Advanced Air Pollution control

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Course : Air and noise pollution control

Control of Heavy Metals

IN EMISSION STREAMS

- Heavy metals are elements have high atomic weight and high specific, have high thermal conductivity & characterized by malleability & ductility.
- Heavy metals in wastes will not be directly exposed to atmosphere, and cannot be completely destroyed by thermal process.
- Thermal process can only oxidize majority of metals to particulate matter.
- Only a small amount of volatile metals having a boiling point lower than the thermal/combustion operation temperature will be vaporized.
- Metals, such as arsenic, barium, beryllium, chromium, cadmium, lead, mercury, nickel, and zinc

Principle and Theory

- Its consist of heavy metal reactions in an incinerator and control of metal emissions.
- The purposes of pollution control and incinerator operation, including metal stoichiometry, thermodynamics, and combustion.

Reaction in Incinerator

- Oxidation and reduction reactions
- “oxidation” used to describe reactions in which an element combines with oxygen . for example, copper metal and oxygen to form copper oxide involves oxidation of copper.
- Metals act as reducing agents in chemical reactions.

- When copper is heated over a flame, surface turns black as copper metal reduces oxygen in atmosphere to form copper(II) oxide.
- Black CuO that forms on surface of metal converted back to copper metal.
- In this reaction, CuO acts as an oxidizing agent & H_2 is reducing agent.
- The first reaction converts copper metal into CuO, thereby transforming a reducing agent (Cu) into an oxidizing agent (CuO).
- The second reaction converts an oxidizing agent (CuO) into a reducing agent(Cu).

$$2Cu\ (s) + O_2\ (g) \longrightarrow 2CuO(s)$$

two half reaction of oxidation & reduction:

$2Cu\ (s) \longrightarrow 2Cu^{2+} + 4e^-$ Oxidation Reaction

$O_2\ (g) + 4e^- \longrightarrow 2O^{2-}$ Reduction Reaction

$2Cu\ (s) + O_2(g) \longrightarrow 2CuO\ (s)$ Redox Reaction

- Oxidation states can present as a hypothetical charge.
- Metal oxides after combustion become very small particles and APCDs can not easily collect them.

Hydrolysis Reaction

- Is a chemical reaction of a compound with water and results in formation of one or more new stable oxide or hydroxide compounds.
- $[M(H_2O)_n]^{z+} + H_2O \quad [M(H_2O)_{n-1}(OH)]^{(z-1)+} + H_3O^+$
- Requires high temperature &pressure, acid or alkali, and catalysts.
- Heavy metal compounds in hydrolysis become fly ashes in incinerator.

Chlorination

- This reaction is related to chloride in incineration as a result of due to waste that contain plastic materials.
- Chloride compounds may convert to hydrochloric acid during combustion (organic or inorganic chlorides).

$$Cl_2 + H_2O \longrightarrow 2HCl + 1/2O_2$$

- Gaseous compounds and alkali chlorides ligand with metals, forming heavy metal chlorides in incinerator.

High-Temperature Metal Absorption

- Chemical absorption reactions between metal vapors and a variety of sorbents at high temperatures

$$2PbO + SiO_2 \longrightarrow Pb_2SiO_4(s)$$

$$CdO + SiO_2 \longrightarrow CdSiO_3\ (s)$$

$$CdO + Al_2O_3 \longrightarrow CdAl_2O_4\ (s)$$

$$PbCl_2 + Al_2O_3{:}2SiO_2 + H_2O \longrightarrow PbO{:}Al_2O_3{:}2SiO_2(s) + 2HCl(g)$$

$$CdCl_2 + Al_2O_3 + H_2O \longrightarrow CdAl_2O_4(s) + 2HCl(g)$$

Control of Metal Emissions

- Effective control of fly ash emission therefore controls emission of metals.
- Semi-volatile metals (i.e. , arsenic, cadmium, and lead), tend to volatilize during combustion & during flue gas cooling to form metal fumes or to deposit fine particulate matter.

Control of Particulate Matters

- The efficient collection of fine PM, either micron or submicron in size, to control the emissions of these metals.
- Particles are collected by a combination of several mechanisms, such as gravity settling, centrifugal force ,electrostatic impaction, inertial impaction, direct interception, and diffusion.

1. Gravity Settling

$$V_S = [\, g\,(P_P - P)\, D^2 \,]/18\mu$$

Where V : velocity, D: diameter of particle, g: gravity, $P_{p:}$ density of the particle, p: density of gas, and μ: viscosity of gas.

2. Centrifugal Force

$$F = mv2\ /r$$

Where **F**: centrifugal force , **m**: mass , **v**: velocity , & **r** radius.

3. Electrostatic Force

$Fe = Ke (qq^*/r2)$

Where **Fe**: electrostatic force, & **qq^***: charges, **Ke :** proportional constant ,& **r** the radius

4. Inertial Impact

Inertia is resistance force to mass in changing of motion.

5. Direct interception

Particles having < inertia, follow gas streamlines.

6. Diffusion

Particles < 0.1 µm have individual or random motion.

Control of metal vapor

- Control of metal vapor depends on characteristics of metal, operational condition in incinerator, and APCDs.
- Volatile metals,(mercury and selenium), are most troublesome because they tend to stay in gas phase , which is difficult to control by APCDs.
- Additional control technologies such as low- temperature sorbent injection/carbon adsorption or acid scrubbing are required to control their emissions.

1- Mercury emission control

- Mercury emissions from waste combustion/ incineration systems and coal- burning .
- Its highly volatile and exists in the vapor phase of combustion flue gases or the form of elemental mercury and mercury salts such as $HgCl_2$, HgO ,HgS.
- Conventional flue gas desulfurization systems are capable of removing mercury and by absorbents or dry sorbent injected with activated carbon –impregnated lime.
- The rate of mercury sorption vary with temperature, gas flow rate, mercury form, sorbent type, sorbent amount, and sorbent properties.

Control Device of Heavy Metals

- Most common APCDs among hazardous waste incinerators are gravity settling chamber, cyclone, quench, bag house, electrostatic precipitator, venture scrubber, wet scrubber, packed tower absorber.
- They are used for gas cooling and PM removal.

1. Gravity Settling Chamber

Gravity is using to remove PM as a gas stream passes through a long settling chamber, gas velocity must be low in order to particles to settle.

2. Cyclone

cyclones use centrifugal force for fine particle removal.

Centrifugal force and inertia cause particles to move outwardly and, resulting in particle sliding down to device

3. Electrostatic precipitator

ESP requires maintenance of a high potential difference between two electrodes, one is discharging electrode and other is a collecting electrode.

4. Quench:

A quencher is cooling unit that used to cool waste temperature, provides reduction of pollutants from emission gases.

5. Scrubber

Devices that remove PM by contacting dirty gas stream with liquid drops , water is used as scrubbing fluid.

6.Fabric filter

Its based on filtration, which is a reliable, efficient, and economic method to remove PM from gases.

Air pollution control equipment using fabric filter are known as bag houses.

7. Verification

This method has chemically applied to process heavy metals and radioactive elements into a durable-resistant glass.

8. Solidification

It is a mechanical binding process that can encapsulate waste in a monolithic solid and then preventing waste from leaching or escaping from surface of encapsulation

- Several physical and chemical properties of ashes can affect solidification include PH, specific gravity , viscosity, temperature, solid/water contents, curing time, redox potential, ion exchange, absorption.

➢ Advantages of Solidification

I. Low cost
II. Good long term stability and low leach ability
III. Low waste solubility and permeability
IV. Non toxic production
V. Easy to operate and in process

➢ Disadvantages

I. High volume increases.
II. Resistance to biological degradation.
III. Increased transportation cost.

9. Chemical stabilization and fixation

They uses physical or chemical technologies to convert toxic substances to least soluble, leachable, and mobile compounds.

10. Extraction

Its removes and recovers substances from waste using extracting solvent and/ or physical operations

11. Fluidized –Bed metal capture

Its conducted in a fluidized bed during coal combustion at high temperatures

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