EXPERIMENTAL STUDY ON PYROLYSIS INCINERATION PROCESS FOR RADIOACTIVE WASTES

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ABSTRACT

In order to treat combustible radioactive wastes containing plastics and rubber in a considerable amount, a pyrolysis incineration process has been developed. Laboratory study and pilot test for the technology were performed. The results obtained in pilot test show that the waste containing a larger amount of plastics and rubber can be burnt perfectly in given technologic conditions, with a high volume-reduction factor obtained, and the process is easy to control.

1. Introduction

Experimental studies have been carried out to develop an incineration process for treating uranium-contaminated wastes. The wastes to be treated contain, besides paper and cloth, a great portion of synthetic materials such as plastics, rubber, and ion-exchange resin. The process developed is pyrolysis incineration. On the basis of laboratory study, a pilot plant has been constructed, and cold test, performed. The purpose of cold test is to demonstrate the results of the laboratory study and obtain the information and data applicable for scaling-up. A continuous operation of 120 h was performed with cumulative operation time nearly 1000 h.

2. Principle

The combustion behavior of cellulose materials such as cotton, paper, etc. is quite different from that of synthetic materials such as plastics and rubber. The former can be readily burnt and the latter fumes heavily when burning. The difficulty of burning the waste containing synthetic materials lies mainly in the flue gas cleaning because of the large amount of soot and tar produced in incomplete combustion. In our opinion, the rational way is to try to assure perfect combustion in order to inhibit the production of soot and tar, rather than to remove them by post-combustion or dust collecting process. This is the reason why we chose pyrolysis incineration for these wastes. In the process, the pyrolysis of waste and the combustion of volatile pyrolytic products proceeded separately. The feature of the process was to convert the direct combustion of solid materials into that of gas and tar mist which is liable to proceed perfectly so as to inhibit the formation of incomplete combustion products and simplify the cleaning of flue gas.

3. Process Description

The pilot test was limited to the processes of pyrolysis, combustion, and flue gas cleaning, excluding waste pretreatment and ash handling. Shredding and packaging of waste were performed manually. The waste bags had the size of 60～80 mm. The simulated wastes were composed of various uncontaminated materials. The typical waste composition was as follows:

cotton and paper	40%
PVC	25%
PE	15%
rubber	5%
ion-exchange resin	5%
poly-perchloroethylene	10%

A simplified flow diagram is shown in Fig. 1.

The throughput capacity of the pilot plant was nearly 4 kg/h.

Pyrolysis

The pyrolyzer was a shaft cylindric furnace made of carbon steel without refractory lining. It was 273 mm in outer diameter and 1,100 mm in height. Waste bags were fed into the furnace batchwise and thermally decomposed into volatile products and pyrolytic char in an oxygen-deficient atmosphere. The heat required for pyrolysis was supplied by the heat evolved from the combustion of pyrolytic char left underneath with primary air. The volatile pyrolytic products, including combustible gases and tar mist, were carried away with the upward gas stream and left the furnace. The ash was swept down through the grate with a rotating rod. Its residual carbon content was below 5%(wt). The volume reduction ratio was 35 : 1 approximately.

There were jackets at the upper and lower parts of the furnace. Cooling air was blown into the lower one to cool the cylinder wall of the lower part of the furnace and thus reduce its corrosion. The hot air leaving the lower jacket entered the upper one for maintaining a higher temperature of the wall to prevent or reduce the condensation of tar mist.

The primary air amounted only to about one fourth of the stoichiometric quantily of air required for complete combustion. The low rate of air stream diminished the entrainment of ash, resulting in a low fly ash content in flue gas. Pyrolysis rate was not quite steady; during a feeding period, it was faster at the beginning and then became slower gradually. Wastes of different composition showed nearly the same behavior in pyrolysis.

Combustion

The volatile pyrolytic products from the pyrolyzer, after mixed with sufficient secondary air, entered the combustion chamber via a nozzle. The horizontal combustion chamber was made of a high alumina ceramic tube (150 mm I. D. , 750 mm L) withelectroheating coil and thermal insulation outside. Under condition that the temperature in combustion chamber was above 1170K and the oxygen concentration, above 5%, perfect combustion could be obtained. The flame was clear and no smoke was perceived. The combustion temperature was commonly within the range of 1220~1420K. Normally, the combustion heat was sufficient to maintain the temperature within the range. External electroheating was supplied only when the temperature fell down below 1170K. As mentioned above, the pyrolysis rate varied in each feeding period, the oxygen concentration in flue gas varied accordingly in t he range of 5~15%. It could be controlled by adjusting the secondary air flow rate.

Cooling

The hot flue gas from the combustion chamber was cooled to 570K with an air-to-gas jacketing heat exchanger before entering the cleaning system.

Cleaning

The flue-gas cleaning system consisted of a filter for particulate removal and an absorption scrubber for acidic gases removal. If the filtration efficiency was high enough, only particulates of very small size could escape from filtration. It was anticipated that the small particulates would not probably be removed effectively in scrubbing, thus the exhausted scrubbing solution should not be managed as radioactive liquid waste. The arrangement of the cleaning system was based upon that assumption.

Bag filter was selected for particulate removal. Filtration had to be carried out at a temperature higher than the dew point of flue gas to prevent acid condensation. The dew point of flue gas was estimated to be about 405～420K. In operation, the filtration temperature was kept above 435K. The filtration medium was NOMEX needle felt with mass thickness 350 g/m^2. The face velocity was about 0.9 m/min.

The content of particulates and their size distribution were determined (see Table 1)...

It can be seen from the table that for the waste containing high content of PVC and rubber the particulate contents before and after filtration are much greater than those for the waste containing only cotton and paper. In the case of the waste with high content of plastics and rubber, the results of chemical analysis showed that the particulate samples collected before and after filtration contain a great amount of Pb and Zn. These constituents are considered to be originated probably from the additives in plastics and rubber. Lead and zinc would sublimate in the form of chlorides in pyrolyzer and are then converted into oxides or other compounds in combustion chamber. In cooling process of flue gas, they are condensed gradually and collected in filtration. The high content of particulates in flue gas behind filtration suggests that condensation of some sublimate could happen after filtration. Generally, the decontamination efficiency is different from the filtration efficiency. The actual decontamination efficiency will be determined using contaminated waste in further experiment.

After filtration, flue gas entered an absorption tower which was packed with ceramic corrugated plate packings (2,000 mm high). The tower was 150 mm in diameter and 4,000 mm in height. The gas temperature at the entry was about 343K. The acid gases were removed from the gas stream by countercurrent contact with alkaline solution (5% sodium carbonate solution). The concentrations of acid gases and the absorption efficiencies are given in Table 2.

Since the results of HCl removal are not satisfactory, further improvement is required.

Whether the exhausted scrubbing solution can be managed as non-radioactive liquid waste remains to be demonstrated in hot test.

A negative static pressure is maintained in entire system with an induced draft fan.

Corrosion problems

All devices and tubes are made of carbon steel. Because of the high acid content in flue gas (see Table 2), corrosion is a serious problem. No quantitative results can be given. By visual observation, the corrosion of pyrolyzer is not serious. In the cooling and cleaning systems, the most serious corrosion occured in the duct sections adjacent to combustion chamber and between the baghouse and absorption tower. The corrosion of devices and ducts in the temperature range of 440～680K was found to be comparatively much slighter. These results agree basically with those given in literatures.

Summary

In general, the results of cold test conform to those of laboratory study. The results obtained show that the process can incinerate wastes with high content of synthetic materials. Other features include low energy consumption and full combustion.

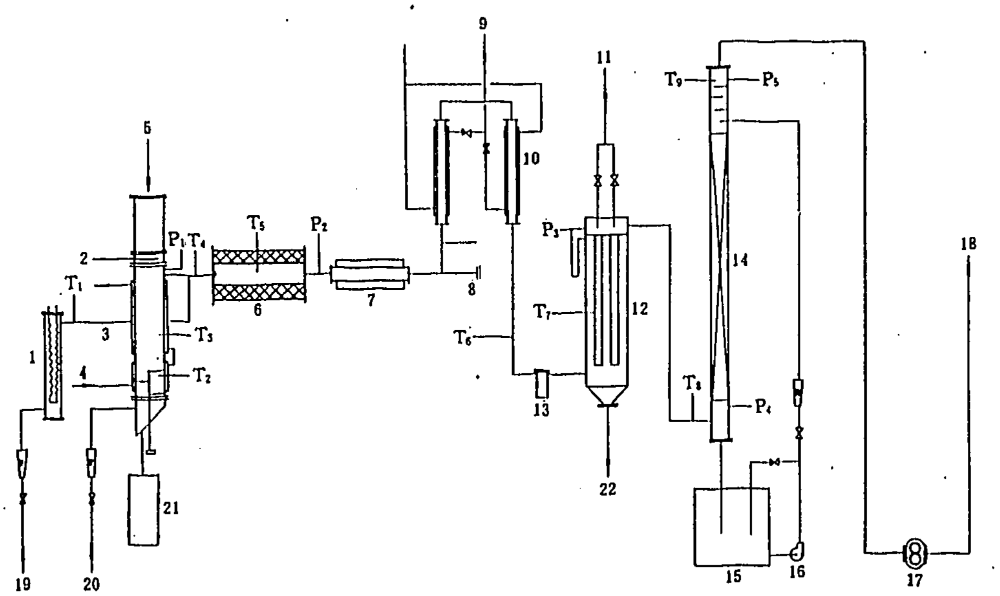
Table 1 Content and Size Distribution of Particulates

Composition of waste	Particulate content mg/m³		Percentage of different sizes (μm) (in number) *					
	before filtration	after filtration	<1	1~2	2~5	5~7	7~10	>10
Cloth, paper 100%	32	2.1	73.6	14.3	9.76	0.34	0.67	1.35
Cloth, paper 60% PVC, rubber 40%	620	39	55.0	23.8	15.3	2.0	2.5	1.33

* before filtration

Table 2 Results of Absorption

Acidic gas	Velocity (m/sec)	Liquid rate ($m^3/h \cdot m^2$)	Concentration of gas mg/m³		Absorption efficiency (%)
			original	after absorption	
HCl	0.5	28	1.08×10^4	1.61×10^2	98.5
SO_2	0.5	28	4.84×10^2	1.00	99.8



1. Air heater
2. Air lock
3. Pyrolyzer
4. Cooling air
5. Feed
6. Combustion chamber
7. Radiation heat exchanger
8. View glass
9. Cooling air
10. Jacketing heat exchanger
11. Compressed air
12. Baghouse
13. Impulsion dust collector
14. Absorption tower
15. Tank
16. Pump
17. Blower
18. Discharge
19. Secondary air
20. Primary air
21. Ash pit
22. Ash

Fig. 1 The flow sheet of pyrolysis incineration

P—manometer; T—thermometer.