hazardous waste and needs to be stabilized.	Bottom ash is a kind of general waste, with a reduction rate of 5%.	Bottom ash is a kind of general waste, with a reduction rate of 5%; fly ash ratio incineration. The process produces a small amount of hazardous waste, which needs to be landfilled after stabilization.	Bottom ash is a kind of general waste, with a reduction rate of 5%; no fly ash is produced.	Bottom ash is a kind of general waste, with a reduction rate of 5%; fly ash ratio incineration. Less process production belongs to hazardous waste, which needs to be landfilled after stabilization.
Waste gas	The investment cost of processing technology is relatively high, accounting for 30% of the total construction cost	Simple flue gas treatment Facilities and pollutants are difficult to reach the discharge standard	Less particles and NOx in flue gas, easier flue gas treatment	The content of particulate matter and nitrogen oxide in flue gas is low, but the content of tar is high.	Less particles and NOx in flue gas, easier flue gas treatment
Waste water	Landfill leachate needs to be treated by a sewage treatment plant.	Generally, there is no waste percolation Liquid generation; however, flue gas washing will generate washing wastewater	Generally, there is no waste percolation Liquid generation; however, flue gas washing will generate washing wastewater	Generally, there is no landfill leachate; however, flue gas washing will produce washing wastewater.	Generally, there is no waste percolation Liquid generation; however, flue gas washing will generate washing wastewater

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Comparison of three typical waste heat treatment methods

Choose the right heat treatment based on your actual needs

Large incinerators: stable operating conditions, pollutants can be stable to meet the standards, the disadvantage is high investment costs, processing capacity, not suitable for the treatment of scattered rural household waste.

Small incinerators: Low investment and construction costs, but pollutants are difficult to meet the emission standards.

Gasifier incinerator: low content of flue gas fly ash, smoke pollution is easy to meet the standard emissions, treatment scale is medium, can be used in a large population of market towns.

Pyrolysis incinerator: beneficial to reduce the secondary pollution to the atmospheric environment, moderate investment， more suitable for medium-sized towns.

Gasifiers: better applicability in rural areas, convenient operation and maintenance, low investment, the disadvantage is higher CO emission concentration in fumes, low capacity of single treatment and suitable for use in rural areas with low waste yields.

Thank you !

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References

[1] Xu Yanping, Huang Lihua, Cui Fangna. Present Situation of the Application and Development of Municipal Domestic Waste Incineration Technology[J]. Guangdong Chemical Industry,2015,42(12):140-141+134.

[2]The data comes from the National Bureau of Statistics

[3] Luo Honglin, Hu Hui, Zhang Min, Zhang Jiangang. Present situation and Trend of Municipal Solid Waste Treatment Technology[J]. Pollution Control Technology,2018,31(03):22-25.

[4] Data from the Shanghai Greening Bureau

[5]MISKOLCZI N, ATEŞ F, BORSODI N. Comparison of real waste (MSW and MPW) pyrolysis in batch reactor over different catalysts. Part II: Contaminants, char and pyrolysis oil properties[J]. Bioresource Technology, 2013,144: 370-379.

[6]李水清, 李爱民, 严建华, 等. 生物质废弃物在回转窑内热解研究——Ⅰ.热解条件对热解产物分布的影响[J]. 太阳能学报, 2000(04): 333-340. Pyrolysis of biomass waste in rotary kiln Ⅰ. Effect of pyrolysis conditions on the distribution of pyrolysis products

[7]MARCULESCU C, ANTONINI G, BADEA A, et al. Pilot installation for the thermo-chemical characterisation of solid wastes[J]. Waste Management, 2006,27(3).

[8]李新禹, 张于峰, 牛宝联, 等. 城市固体垃圾热解设备与特性研究[J]. 华中科技大学学报（自然科学版）, 2007,35(12): 99-102 Research on Urban Solid Waste Pyrolysis Equipment and Characteristics.

[9]李清亚, 卢晓涛, 刘辉. 立式旋转热解焚烧炉工艺在医疗废物处理中的应用研究[J]. 河南科技, 2019(22): 40-42. Application Research of Vertical Rotary Pyrolysis Incinerator Technology in Medical Waste Treatment[1]Zhang

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References

[[10]Shuting, Huang Lianqing, Mai Qizhou. Discussion on Technique Reform of CAO Air Control Waste Incinerator[J]. Environmental Sanitation Engineering, 2006(02):48-50.
[11]Yuan Hongwei, Shen Kai, Chang Peng, Li Zhenghua, Liu Gang. LXRF Vertical Pyrolysis Gasification Incinerator Technology and Municipal Solid Waste Incineration System[J].Boiler Technology,2004(06):71-76.
[12]Cheng Baohua, Hu Yaxin, He Gang, Sun Shiwen. The Structure and Technology of CAPS Waste Incineration Treatment System[J]. Environmental Engineering, 2008(04):48-50+4.