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Design and Operating Experience for a Fluidized Bed Incinerator to Treat Industrial Hazardous Scum and Waste Oils

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Abstract−The production of industrial hazardous wastes increases with population growth and industrial progress. Most industrial hazardous wastes are in the forms of sludge, scum or waste oil and have organic properties. The best way to treat those wastes is to burn them in a fluidized bed type incinerator. Because the properties of scum and waste oils are different from those of industrial sludges, the design and operation of such kinds of incinerators are also different from that for industrial sludges. This paper presents the design method and the operating experience for a fluidized bed incinerator to treat specifically industrial hazardous scum and waste oils.

Key words: Design, Operating Experience, Fluidized Bed Incinerator, Scum, Waste Oils

INTRODUCTION

The production of industrial hazardous wastes increases with population growth and industrial progress. Most of the wastes are hazardous and, if not treated properly, will cause serious environmental pollution. Currently, most industrial hazardous wastes are landfilled; however, water and air pollution result frequently. In addition, to procure a landfill site is extremely difficult; consequently, another treatment method, the incineration of the wastes, has become more popular in recent years [Trethaway, 1976]. There are two prerequisites if the wastes are to be treated thermally: (1) the wastes must consist of combustible materials or organics, and (2) the wastes must be low in moisture content and high in heating value.

Most industrial hazardous wastes are obtained by the chemical, physical or biological treatment of industrial wastewater. Sludge is formed if the wastes are heavier than the water. Scum or waste oil is formed if the wastes are lighter than water. These wastes must be uniform in particle size and have a rich organic before they are suitable to be treated thermally [Becker and Wall, 1976].

The main advantages of the incineration of industrial hazardous wastes are the following: (1) the marked reduction of the organic part of the wastes by the oxidation reaction with the oxygen in the air supplied, (2) the complete elimination of the hazardous properties in the wastes, and (3) the recovery of the waste heat released by the incineration of the wastes to generate steam or in turn, power [Ioakimis and Davetoy, 1975].

The incineration treatment for industrial non-hazardous wastes has been in practice for many years [Zenz and Othmer, 1960; Howard, 1989; Water Pollut. Control Fed., 1988]. In recent years, environmental pollution problems have been a serious concern, and many different types of incinerators have been attempted. It has been concluded that the suitable equipment for thermally treating industrial hazardous wastes is the fluidized bed type incinerator. The fluidized bed incinerator provides all the advantageous characteristics of gas-solid fluidization technologies [Brunner, 1985; Wentz; 1989; Desai et al.; 1981].

There are many advantages in applying the fluidization technologies to the incineration of industrial hazardous wastes. First, the particle sizes of industrial hazardous wastes are usually small and uniform; therefore, they have relatively large contact areas with the oxygen in the air to carry out carbon oxidation. Second, the waste particles are suspended by means of the fluidizing air; therefore, further contact between the waste particles and the fluidizing air is obtained. Third, the fluidization promotes the mixing of the waste particles and the bed sand particles; consequently, a uniform combustion temperature is achieved in the fluidized bed. Finally, industrial hazardous wastes usually consist of high moisture contents; once added into the incinerator, the huge amount of heat sink stored in the bed sand will evaporate the moisture instantaneously without any change of the combustion temperature. Once the moisture evaporation of industrial hazardous wastes is complete, then combustion follows. The heat released during the combustion will be absorbed by the bed sand. This type of heat recirculation in the fluidized bed will maintain a uniform total heat content, and under such favorable conditions, industrial hazardous wastes are burned with a high combustion efficiency [Niessen, 1995; Robinson, 1986].

Scum and waste oils are very common in industrial hazardous wastes. They are characterized by a high moisture content (above 90%), plentiful organic content, high heavy metal content and high viscosity. Thus, they are very suitable to be treated thermally in a fluidized bed incinerator. The designs of such a fluidized bed incinerator are different from those for burning industrial sludges. This paper introduces and presents the designs and operation experiences of a large size bubble type fluidized bed incinerator, specially designed to burn industrial hazardous scum and waste oils.

FLUIDIZED BED INCINERATOR FOR SCUM AND WASTE OILS

1. General Plant Description

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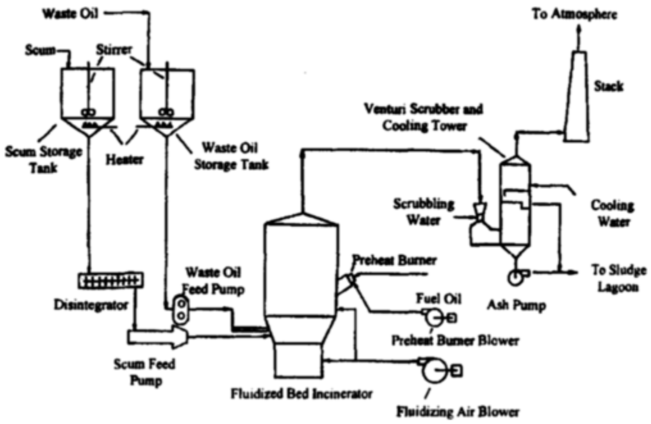

Fig. 1. Scum and waste oil incineration equipment.

The main facilities to treat the industrial hazardous scum and waste oils (shown in Fig. 1) are introduced respectively as follows:

1-1. Scum and Waste Oil Storage Tank

Usually, there are two storage tanks. One is for the storage of scum and waste oils collected from the concentration tanks or the flotation tanks. The other one is used as a feeding tank to the incinerator. The storage tank is able to feed the incinerator for 35 hours continuously. The tanks are equipped with an agitator to prevent the settling of the solid particles and a heater to keep the temperature of the tanks in a range between 50 °C to 60 °C in order to maintain a lower viscosity of the scum and waste oils.

1-2. Disintegrator

Because the scum and the waste oils usually consist of large-sized materials such as wood chips, plastics, rugs or slime, they are passed through a disintegrator before being fed into the incinerator.

1-3. Feed Pump

A progressive cavity feed pump is recommended, because the scum is more viscous and consists of larger solid particles. And as for waste oil, a reciprocating pump with a feed gun can be used.

1-4. Fluidized Bed Incinerator

The fluidized bed incinerator consists of three major parts:

(1) Windbox: The windbox is situated below the fluidized bed. It is a space where the combustion air or the fluidizing air is introduced into the incinerator. The diameter of the windbox is the same as that of the fluidized bed, and the height is about 2 m.

(2) Fluidized Bed: The fluidized bed is filled with the coarse sand used to mix and burn the scum or the waste oils.

(3) Freeboard: The freeboard is the space above the fluidized bed with a diameter about 20% larger than that of the fluidized bed. The height of the freeboard is usually about 4 m to 5 m in order to reduce the carry-over of the solid particles by the flue gas and also to maintain a sufficient residence time for the combustible gases and the tiny carbon particles (the smoke) to be oxidized completely in the freeboard.

The fluidized bed incinerator is equipped with a preheat burner used to heat the bed sand to the combustion temperature during the start-up of the incinerator and also to maintain the combustion temperature during operation. The combustion and fluidizing air is supplied by a high power centrifugal blower.

If the industrial hazardous wastes have a higher moisture content or a lower heating value, then the heat balance in the incinerator is under a less autogenous condition, and thus supplementary fuels are required to be added into the fluidized bed in order to maintain a certain combustion temperature. The alternative way is to design and operate a hot windbox type incinerator in which the combustion and fluidizing air is preheated up to 540 °C by a flue gas and fluidizing air heat exchanger.

Bed sand is subjected to attrition by erosion and decrepitation in the fluidized bed, and results in finer sand particles that are eventually carried over by the flue gas. Therefore, a sand feeder is necessary to make up the bed sand automatically in a certain time interval. Usually, the loss of bed sand is about 3% of the total amount of sand in the fluidized bed for every 24 hours of operation.

2. Design of the Fluidized Bed Incinerator

The fluidized bed incinerator is constructed with a carbon steel cylindrical shell 2.0 cm thick and lined with refractories at least 35 cm thick.

The diameter of the fluidized bed is decided by the total amount of air required in m^3/hr, which includes both theoretical air and excess air divided by the superficial velocity of the air rising through the fluidized bed, usually 0.75 m/sec.

The height of the bed sand in a settled fluidized bed is about 1.0 m. After fluidizing, the sand bed will expand 50% and reach a level of 1.5 m.

The diameter of the windbox is the same as that of fluidized bed, and the height is about 2.0 m.

The diameter of the freeboard is about 20% larger than that of the fluidized bed and the height is usually above 4.0 m.

The bed sand is of a hard silica type, and usually the particle size distributions are at least 70% in a range of US mesh 20 to 50 (0.3 mm to 0.8 mm). The bulk density of the sand is around 1,600 kg/m^3.

OPERATING EXPERIENCE

1. The Formation and the Prevention of the Low Fusion Materials in the Fluidized Bed.

Industrial hazardous wastes in most cases contain large amounts of low fusion point inorganics which are the compounds of sodium, potassium, iron or aluminum. The fusion points of these compounds are usually below the combustion temperature in the incinerator. Once these compounds are fused, they become very sticky and agglomerate with the bed sand and form the large slugs, which will settle in the bed bottom and cause very serious bed defluidization phenomena.

Many resolutions to solve the solid particle agglomeration problems have been tried [Becker and Wall, 1976]. The most effective way is to add clay into the fluidized bed. The main components of the clay are $Al_2O_3 \cdot 2SiO_2 \cdot XH_2O$. Once the clay particles come into contact with the fused low fusion point materials, they will react and form a high fusion point compound

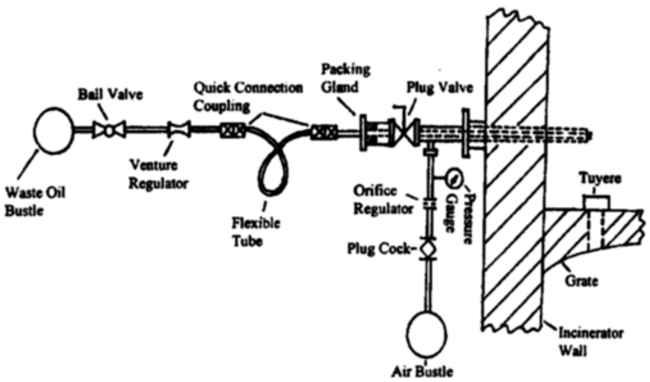

Fig. 2. Waste oil feeding equipment.

$Na_2O{\cdot}Al_2O_3{\cdot}2SiO_2$ in which the fusion point rises up to 880 °C. This is well above the normal combustion temperature in the fluidized bed. By a trial test with a large fluidized bed incinerator to burn the sewage sludges, the proper dosage of the clay added to eliminate more than 90% of the slugs formed is about in a ratio of clay : Na_2O =7 : 1.

2. The Corrosion of the Tuyeres in the Fluidized Bed

During the preheating of the fluidized bed, fuel oils are supplied to the preheater. Fuel oils contain some impurities of sodium and vanadium compounds. After combustion, sodium and vanadium in the fuel oils will be released and form the compounds V_2O_5 and $NaVO_3$ in the flue gas. These compounds will react vigorously to the metal part of the tuyeres and form a compound $FeVO_4$. The fusion points of V_2O_5 and $NaVO_3$ are close to 650 °C. In order to prevent the tuyeres from the vanadium corrosion, the fluidizing air preheating temperature in the hot windbox should be kept lower than 650 °C.

3. The Design of the Waste Oil Feeding Gun

The usual way to feed the waste oils into the fluidized bed is by means of a waste oil feeding gun. The waste oil feeding gun which is shown in Fig. 2 is constructed with a piece of 13 mm I.D. stainless tube slipped into a 32 mm I.D. protecting tube. Cooling air is introduced into the protecting tube. The function of the cooling air is to cool the waste oil feeding gun when inserted into the fluidized bed and to assist the waste oil feeding gun to be inserted into or pulled from a stationary fluidized bed. Before the waste oils are added, the fluidized bed temperature must be above the oil combustion temperature (620 °C). When the waste oil feeding gun is not in use, it must be pulled out from the fluidized bed to avoid damage by overheating. In addition, a path with a packing gland and a plug valve are required to be fabricated through the incinerator wall to prevent hot gases from leaking from the fluidized bed when the waste oil feeding gun is not in use.

CONCLUSIONS

Industrial hazardous scum and waste oils are suitable to be treated thermally in a fluidized bed incinerator with a high combustion efficiency and without producing any water and air pollution.

Industrial hazardous scum and waste oils usually have high heating values. They can be treated in a fluidized bed incinerator autogenously without any supplementary fuel.

The most often occurring problem in the operation of a fluidized bed incinerator that burns the industrial hazardous scum and waste oils is the slug formation in the sand bed. The trouble shooting of this problem is to add clay into the fluidized bed.

In preheating the incinerator with fuel oils, the preheat temperature should be lower than 650 °C to prevent the corrosion damage to the tuyeres.

The design of a waste oil feeding gun is suggested to provide a longer gun life and a lower maintenance cost.

REFERENCES

Becker, K. P. and Wall, C. J., "Fluid Bed Incineration of Wastes," *CEP*, 61 (October, 1976).

Brunner, C. R., "Hazardous Air Emission from Incineration," Chapman and Hall Ltd., New York, NY, U.S.A., 89 (1985).

Desai, T. B., Kamp, J. F., Hughes, T., Kennedy, E., McCormick, R., Peters, J. and Zanders, D., "Hazardous Waste Incineration Engineering," Noyes Data Co., Park Ridge, NJ, U.S.A., 13 (1981).

Howard, J. R., "Fluidized Bed Technology: Principles and Applications," Adam Hilgar Ltd., New York, NY, U.S.A., 143 (1989).

Ioakimis, E. G. and Davetoy, A. D., "Management of Oil Sludge from a Refinery Waste Water Treatment Plant," USSR-USA Joint Committee on Cooperation in the Field of Environment Protection, Moscow, USSR, 27 (May 13-16, 1975).

Niessen, W. R., "Combustion and Incineration Processes: Applications in Environmental Engineering," 2nd Ed., Marcel Dekker Inc., New York, NY, U.S.A., 380 (1995).

Robinson, W. D., "The Solid Waste Handbook," John Wiley & Sons, New York, NY, U.S.A., 405 (1986).

Trethaway, W., "Energy Recovery and Thermal Disposal of Wastes Utilizing Fluidized Bed Reactor Systems," Proceedings of 1976 National Waste Processing Conference, Boston, MA, U.S.A., 117 (May 23-26, 1976).

Wentz, C. A., "Hazardous Waste Management," McGraw-Hill Book Co., New York, NY, U.S.A., 25 (1989).

Zenz, F. A. and Othmer, D. F., "Fluidization and Fluid-Particle Systems," Reinhold Publishing Co., New York, NY, U.S.A., 25 (1960).

"Incineration Manual of Practice," Water Pollut. Control Fed., Alexandria, VA., U.S.A., 39 (1988).