The Research and Development of Garbage Burning Power

Thesis

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Abstract

The aim of the thesis is to introduce the application and development of garbage burning power, so that the reader can understand better the process of garbage burning power technology, and carry out the garbage treatment issues in theory and practice.

The thesis focuses on garbage treatment and research equipment of garbage burning power. Through the analyzes and comparisons of different types of incinerators, it was found that the CFBI (circulation fluidized bed incinerator) and rotary kiln incinerator are the mainly used equipment in garbage burning power. The specific structure and operation process of CFBI and rotary kiln incinerator are described in the main chapters. Some key systems and techniques were researched in this process, and technical details in the entire process and application were analyzed.

As a result, the garbage burning power technology is the best way to treat waste in humans' normal life. However, this technology has both disadvantages and advantages, such as: the pollution control issues cannot be ignored. Therefore, the de-dioxin system has been created to minimize pollution; the application and working process of this system are represented in the thesis. To generate the power and to dispose of the waste with low pollutants in the same time is a decisive factor in the feasibility analysis of the garbage burning power technology in the future.

Keywords

MSW, Garbage Power, CFBI, Kiln Rotary Incinerator, Dioxin, Pollution Control, BOT Method

Confidentiality

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ABBEREVIATIONS

MSW Municipal Solid Waste

GDP Gross Domestic Product

UNEP United Nations Environment Program

RDF Refuse Derived Fuel

CFBI Circulated Fluidized Bed Incinerator

FBC Fluidized Bed Combustion

PCB Printed Circuit Board

PLC Programmable Logic Controller

BOT Build-Operate-Transfer

BOOT Build-Operate-Owner-Transfer

1 INTRODUCTION

Municipal solid waste is the main environment problem all over the world that needs to be faced at present. Municipal waste is increasing gradually every year. Improper handling of garbage causes great harm to the environment: land occupation, contaminated soil, contaminated groundwater resources, impact on air quality, polluting the atmosphere, spreading diseases, environmental health and the health of residents. Sound waste disposal and effective management of waste disposal has become a serious problem in many cities.

The relatively common garbage treating methods are sanitary landfill, incineration, and utilization (such as the produce of organic fertilizers, building materials, heating and power generation, etc.). Municipal solid waste burning is a high temperature thermo-chemical treatment technology; the waste goes into the combustion chamber as solid fuel, in 800 ~ 1000 ℃ high temperature conditions, garbage and combustible components react with oxygen from the air. When there is enough waste heat value, the garbage can maintained its own spontaneous energy, rather than to provide supplementary fuel. In waste combustion temperature combustion gas can be recycled as heating, stable residue can be disposed of directly to landfill. After incineration, waste of bacteria, viruses and a variety of malodorous gases can be eliminated by high-temperature decomposition. [B1]

Garbage burning treatment has its own exclusive advantages: [B1]

- Good in volume reduction. Garbage burning could reduce 80 ~90% of the volume of the waste;
- Thorough disinfection. Garbage in the high temperature combustion can be completely broken down to harmful ingredients, and can completely kill the pathogens, especially combustible carcinogens, viruses, contaminants, toxic organic

compounds;

- Follow-up to reduce or eliminate the environmental impact of disposal process. It also can significantly reduce pollutants in landfill leachate concentration and the release of the combustible gases and odor components;
- MSW conducive to the resource. High temperature incineration flue gas, the heat absorbed by the waste heat boiler into steam, which can be used to heating or power generation.
- Processing efficiency. Incineration plants occupy small areas of land and are close to urban areas. This could save space and reduce the transport distance of waste for the economic development of the city. This is particularly important.

Based on these advantages, the realization of garbage incineration, reduction and recycling is one of the most effective means of waste disposal in the future.

The purpose of the thesis is to reveal the basic research and development of waste to energy program, and to introduce the garbage burning power. Overall, the thesis is divided into three parts: theory, research and conclusions.

It the theory part, the basic properties of garbage is introduced first. It contains the current situation and the composition of MSW. Secondly, development of garbage power technology and then garbage burning power technology are presented. In these two parts, I will make the comparison between a foreign country and China. Also the integrate treatment of waste is introduced.

In the research part, we will do the experiment to measure how much energy we can get from burning waste is carried out. Some data to certificate the efficiency of garbage power is given. Another point is to present the pollution control in garbage burning. The environmental protection is the theme nowadays all over the world. We cannot ignore this main point when we are developing our industry.

The last part is conclusions. This part states the development prospects of garbage power. This will make garbage power popular when population and MSW increase. This will bring benefits for all over the world. In the end of this part, I will also give some advice for garbage power development.

Garbage as a new renewable energy, besides of others like wind, solar, nuclear and water, should be paid attention to. With increasing population, the MSW is also growing gradually. Some places cannot be lived in because they are filled with trash and waste. It is not only influencing the environment, but it also brings hazards to human's normal life. Striving to develop garbage power is the best way to improve the living environment and global environmental protection issues.

2 THE BASIC PROPERTIES OF GARBAGE

Waste is produced by humans in daily life. With the developing of economy, the municipal waste grows every year.

2.1 The Current Situation of Municipal Solid Waste

From a global perspective, there is 1.0×10^{10}t of waste discharged all over the world per year currently. The United States is the most trash producing country with over 2×10^{8}t per year; Germany produces about 800k_g of waste per person. However, in the UK the waste produced by person everyday just increased to 0.27kg from the year 1971 to 1990. In contrast, the waste has reached 1.2 × 108t of waste per day in Tokyo Japan. [B1]

In China, according to the development of national economy and increase of population, the industrial waste and household garbage are accumulated more and more. The situation of environment becomes more serious, some cities surrounded by wastes have become a challenge to the government. The statistical sources revealed that every citizen produced 400k_g of waste and main cities produced 1.5×10^{9}t in average annually. Nowadays, the domestic garbage storage volume has reached 6.0×10^{9}t and occupied a land area of about $5\times10^{8}m^2$ with an annual increasing rate of about 8%~10%. At present, there are 200 cities surrounded by garbage among the whole cities. This has brought up a series of serious social problems, which caused huge pecuniary losses. Solely in emission and sewage, they caused 4%~ 8% GDP losses directly. The danger of the municipal refuse not merely embodies in taking up too many lands; it forms the abominable environment where rubbish surrounds the city. It will also cause pollution in the atmospheric environment, underground sources of water, soil and crops. The organism from the waste is deteriorated and the harmful gas goes into atmosphere to pollute the environment, which affects the normal life and health of citizens. Otherwise,

the organic matter content is higher in the municipal waste, rubbish produces methane after fermentation, the main ingredients are CH_4 and CO_2, both of them will impede the growth of vegetation and destruct the ozone layer. Even more, the CH_4 is a flammable gas and when it mixes with air in certain proportion and meets the sparks, it will explode. Because of garbage also has lots of pathogens, parasitic ova and other factors to harm the health of humans, it will influence the humans' environment and cause the spreading of diseases. [B1]

Table 2.1 Proportion of waste treatment methods in different foreign countries [B1]

Country	Landfill %	Compost %	Burning %
America	75	5	10
Japan	23	4.2	72.8
UK	88	1	11
France	40	22	38
Netherlands	45	4	51
Denmark	18	12	70
Australia	62	11	24

Recently, there are three garbage treatment ways: sanitary landfills, compost and burning, which is aimed at reduction, decontamination and waste resourcization in garbage treatment. In the year of 2002, there were 740 garbage treatment factories for different kinds of rubbish among 664 cities in China. It could dispose of 7835×10^8t in one year that has been improved from 2% in the 1980s to 58.2% today. [B1]

2.2 The Composition and Characteristics of Municipal Waste

The composition and characteristics of municipal waste depend on the life quality, habits of life, season and refuse classification or any other factors in different regions. In European developed countries, because of different habits and customs the composition of waste has great differences. Same as in China, municipal waste has different moisture content in different season.

Table 2.2 The composition of garbage in different cities in China [B1]

Region	Combustible %			Noncombustible %			Heating value (kJ/kg)	Capacity (t/m^3)	moisture content /%
	Food waste	Paper	Plastic	Dust	Metal	Glass			
Beijing	32.60	15.10	14.60	21.46	1.96			0.402	53.90
Shanghai	42.22	1.80	0.60	55.31	1.07			0.898	37.00
Guangzhou	36.35	1.32	1.26	57.43	3.64			0.543	30.00
Shenyang	34.96	2.11	1.74	58.14	3.05			0.640	44.12
Chongqing	41.61	1.59	0.74	52.68	3.48			0.600	45.00
Xi'an	38.24	3.80	1.20	55.66	1.10			0.556	29.00
Shenzhen	56.41	12.90	11.16	19.53	19.53		5000		43.63
Suzhou	58.30	7.91	7.17	19.63	19.63	1.68	4370		53.63
Ningbo	47.51	8.287	15.47	20.44	20.44	3.867	3977		51.00
Jinan	32.68	2.37	0.61	70.45	1.90			0.370	13.00

China is a developing country and its' economy is also under development. The following characteristics of municipal waste are compared with foreign developed countries:

1. Complicated ingredients. Most cities in China use a mixed collection method to

collect waste, but there is no classification. So many kinds of wastes are mixed together.

2. High moisture content. There are too many peels of fruits and vegetables, so the moisture content is about 30%~50%.

3. High inorganic substance content. At present, most cities in China using coal as the main fuel. It contains slack, sandstone, metal and glass from the waste, which have a high inorganic substance content.

4. Low organic substance content. In organic matter, there is a lot of food trash, which has high moisture content. However, paper, plastic, wood, leather and textile fabrics these kind of high heating value matters are lower.

With the improvement of living standards and popularity of using gas in the normal life, the organic matter and heating value in municipal waste has increased a lot. For example, in Beijing the waste heating value has increased from 3349kJ/kg to 5862 kJ/kg from the end of 1990s to the 21st century.

2.3 Integrated Treatment of Waste

Basically, the main waste treatment method has been divided into two categories, which is marine disposal and continental disposal. The marine disposal refers to ocean dumping and ocean burning. The continental disposal contains landfill, compost, burning and integrated treatment. Because of the high costs of marine disposal and this method produces a lot of secondary pollutants, so it is now rarely used. But the continental disposal is widely used.

Landfill method is filling the waste into a pit or sunken pool, which also benefits the recovery of the landscape and keeps ecology in balance. However, the disadvantage of this method is that it occupies too much land (1t waste needs 3m^2 of land), or even the secondary pollution, such as: underground water polluting, noxious gas scattered in the

air and the filled waste ferment to produce methane that easing causes explosion. In 1996, the EU environmental protection council made a rule that the garbage without treatment is forbidden to be land filled directly. [B2]

Composting treatment method is a way to transmit the municipal waste to outskirt village to be used as a fertilizer. This method is good for improving soil and of low cost, large handling capacity; but without classification. Then a lot of trash had been wasted, which could have been used as other resources. At the same time, such as glass, metal, plastic could not be used as fertilized waste because they cause secondary pollutants to the environment. Therefore, this method is only used in small scale and in France, Sweden, and the Netherlands only accounts for 1.3%~1.5% of handling capacity. [B2]

The aim of the burning method is to reduce the volume and mass of the waste. In some countries like Japan, Denmark, Sweden and so on, because of limited in land area resources, burned waste has became the main method of municipal waste treatment. The advantage of this method is to reduce the filling waste efficiently, after burning only 10% of the initial volume waste needs to be taken to the landfill and also the energy could be recycled; parts of leavings after burning could be used again. Otherwise, burning method costs so much. According to UNEP provision, the waste is suited for burning treatment when the heating value is between 3350~7100kJ/kg. Furthermore, if the garbage treatment devices are not good in quality or make noxious gas during burning, it is forbidden to use this method.

The following are the advantages of garbage integrated treatment: [B2]

1. Reduction of waste. The integrated treatment method can use 90.6% of the ingredients of waste; only 9.4% needs to be land filled. If burning directly, 86% of the waste can be reduced and the rest of 14% put into landfill.
2. Generating capacity. Most of moisture content and noncombustible material need absorb heat when burning directly. So, using 35% RDF of waste as fuel could make

more heating power than 100% burning.

3. The address of electric power plant. It is chosen around the city or dwelling district that can be able to exert the advantage of combined heat and power generation together thoroughly.
4. The hearth of boiler volume. Because of the boiler in integrated treatment electric power plant only burns the RDF (Refuse Derived Fuel), so the volume of hearth has 1/3 of a normal incinerator. Then the other accessories also correspond to smaller than normal one, the cost of incinerator can greatly be reduced.
5. Discharge amount. Generally, the direct burning waste is more than integrated treatment waste, so the rate of discharge amount in exhaust is 1.8:1. In accordance with same environmental requirements terms to treat exhaust, the actual emissions of direct burning were doubled compared to integrated treatment.
6. Aggregate investment and operating maintenance cost. The data reveals that the rate of aggregate investment and operating maintenance between direct burning and integrated treatment is 1.15:1 and 1.55:1 respectively.

Table 2.3 Comparisons of several garbage treatment programs

Items	Sanitary landfill	Direct burning	Integrate treatment	Integrate burning
Program introduction	Waste landfill, sewage disposal and biogas collection system	Direct burning power plant	Sorting of refuse, composting and RDF burning factory	Improve incinerator to use run coal and RDF as mixed fuel
Process flow	Remote of living area, laying treatment and biogas export safely	Heating value must meet requirements, exhaust disposal device complicated	Stable RDF heating value and easy exhaust disposal device	Low requirements of RDF heating value through the run coal to adjust stability
Reduction rate of waste	Almost no reduction	86%	90.6%	90.6%
Environmental influence	Affects the surface water and underground water	Causes huge exhaust emission, 50% of water evaporates to the atmosphere	The real emission only have 60% of burning	The real emission only have 50% of burning
Aggregate investment	About 30 million Euros	Disposal of 1200t waste, 80 million Euros	Disposal of 1200t waste, 55 million Euros	Disposal of 1200t waste, 9.4 million Euros

Items	Sanitary landfill	Direct burning	Integrate treatment	Integrate burning
Operating cost	Collection and transportation of waste, sewage disposal costs	The expenses are 6% of investment cost annually	The expenses are 6% of investment cost annually	About 3 million Euros per year
Income situation	No-direct incomes	Waste metal recycling	Compost, waste metal recycling	Compost, supply heat, waste metal recycling
Integrate evaluation	Because of capital had been invested, the influence of sewage leaking cannot be solved, so this method has been abandoned by European countries.	Huge investment and complicated exhaust treatment process.	Low investment and pollution. The garbage resources are utilized thoroughly. This is the direction of foreign garbage treatment development.	Besides the advantage of integrated treatment, even reduces the investment costs from improvement of old power plant. Makes the best benefits of garbage resources utilization by combined heat and power generation.

2.4 The Recycling Method of Energy in Waste

The use of MSW energy was popularized in the 1960s. The basic ways are burning power, marsh gas generation, thermal-decomposition and the use of waste plastic to make oil.

Garbage burning process resembles to normal industrial burning process. When analyzing in the fuel aspects, the combustive matters in fuel could be released and utilized in burning process. But the burning efficiency cannot be 100%, so all the waste energy could not be used when the garbage is burned. [B2]

The marsh gas is produced by landfill waste disassemble. Only the resolvable waste can be used when produce energy in marsh gas form produced. It also cannot be resolved 100%, so the landfill waste energy cannot be used in marsh gas form totally.

The biggest difference between thermal-decomposition and burning process is the nonsufficient oxygen supply. So it would be harder in burning process, even if the same mechanism the energy was used the efficiency may be lower than in garbage burning

Obviously, using waste plastic to make oil only used the plastic without any other ingredients. So it can only use the energy from plastic in all waste.

3 THE DEVELOPMENT OF GARBAGE POWER TECHNOLOGY

The use of garbage burning to make steam and electricity could be traced to time a hundred years ago.

3.1 The Development in Foreign Countries

The first solid waste burning power equipment was built in Germany in 1895. In 1905 a garbage burning power plant was established in New York. Until 1950, the garbage burning equipment consisted of a fire resisting incinerator and heating recycle boiler. Some developed foreign countries have developed garbage burning technology to solve the MSW pollution problem earlier. Most of them have some typical technology, such as: Germany, Martin boiler technology, the USA, Foster Wheeler fluidized bed technology and Japan, IHI rotary kiln technology.

In recent years, using MSW burning power and heating supply has been developed fast in a large scale. In Paris, 90% MSW supplies heat to the entire city through four garbage burning factories. In the USA and Germany, the government supports and promotes the development of garbage power. They have built many garbage power plants for the production of electricity and disposal of MSW.

In Finland, the government has improved MSW disposal methods continuously in the past 20 years, from the pour and landfill to recycling and classification of waste. To recycle and classify the disposal of MSW efficiently, it is not only good for maintaining the environment, also good for trash to treasure. In each residential area and shopping center, there are several different waste recycling dustbins in different colors. All the waste can be collected into a recycling point. Then the waste is sent to different places which have been classified clearly. Such as: metal waste sent to metal disposal factory,

waste woo is sent to power plant as fuel and batteries, medicines, waste oils are sent to a burning factory, which could use the burning heat to make electricity. Even though all kinds of MSW is classified and recycled, still a lot of mixed garbage is poured into waste landfill. In order to reduce the poured waste, the garbage treatment center built a mixed garbage disposal factory in 2005. Then it could classify remain waste and deliver the unrenewable waste to landfill again. In this method not only landfill area was reduced sharply, there were not odors to pollute the air by biological waste separation. Moreover, mixed garbage disposal factory produces 2.0×10^{3}t of combustible refuse every year, that could make 6.0×10^{5}kW·b of power instantly. [B1]

Japanese development of MSW burning power technology is fast. There are 131 garbage power plants in Japan, which have 420MW of power to make electricity. The burning treatment rate occupies 84% of the whole MSW. Otherwise, Japanese have good habits to classify garbage; the government's policy is aimed to minimizing, recycling and safe treatment of MSW. [B1]

There are almost 300 garbage burning incinerators in France which can dispose of 40% MSW. Based on the classification of treatment system statistics, there are 5.2% MSW renewable, 74.6% could be fuel to make electricity, 18.7% cam be reacted and filled in landfills and 1.5% can be stacked. Large benefits can be reached and the residents must pay the waste disposal tax based on their living area. [B1]

3.2 Garbage Power and Environmental Protection

With the rapid growth of economy and development in cities, the pollution is also increasing all the time. This problem is always ignored when a country is dedicated to industrial development when a mass of waste is stacked, it easily spreads diseases, polluting the environment and is unsightly. How to dispose of MSW in scientific processing is an urgent problem which needs to be solved in modern cities nowadays.

3.2.1 Orientation of Garbage Treatment

Basically, the treatment of garbage is divided into three kinds of methods: landfill, compost and burning method. These are also the three accepted standard methods for garbage treatment.

Landfill treatment is the most basic method that is easy to use and has a large handling capacity. But it occupies too much land and the land is limited nowadays. Otherwise, in the process of landfill, a lot of waste is exposed in the air, which provokes the breeding of many pests. Then pesticide has to be sprayed to avoid secondary pollution and high costs. [W1]

Composting is using the organic matters in waste to achieve the utilization of recycling and also reduction of water. Meanwhile, it could reduce the capacity of nonrenewable waste and landfill costs. However, the same as landfill treatment, compost also needs quite a large area to process. Some wastes also need to be classified and that increases the costs of composting. Although compost treatment achieves the goals of waste reduction, recycling and safe treatment in some parts, not thoroughly. It must be integrated with other methods like burning or landfill. [B1]

Burning treatment is the delivery of the MSW to a burning power plant; it reduces the volume of the waste, mass and the need of decontamination. After burning, the volume of wastes could be reduced by 90% and the mass by 75%. The heat made by burning can be used to make electricity; the combustion efficiency is 85% and thermal efficiency above 50%. The main problem in garbage burning is that the exhaust gases cannot always stay within the set limit. Western developed countries have strict garbage emission management standards, especially in smoke treatment and exhaust emission. A bag-type dust remover is used which has 99% dust abatement efficiency; spray CaO_2 to absorb SO_2, HCL, and HF; it uses active carbon to absorb dioxin and so on. Garbage

burning treatment must be integrated with landfill, when after burning 10% of the remained waste should be filled in landfills. Then the landfill volume is reduced without pollution, also costs decline. [W1]

3.2.2 Introduction of Burning Equipment

Grate incinerator is used in nonrenewable heating power garbage, which has low operating costs and reduces large volume of waste. If the waste has a low moisture content, high heating value (above 8374kJ/kg) and few nonflammable matters, the incinerator will burn steadily. It is also easy to ensure the vapor pressure, temperature, flow rate. Because western developed countries have these features and a good standard of living, good quality of waste, most of the garbage power plants use this incinerator. [W2]

CFBI is circulating fluidized bed incinerator, which is used in burning special waste or rubber and bark. The use of CFBI is a trend to develop MSW burning technology in the future years. The features of CFBI: large applicable scope, use lot coal to support combustion, low requirements for MSW and burning the MSW when the heating value is above 3349kJ/kg in theory. [B1]

Overall, grate incinerator is not suited for MSW burning at present; however CFBI has good adaptive capacity for many kind of waste. The price of the combustion supporting coal is 1/20~1/7 price of coal. Then makes it more competitive to those heat and power combined generations which is using coal for thermoelectric plant to support combustion in CFBI. It is also good for market-oriented management and development of wastes treatment.

4 GARBAGE BURNING POWER TECHNOLOGY

There is a hundred of years of history of garbage burning power. The heat input of garbage burning power is using the incinerator burning to transmit heat to water, and then the water turns into steam and go through the steam turbine to drive a dynamo generate electricity or support heat directly. Basically, the technological process of garbage burning power is divided into non-sortation and sortation garbage power.

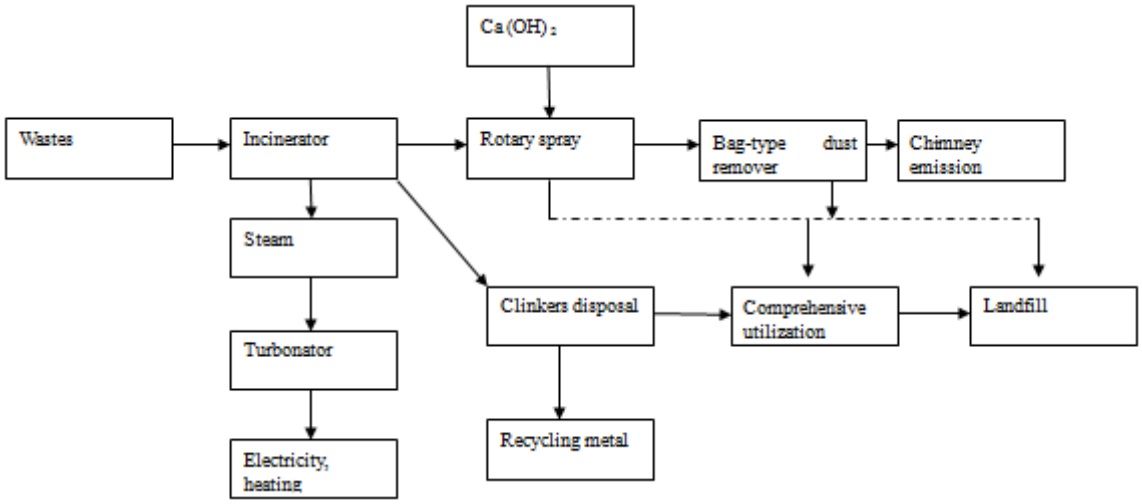
4.1 Technological Process of Garbage Burning Power

Generally, there are two main ways for garbage burning power: non-sortation garbage power and sortation garbage power. Actually, these two methods are quite similar, the only differences are in the beginning of the process.

Non-Sortation garbage power

The delivered waste is poured into a designed cesspit that could store 3~4d quantity of refuse. After microbial fermentation and dehydration, the crane puts the waste into the hopper of incinerator. In the bottom of the hopper, there is a parts feeder that delivers the waste into incinerator continuously. However, the moisture content of waste is high, and then it needs burner aid to put some oil or coal to support combustion before it starts burning. Once it starts burning it, the preheated ventilator works making the steam get hot and delivers into the bottom of the grate to ensure the adequately combustion of the waste. In addition, the entrance of ventilator connecting with wastes, so the waste gases in cesspit can be delivered into 800~900℃ incinerator to thermal decomposition. Then the smokes go through the exhaust purifier, bag-type dust remover and vent to the chimney. The burnout clinkers are dropped into refuse vessel and delivered on travelling

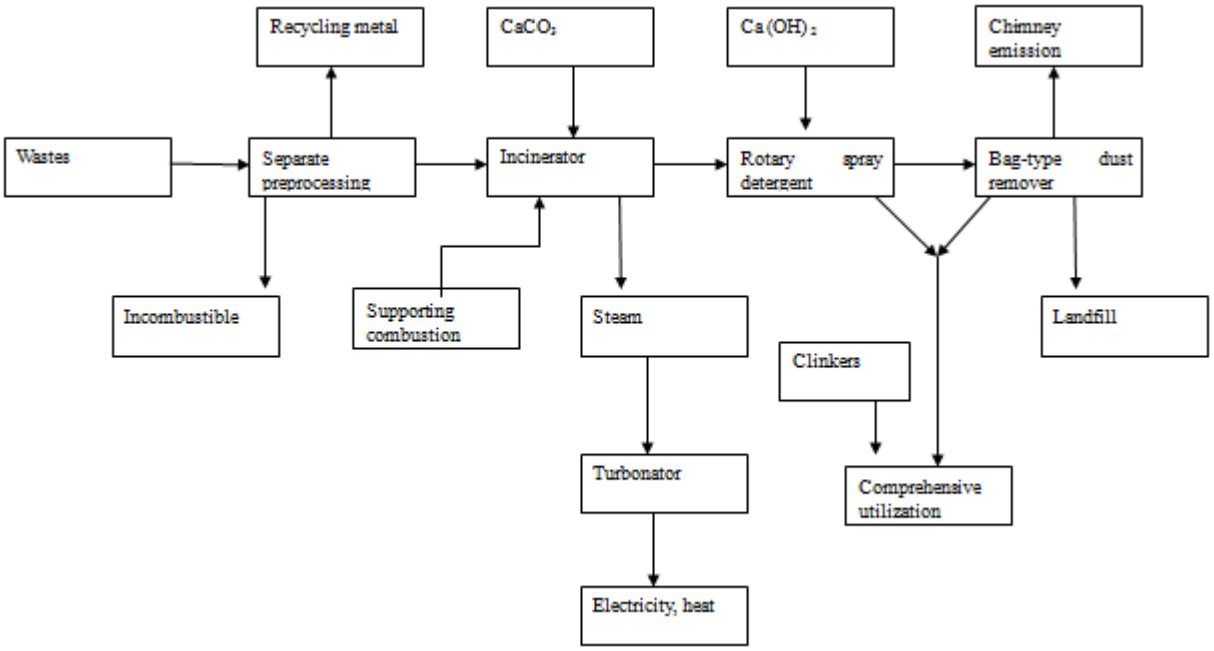
belt after cooling down. There is an electromagnet on the belt which attracts those metals in clinkers to recycle. At last, these ashes and clinkers can be integrated to treatment or land fill.



Graphic 4.1 Technological process of non-sortation garbage power

Sortation garbage power

The differences of technological process between non-sortation and sortation are recycling and clean no-combustion before burning. Then they have the same working process in the following stages.



Graphic 4.2 Technological process of sortation garbage power

4.2 Post-Processing of Garbage Incineration

There are exact demands for garbage burning after-treatment. Not only the inside temperature of the incinerator must be above 850℃ and the duration more than 2s to reduce pollutants, but the exhaust treatment is also very important which contains dust, toxic organochloride, SO_2, NO_2 and CO. Generally, a semidry process is used to clean up the poisonous gases in the smoke and active carbon is used to absorb dioxin, and

then they go through a bag-type dust remover to the filter. After a series of processes, it can meet the environmental protection standards easily. [B1]

The solid slag should be reduced instantly after waste burning and metals should be recycled. Otherwise, the slag and dust are collected by a dust collector which could be separated in different collecting, storing and delivery ways. Different kinds of waste need to be disposed of in different ways, for instance, slag to garbage; fly ash to hazardous waste; solid waste exhausted by gas cleaning unit must be discerned if it is dangerous waste before it is disposed of. [B1]

Table 4.1 The requirements for the height of garbage incinerator chimney

Quantity of waste(t/d)	<100	100~300	>300
The lowest allowed height(/m)	25	40	60

Note: t/d = ton per day

The height of chimney refers to the assessment of environmental impact. In addition, the chimney must be 3m higher than all the buildings in 200m distance at least. Moreover, if there are any garbage burning plants consisting of several types of incinerators, the chimney must be set as a single discharge cylinder or multi-discharge cylinder. The chimney and flue should be according to international standards, which set the permanent hatch and install sample detection platform.

4.3 Technology of Fluidized Bed Combustion

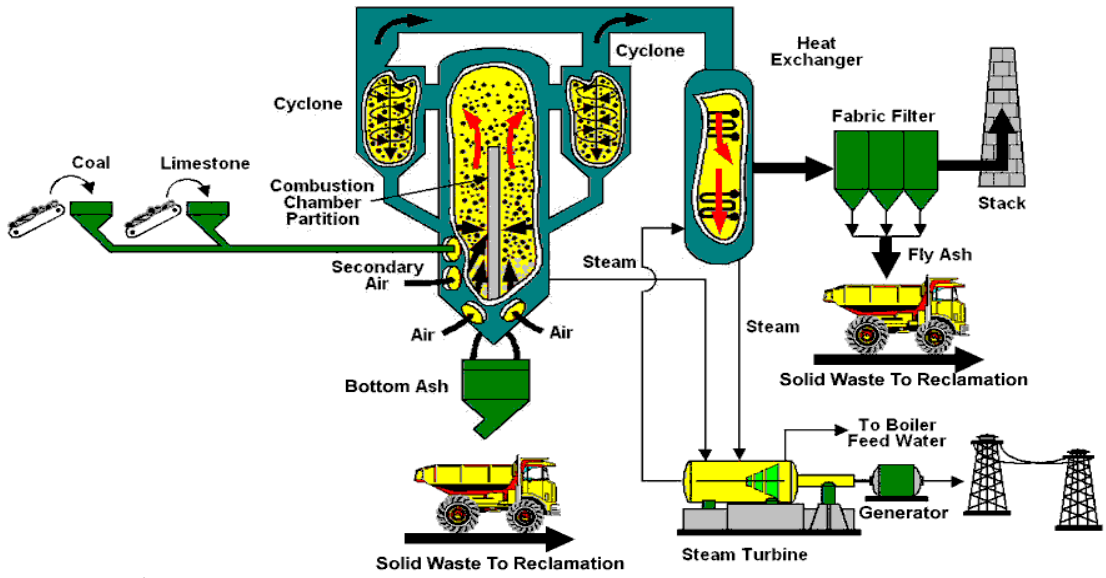
Technology of fluidized combustion is the most common method to the disposal of refuse. At present, the amount of emission is over 1.0×10^{10}t all over the world annually. The development of fluidized combustion technology is a new technology for waste burning. It also creates a new area for environmental protection.

At present, most foreign countries prefer to use mechanical grate combustion. The drying and combustion area is in the front of the furnace, where the high moisture and low heating value waste was reacted in the high temperature radiation condition, so it is easy to make them dry and fired in advance. Hence, a temperature area for waste combustion is established.

The grate combustion technology is suitable for high heating value waste. Because of high life standard in European countries, MSW could combust directly even without classification that the Qdw is over 8378kJ/kg. However, RDF heating value is much higher after classification, for instance in Finland, it is about 25958kJ/kg. Nevertheless, due to the low combustion efficient and unique manufacturing technology of grate system, this causes high costs and high maintenance fees. Otherwise, to make sure the boiler achieves the needed technological parameters in combustion, the fuel and high operating cost should be added. So the application of grate combustion technology is limited. [B2]

Fluidized bed combustion is a combustion technology used in power plants. A fluidized bed suspends solid fuels on upward-blowing jets of air during the combustion process. The result is a turbulent mixing of gas and solids. The tumbling action, which is much like a bubbling fluid, provides more effective chemical reactions and heat transfer. FBC plants are more flexible than conventional plants in that they can be fired on coal and biomass, among other fuels. [W3]

There are two reasons for the rapid growth of FBC technology. At first, the liberty of choice in respect of fuels in general, not only the possibility of using fuels which are difficult to burn by using other technologies, which is essential for fluidized bed combustion. Furthermore, which has become increasingly important, is the possibility of achieving, during combustion, a low emission of nitric oxides and the possibility of removing sulfur in a simple manner by using limestone as bed material.



Graphic 4.3 The process of circulating fluidized combustion [W4]

FBC developed from efforts to research a combustion process that is able to control pollutant emissions without external emission controls, for instance, scrubbers-flue gas desulfurization. This technology burns fuel at temperatures of 1,400-1,700°F (750-900°C), good control under the threshold where nitrogen oxides form, at approximately 2,500°F / 1,400°C, the nitrogen and oxygen atoms in the combustion air combine to form nitrogen oxide pollutants; it also avoids the ash melting problems related to high combustion temperature. The mixing action of the sulfur-absorbing chemical would contact with flue gases which are brought by fluidized bed, such as

limestone or dolomite. More than 95% of the sulfur pollutants can be captured inside the boiler by the sorbent. [W3]

4.4 Garbage Burning Power Equipment

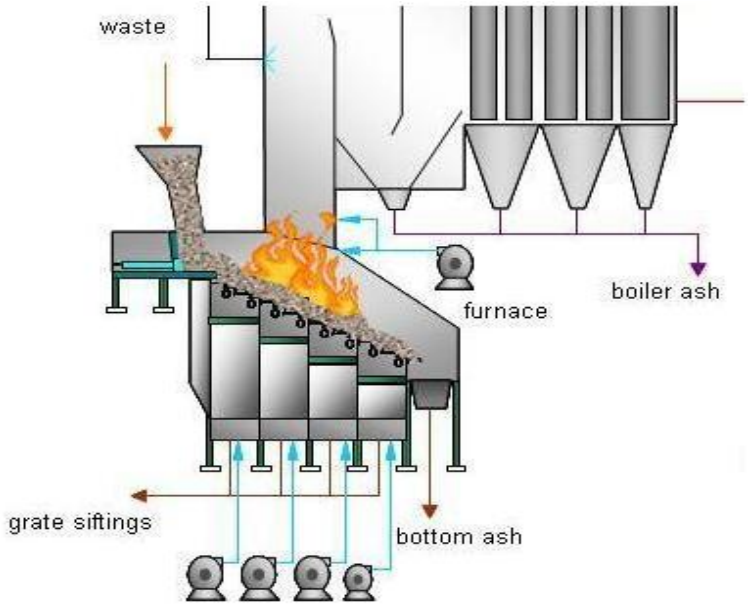
Garbage incinerator is the main equipment for garbage burning power, which is divided into grate furnace, rotary kiln incinerator, circulating fluidized bed incinerator and gasification-melting incinerator. [W4]

4.4.1 Grate Furnace Incinerator

The principle of grate furnace incinerator is sending the waste to the conveyor. With the movement of the conveyor, the waste is dried and fired in the forepart of the conveyor in the high temperature condition. The waste is combusted thoroughly with oxidizing air reaction, then pernicious gases from the wastes could be decomposed and combusted in the high temperature smoke. The inside temperature is almost above 850℃, to avoid unburned combustible produces odious smell out of chimney. Therefore, it needs fuel support combustion when the waste has a low heating value. High temperature flue gas cools down through the boiler, using a draught fan to suck acid gas. Then a bag-type dust collector removes dust in the waste. After a series of process, the flue gas exhaust to air from chimney. [B3]

The main features of grate furnace incinerator:

1. Using of different kinds of wastes as fuel that are easy to operate
2. The system has good reliability and stability.
3. Keeping combustion gaseity in high temperature and retention period in furnace, to reduce the emission of pernicious gases.

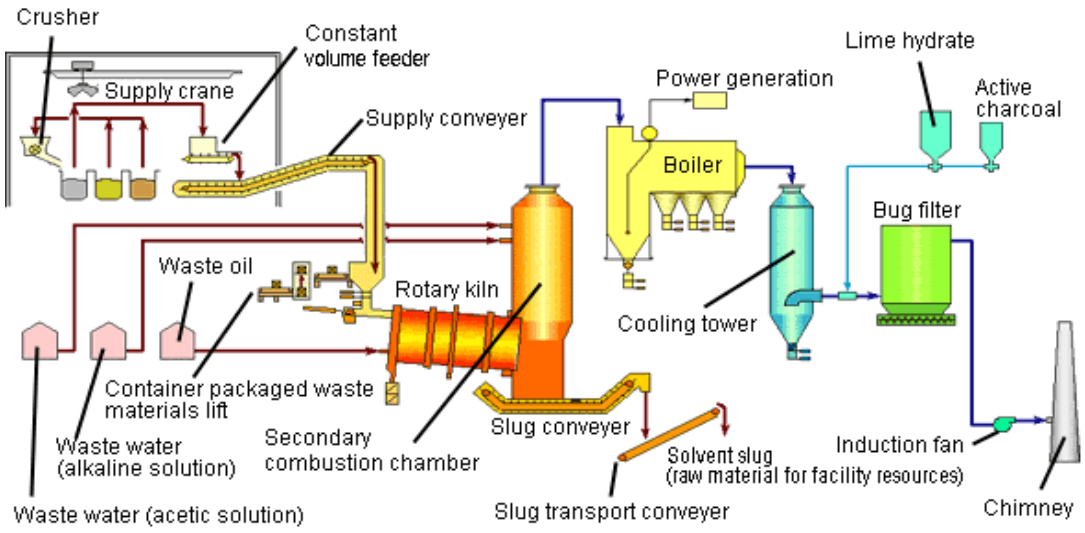


Graphic 4.4 Grate incinerator for MSW burning [W5]

4.4.2 Rotary Kiln Incinerator

The rotary kiln incinerator is manufactured with a rotating combustion chamber that keeps the waste moving, so that allowing it to vaporize for burning. It is widely used in several types of wastes. For example: [W5]

- PCB waste and hazardous waste
- The waste used in medical or clinical like “Red bag waste”, injection needles, rubber gloves and tubing, blood plasma remains, laboratory waste, steel tools, glass pipette, etc.
- Sludge waste, cattle waste, industrial waste, petrochemical waste, etc.



Graphic 4.5 Operating system of rotary kiln incinerator [W5]

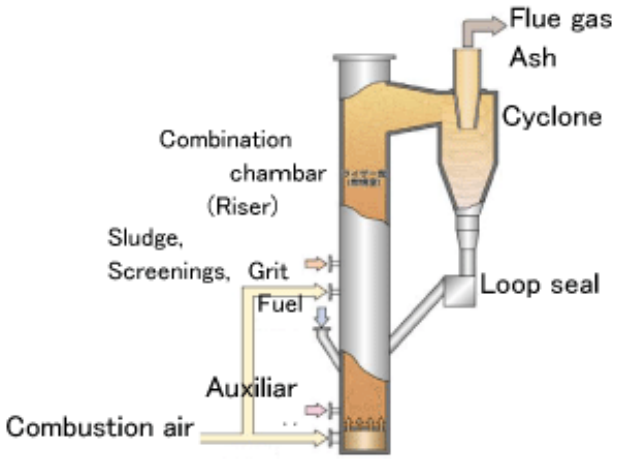
The system depends on the amount of chlorine in the waste steam, there is another dry cleaning system used for the flue gas treatment. Generally, there are two combustion chambers in the whole system. They all have a drive motor and a gear box inside of secondary combustion chamber, which with support burner has 1300℃ degrees and a residence time of 2 seconds per minute. In the whole system working process, there is an energy recuperation system that donated units for active carbon and Sodium-Bi-Carbonate to the flue gas in the drying scrubbing system, HCl, SO_2 scrubbers and dioxins were removed from the system. The continuous emission monitoring system with all instrumentation and controls that control panels with programmed PLC to control the installation. By the way, the supporting fuel burner for the combusting chamber and the de-ashing chamber at the end of the rotary kiln. [W5]

The main characteristics of rotary kiln:

1. Has great resistance to high temperature
2. It can handle liquid, gas, solid and sludge in large amount
3. Operating temperature from 800-1300 degree
4. It can batch modes like barrels and allows more flexibility than continuous modes

4.4.3 Circulating Fluidized Bed Incinerator

The circulating fluidized bed furnace consists of a combustion chamber, a cyclone and a loop seal. The combustion air blows silica sand and fluidizing medium upward from the bottom of the riser to the top of the riser. The gas velocity inside of the riser is as high as 4-6m/sec and the air is in a turbulent state. In the riser, sludge and screen surplus are dried and burned rapidly, turning into fine ash except the incombustibles. The combustion ash is delivered to the cyclone with the silica sand. Because of the differences in specific gravity and particle size, the sand and the ash are separated, which is sent to the flue gas treating unit with the exhaust gas, the sand falls into the loop seal then is returned to furnace. [W6]



Graphic 4.6 System flow of circulating fluidized bed incinerator [W6]

The main features of CFBI:

1. It is easy to adjust the amount of circulating particles by controlling the primary air. It prevents local temperature drop or balloon.
2. There are no such limitations of CFB furnace because the temperature inside furnace is easy to control.

3. It is widely used in sewage treatment and sludge, filtration surplus treatment.
4. The required static pressure of the fluidizing blower is so low that it consumes less power. It only needs 15-25kPa of circulating type compared with bubbling fluidized bed (25-30kPa).
5. Compared with the bubbling fluidized bed in air speed of 1m/sec, the CFB gets 4-6m/sec, which is good to halve the inside diameter of the furnace.
6. The medium intensifies contact, mixing and blending of air, raising the combustion efficiency and enabling low air ratio combustion.
7. The heat taken back by the circulating particles that help to dry sludge, the preventing temperature drop in the lower part of the furnace and without auxiliary fuel.

Consequently, the CFB combustion can be applied to coal in a high fixed carbon content and sewage sludge with high water content. The CFB technology may be applicable to burn a variety of fuels and waste since then that as a means of effectively and efficiently utilizing energy, the one will become increasingly diversified. For sewage sludge treatment in particular, the technology has the potential to reach mixed combustion with screenings, grit or other types of wastes, including energy recovery. [W6]

4.4.4 Gasification-melting Incinerator

Gasification-melting incinerator uses high temperature melted iron as fuel which has 1400℃ degrees. The MSW is melted and gasified rapidly when thrown into the furnace. With thermal decomposition and burning, the gas was exhausted from the traditional incinerator. Moreover, residue would be ejected as grainy within fluid that is a kind of new model incinerator in low secondary pollution. However, the gasification-melting incinerator is still under development. So it is not as widely used as several types of incinerators mentioned above.

5 POLLUTANT CONTROL IN GARBAGE POWER

In MSW burning process, the limitation of dioxin is the main problem concerned all over the world. This kind of super-class toxic gas would affect the environment seriously. The production and diffusion of dioxin should be controlled effectively it influences the application of garbage burning and garbage power directly.

5.1 Generation and Control of Dioxin

Dioxin is a general term for a group of elements that in super-class toxic, but it is categorized by its isomeride. The most poisonous substances are 2.3.7.8-PCDD, which almost like 1000 folds of KCN (potassium cyanide). The dioxin exists as a gas and in a solid form, it has a high melting point, immiscible solvent to water, but it easily dissolves to fat and accumulates in vivo. It should be limited in garbage burning treatment strictly.

Besides of normal garbage burning would produce dioxin, incomplete combustion also makes that happen. When there is not enough oxygen during the combustion process, then precursor of dioxin is produced. Those precursors, chloride in waste and oxygen generate dioxin substances by complicated thermal reaction. In another way, the precursor and cyclic hydrocarbon will response with chloride and O_2 under the catalyze of Cu, Ni, Fe these kind of metallic particle in smoke around 300 ℃ reaction temperature. [B4]

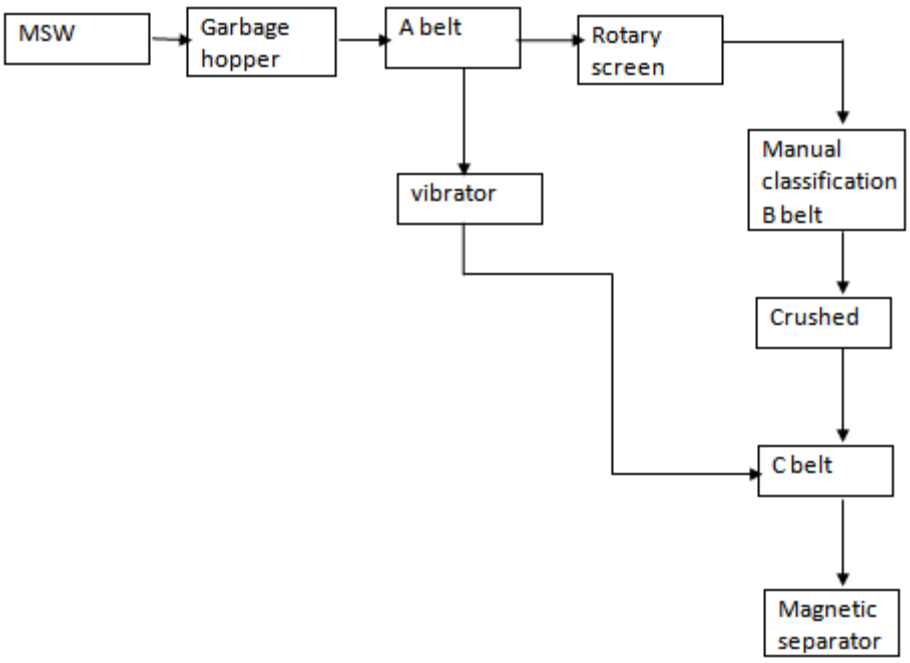
A proper polluted material for incineration is the best available way to prevent and control exposure to dioxins, which can also destroy the waste oil based on PCB (polychlorinated biphenyl). The incineration process requires high temperatures of over

850℃ to destroy large amounts of contaminated material, or even a higher temperature is required. [W6]

In addition, the use of a new model bag-type dust remover is necessary, controlling the smoke temperature under 200℃ beside entrance of dust remover. A spray unit like activated carbon in the funnel of dust remover to absorb dioxin is set. Choosing of an advanced control system in garbage burning plant is also necessary to accomplish burning and refine waste effectively.

5.2 The De-dioxin System

The de-dioxin system is a system that preprocesses the waste before burning. It combines manual and mechanical devices to classify waste. It aims at picking out recyclable waste like metal, glass or plastic; and the waste cannot be burned such as dust, bricks or stones that are used in building materials or landfill. The preprocessing of wastes is good to improve the combustion efficiency and operation stability. However, the most important thing is reducing the PVC (polyvinyl chloride) in waste and also decreasing the source of chloride that easily produces dioxin.



Graphic 5.1 The flow of de-dioxin system

As we can see from the flow chart, the MSW went into rotary screen through by garbage hopper and A belt. Then it went to B belt, after manual classification that parts of waste can be recycled or landfilled, others enter a waste crasher. Then they pass to C belt as the required size, in the end of C belt there is a magnetic separator that sucks metals from waste. Finally, all the waste is sent to incineration after this series of processing. Some of waste goes to another branch apart from A belt. It meets vibrator, which extracts the dust or organics for landfill and composting. The remaining waste then goes to the C belt where it merges together with the trash out from the crasher in incinerator as the same process. [B4]

Another successful de-dioxin system is for CFBI, a tail gas cleanup unit has been set with bag-type dust remover together. The basic principle is using alkaline compound to absorb acidic gas, meanwhile the porous media will also absorb little of dioxin organic pollutant and heavy metal. A bag-type dust remover is adopted to archive gas and solid intensely segregated. Further trace amounts of dioxin are absorbed through the surface of filler material media to prevent dioxin diffusion. [B4]

This system is aimed at reducing the emission of dioxin through tail gas cleanup. The smoke produced by burning is accelerated through zoom nozzle, and then it enters the CFB cleanup unit that uses denitrification and porous absorbent as bed materials. After chemical reaction the bed material is fluidized with smoke and it reacts with acidic gases; the dioxin is absorbed by remover, heavy metal and fly ash fine particle are disposed by the cleanup unit. The products produced from reaction leave in peeling agent in solid form, mixed with not completely reacted bed material, and then they go to the gas-solid separator. The solid particle goes into buffer tank, but most of solid particles mix with absorbent go in a mixer and are then recycled using a CFB purification reaction device. Redundant matters in buffer tank exhaust from flash gate. Purged smoke goes out from chimney through a dust remover exit. [B4]

5.3 The Control & Treatment of Secondary Pollutant

Most of waste produces secondary pollutant after incineration, like dioxin, heavy metal, toxic gas and dust. Those pollutants affect the environment as solid or gas, but tail gas is the one of the most serious pollutant in environment pollution. Therefore, there are several methods below to reduce secondary pollution effectively.

Controlling contaminant sources

First of all, the waste should be classified and recovery should be enhanced, the component with high chlorine like PVC or metal catalyst needs to be dislodged. Secondly, to make sure leak tightness of garbage warehouse that blower pumping is used inside of warehouse under the negative pressure environment, and then all the gases are delivered into incineration to support combustion. Thirdly, moisture content in waste should be collected in a sewage pit and pumped into furnace burning scission. [B4]

Furnace combustion control

In aspect of pollution control, CFBI is a typical one that solves sufficient combustion and contaminant deprivation problem. It uses quartz sand as thermal medium, in large heat storage capacity, good burning stability and temperature uniformity between 850 ~ 900℃, low quotient excess air, produces a few NO_x substances (only produced a large amount over 1300℃). At the same time, it also controls the production of dioxin effectively. The conditions for dioxin generation are unstable combustion, temperature in a furnace is lower than 700℃ and mixing is done with a catalytic agent. However, the temperature in CFBI could be controlled above 850℃, the coal is mixed up with fumes that stay in furnace about 3 ~ 5s. This method is not only increasing combustion stability, but also restraining dioxin with SO_2 produced by coal burning. The limestone is desulfurized effectively, when Ca/S is 1:2 the percentage of desulfurization is over 85%. There are 100% organic matters burned out in CFBI, 75% of waste and 90% volume have been reduced. The ash is non-toxicity, odorless that could be land filled or paved directly. Because of the reduction of 90% of waste to be land filled, it is also good to extend the using time of landfill method. [B4]

Tail gas treatment technology

Fumes after burning have many kinds of toxic matters, using of regular desulfurization technology cannot meet the emission standard. So integrated treatment technology should be used.

1. Dust treatment

The equipment most widely used is electric dust collector and bag-type dust remover, both of them could remove the fine fumes shorter than 1mm. Bur for heavy metals, electric dust collector works worse than a bag-type dust remover, because of tail gases

enter into electric collector in high temperature that heavy metals could be not fully condensed. By contrast, when the bag-type dust remover is combined with aeration tower, the product of non-complete reaction Ca $(OH)_2$ adhered on filter bag. To increase the possibilities of surface contact with exhausted gas that improves the efficiency of dislodged acid gases. Meanwhile, the operating temperature is under 250℃ that heavy metals and chlorine organic compounds (PCDs/PCDFs) reach saturation then they are condensed as fine granule sucked by filter cloth. Moreover, add some active charcoal powder in front of remover's air flue, which is good to adsorb heavy metal ion and dioxin. [B4]

2. Acid gas treatment

The acid gases that exit in tail gases such as: SO_2 and HCL. There are dry type, semi-dry type and wet type cleaning methods. The cleaning principle is using CaO or Ca $(OH)_2$ react with acid gas in neutralization reaction, to produce $CaSO_4$ or CaCl.

Dry type cleaning method is compressing the air then an insufflator is used to move lime powder into flue reactor. Accordingly, the acid gases are neutralized and absorbed from the exhaust gases. This kind of method is in low investment and low operation costs but in huge medicine consumption and low working efficiency. [B4]

Wet type cleaning method is aimed at establishing a filler absorption tower. In the tower, fumes convect with alkaline solutions; then it can react on surface and gap of filler that absorbs the acid gases from the tail gases. The advantage of this method is high exhausting efficiency. But it needs a lot of investments and sewage produced by reaction needs to be disposed of. [B4]

Semi-dry type cleaning method consists of the features of dry type and wet type methods; it consumes some lime and reduces the production of sewage. Because of slurrying system is quite complicated that inner wall of tower is easy to bond with

seriflux and high power consumption of the nozzle. At present, there is a MHGT (Multi-Constituents Hazardous Gas Treatment) technology based on semi-dry cleaning method to dispose different kinds of exhaust gases. The principle of MHGT is using CaO or Ca $(OH)_2$ to absorb SO_2, HCl, SO_3 in tail gases, using high quality activated carbon remove dioxin and heavy metals. Additionally, the slurrying system is canceled within this technology. Not merely the leakage and stoppage problem are solved in digestion, but also the steam is produced and enters into reactor to increase relative humidity. The MHGT achieves the recycling of reaction several times and improves the using of desulfurizer over 95%. The system takes small spaces and low operation costs, the end products are used in pneumatic drive. Its high absorptivity is good to absorb acid gas. The bag-type dust remover is combined with it that also has very good effect. After professional testing, all the exhaust gases went through this system with low emission loads. Especially dioxin discharged only 0.048mgTEQ/m^3 that much lower than 0.1mgTEQ/m^3 as European emission standard. [B4]

5.4 Emission Standard

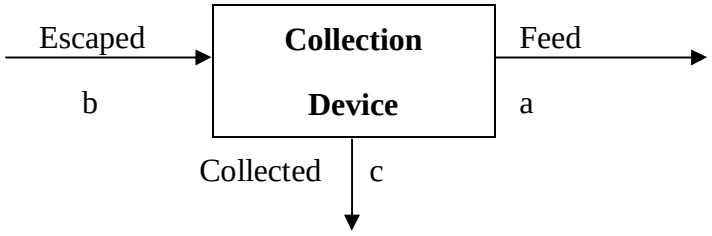


Figure 5.1 Basic collection device for formula

After the pollutant enters a collection device, there are two options: collected or escape from the device, generally to be emitted to atmosphere. Then a simple mass balance has been given:

$$Ma = Mb + Mc \quad (1)$$

Where Ma = amount of pollutant into collection device [kg/s]

Mb = amount of pollutant not collected [kg/s]

Mc = amount of pollutant collected, [kg/s]

With all measured in kg/s or equivalent units. [B5]

The efficiency,η of the collection device is the percentage of the total pollutant that is collected, thus is relatively given by

$$\text{Efficiency:} \qquad \eta = Mc/Ma \quad (2)$$

However, since Ma= Mb +Mc, so it can also written like

$$\eta = Mc/(Mb + Mc) \quad (3)$$

In some circumstances if one might know, instead of the mass flow rates, the air flow rates, Q (m^3/s), and the concentration of the pollutants, C (kg/m^3). Since M = Q * C, given this information, the collection efficiency can also be calculated by either

$$\eta = QcCc/(QaCa) \quad (4)$$

or

$$\eta = Cc(Ca - Cb) * 100/[Ca(Cc - Cb)] \quad (5)$$

The use of these formulas is determined by the information available that results are identical. [B5]

There are many of collection devices that vary in their collection efficiency and the nature of the pollutants. In general, the simpler, less energy-intensive devices are less efficient, making them suitable primarily for large and dense molecules. Fine particulates and other types of pollutants need more sophisticated collection devices. [B5]

6 RESULTS

Garbage burning technology has been practiced as many years as a waste treatment method. Compared with landfill method, it takes quite small land occupation and has high working efficiency. With the development of the technology in Japan and Germany, this industry has been popularized, many developed countries have been attracted to imitate. Since then the garbage burning technology has been put into climax. However, after hundreds of years practicing, this technology has not been accepted by most people.

Disadvantages

The basic reasons for not accepting the method are: serious potential pollution, high investment for this technology and resources wasted. Although the pollutant protection technology is developing all the time, it is still not maturely enough.

As the data revealed, it produces about 5000m^3 exhaust gases after one ton of waste had been burned. After a part of pollutants are burned from the solid into gases, its weight and the total volume is not reduced but increased. Incinerator discharges hundreds of major pollutants; the composition of pollutants is extremely complex, it contains many greenhouse gases and toxins. At present, the burning equipment in normal operation condition, release dozens of harmful substances, which are and hard to absorb by filtering, washing and cleaning. Especially the normal life has been influenced by dioxins seriously.

Otherwise, huge investments and waste of resources were not suited for those developing countries. The technology is still under developing stage and invested money may not get valuable revenues. Moreover, the environmental protection program should be considered itself.

Advantages

Although this under developing technology has many problems need to be solved, it still has some benefits.

1. Simple process, operation reliability

   No pre-sorting and waste can be directly burned. The industrial mode of production can be impacted of natural conditions independently; the usage ages of incinerator are over 20 years.

2. Waste disposal rapidly, high capacity

   In operation process, because of several waste incineration plants treated large numbers of waste, this has been set in their respective cities to create good social benefits.

3. Reduction of waste

   Reduction of 70% ~ 90% of waste, the increasing of garbage has been restrained that is so important for land occupation limited countries.

4. In the high temperature incineration process, a large number of pathogens in the waste are eliminated (it is particularly for the medical waste), improving the sanitation of cities.

5. Using waste to generate the power, make waste profitable

7 DEVELOPMENT PROSPECTS OF GARBAGE POWER

With the developing of garbage power in recent decades, the technology has been applied by many countries gradually. However, under the harsh economic circumstance, for widely used and contributed to improve environment that still needs some policies and regulatory leading.

7.1 BOT Method for a Factory

BOT (build-operate-transfer) method means that the government grants to the private sector through contracts (including foreign state enterprises) for exclusive license in a period, and allow it pay off the loan through the subscription fees or sell products, recover the initial investment then make profits. The infrastructure transferred to the government for free when the concession period expires. [W8]

Using BOT method to construct and operate municipal waste incineration power plant is a very profitable program, local governments can remove the burden of investment and running costs of municipal waste incineration facilities. Under the condition of marketing economy, the construction and operation a corporation is relatively simple. The costs are lower that provide very stable social funds and long-term returns of investment. These funds play an important role to the national constructions and urban environmental improvement. According to the technical and economic principles, the establishment of large municipal garbage incineration power plant is in order to achieve good social and economic benefits. In the specific principles to mobilize the initiative of corporation, speed up the establishment of the municipal solid waste incineration facilities. The better technical and economic performance process can be improved. Otherwise, a part of research and development of high-tech equipment could improve

the technological level of mechanical and electrical manufacturing; if municipal waste incineration power plants were constructed in many cities, the extensive using of mechanical and electrical equipment, a lot of designs, installations and operation of the personnel strength should be required, which can provide many jobs, laid-off pressure of the local relief workers. [B6]

Nevertheless, some problems of this program exist in specific processing. In economy aspect, to expect earn the money from waste disposal to reduce costs and increase profits. Although there are many departments and local governments to promote the implementation of waste disposal charges, refuse disposal fees received by authorities much less than estimated value. This means the costs of waste disposal for building municipal waste incineration power plants in BOT method also need to be sponsored by government's financial support. On the other hand, some areas still have to limit the power generation of waste burning, the price departments jointly determine the price of municipal waste generation; also in some places there is no internet access that payment of it almost same with some heat-engine plants . In terms of oversight, there must be unity, integrity, and improve of the norms with strict supervision. Therefore, use of BOT method to construct an urban waste incineration power plant still needs to be considered in more detail, which could make it more profitable. [B6]

7.2 Strategies of Garbage Power Development

Government investment in the construction, management and operation of the environmental protection facilities have been gradually updated. Recently, the trends of global issues are surrounded by garbage disposal socialization, marketization and privatization. In the future evolution for the use of BOT and BOOT (build-operate-own-transfer) franchising model, that is based on sales of generated electricity as revenue. The burning industry of municipal solid waste plays an active

role to promote technological advances in the development process. [B7]

Many countries all over the world have reached a consensus on global environmental protection. In the current international economic situation, the environmental protection industry has unique conditions in technology transfer, international assistance and traders that more international multilateral and bilateral environmental assistance would be attracted. [B8]

In recent years, waste from power generation technology development is gained momentum in all aspects, to promote the waste for development of energy technology. However, on whether the legal system or policy consummate, as well as create a marketing circumstance that access to technical and financial assistance for both. There are still many problems need to be further dedicated to improve development of garbage power generation technology and human living environment.

8 CONCLUSIONS

Currently there are three methods used for waste disposal: sanitary landfill, composting and incineration. Landfill is mainly used in some areas, but a lot of foundation treatment is not good enough, it causes infiltration of groundwater and soil pollution. The proportion of burning should be increased gradually, such as: construction of waste incineration power generation projects, electricity and heat supporting. Through the overall testing, the CFBI is the best recommended incinerator, which is based on grate furnace technology.

Another important point is that garbage burning power is not only for generating energy, but for garbage disposal and to prevent some regions add large amount of combustion material to produce secondary pollution. Furthermore, especially in some places that lack of land area also with high heating value, the corporations developed garbage burning power technology in business ways that buy the spare lands from private owner to release the pressure of land scarcity. Cogeneration was used in waste incineration or landfill gas power generation, comprehensive utilization of resources; it has become an important way to alleviate the financial burden of the government. But according to the requirements of capacity, the number of some local waste incineration power plants is increasing, which the way to plan and construct power plants completely against the environmental protection rules. The principle of the phenomenon is making the future management of waste disposal difficultly.

The fundamental purpose of waste disposal is a comprehensive treatment and prevention of secondary pollution. To reduce waste and to convert waste into energy is the obviously advantage of waste incineration power, but if in one-sided pursuit of industrial waste generation and economic benefits, not only secondary pollution is caused, this also affects the development of waste disposal industry seriously.

Waste incineration power plant should be based on waste-based fuels, the combustion of the fuel mass fraction should be about 20%, and mixed waste with calorific value of coal below a certain standard appropriately. It is so difficult to burn the waste with different heating value with different mass fraction of waste. With the introduction of the concept of the mixed heating value, it also applies to distinguish the power input of the grate furnace after blending with supported fuel with the constant power output.

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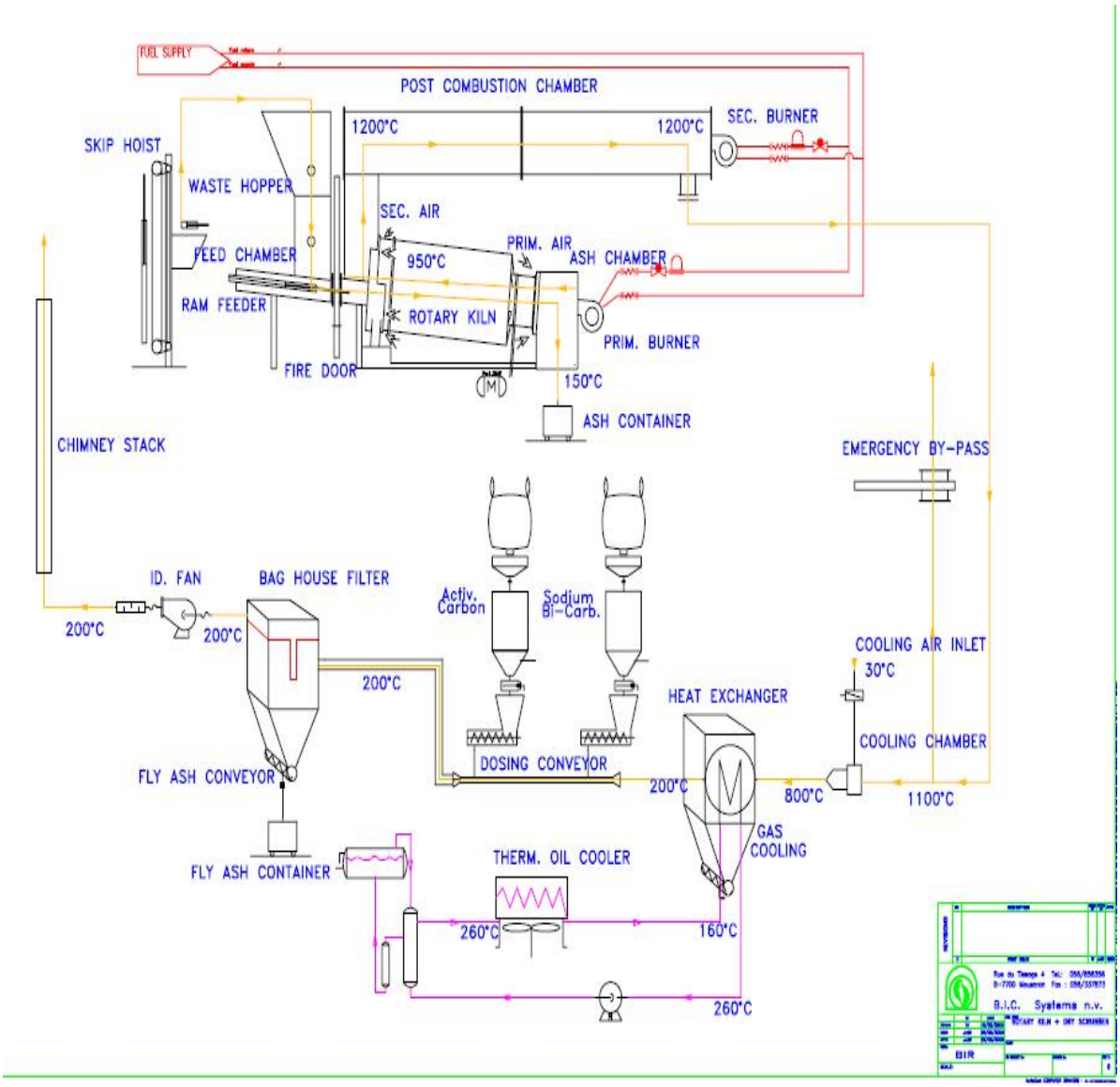
APPENDICES

Appendix 1 Rotary Kiln Incinerator Lay out



Appendix 2 Dioxin Heterotypic Toxic Equivalent Factor Table

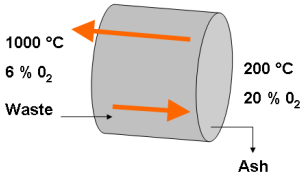
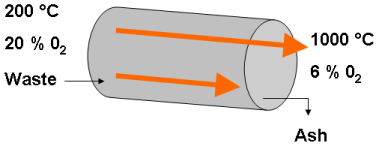
PCDDS	**TEF**	**PCDFs**	**TEF**
2.3.7.8-TCDD	1.0	2,3,7,8-TCDF	0.1
1,2,3,4,5,8-P_5CDD	0.5	1,2,3,4,8-P_3CDF	0.05
		2,2,3,4,8-P_3CDF	0.5
2,3,7,8-instead of H_6CDD	0.11	2,3,4,7,8- instead of H_6CD	0.1
1,2,3,4,5,7,8-H_2CDD	0.01	2,3,7,8- instead of H_7CDF	0.01
OCDD	0.001	OCDF	0.001

Appendix 3 Air Pollutant Program and Testing Method

Program	Testing Method	Method Resources
Fine Particles	Gravimetric method	GB/T 15432-1995
Odor Strength	Three point test	GB/T 14675-93
Ar	NaClO testing	GB/T 14679-93
H_2s	Gas chromatograph	GB/T 14678-93
Methanethiol	Gas chromatograph	GB/T 14678-93

GB/T- is the units from pollution control standard for hazardous wastes incineration.

Appendix 4 Comparison of two types of rotary kiln technology

	TYPE 1	TYPE 2
	Counter current rotary kiln	Co-current rotary kiln
		
Amount of waste in	1000 kg/h	1000 kg/h
Waste inlet temperature	1000 °C	200 °C
Oxygen % at waste inlet	6%	20%
Waste residence time	>2h	>2h
Ashes		
Unburned C in Ash	<0.5%	>2%
Temp.	200 C	1000 C
Mass reduction (%)	>85%	>75%
Post combustion additional support fuel consumption	0 kg/h	>100 kg/h
Fly ashes	750 mg/Nm^3	1500 mg/Nm^3

Appendix 5 Rotary Kiln Incinerator Size & Capacity

No	Type	Thermal Capacity (kcal/hr) [1]	Throughput (kg/hr) [2]	Throughput (MT/day) [2]	Steam Generation (MT/hr @ 15 bar G) [3]	Electricity Generation (kW) [3]	Approximate Footprint (sqm) [3,4]
1	BIR 0050	500	120	3	1.2	-	200
2	BIR 0125	1,250,000	300	7	2.3	-	250
3	BIR 0250	2,500,000	600	14	4.6	186	500
4	BIR 0375	3,750,000	900	22	7.0	280	550
5	BIR 0500	5,000,000	1.2	29	9.3	372	600
6	BIR 0600	6,000,000	1.44	35	11.2	448	650
7	BIR 0750	7,500,000	1.8	43	14.0	560	700
8	BIR 1200	12,000,000	2.88	69	22.4	896	750

Notes: 1. 1,000 kilocalories = 4.184 MJ.

2. Calculated based on waste material having a CV of 4.167 kcal/kg.

3. Figures are approximate and are subject to confirmation depending on the detailed system specifications.

4. Excludes area required for the stack.