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PRINCIPLES OF COMBUSTION:

INCINERATOR SYSTEM DESIGN OVERVIEW

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INCINERATION DESIGN OVERVIEW

Principles of Combustion

Many terminologies have been utilized when referring to incineration: thermal oxidation, pyrolysis, thermal destruction, etc. to name a few.

Typically the term incineration brings about an incorrect negative connotation, whereas the term thermal oxidizer is related to primary air pollution control.

As such, thermal oxidation system implies that the system is an effective method of total pollution control in and of itself.

The modern controlled air combustion process effectively:

- destroys biological hazards
- reduces solid waste residue volume to land fill by over 90% of mass volume
- effectively treats VOC and HAP emissions.

In order to understand how and why an incinerator works, it is important to understand exactly what incineration is.

INCINERATION DESIGN OVERVIEW

Modern Design

Modern solid waste incineration systems utilize a two stage combustion process whereby the waste is charged into the primary combustion chamber,. (Bottom chamber) where it is treated to under-fire air injection along the hearth with optimally positioned, primary ignition burner(s) to ensure adequate flame dispersion and carbon reduction.

The by-products of the first stage combustion process, VOC's and HAP's) are then further oxidized in the secondary combustion charger which provides turbulent, secondary over-fire air injection and a controlled, temperature maintenance/oxidizing burner.

- VOC's or Volatile organic compounds are emitted as gases from certain solids or liquids.
- HAP's, also known as Hazardous Air Pollutants, toxic air pollutants or air toxics, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects.

INCINERATION DESIGN OVERVIEW

Burning

By Definition, incineration is to burn to ashes through a combustion process. That is probably the most relevant statement that can be made. All we are really doing – is burning.

The implication is that the incinerator provides for a controlled combustion process through the application of engineered, proven technology. It is generally accepted that modern incineration is only about 30 years old. The point is that all an incinerator can do is provide the conditions for a highly-controlled combustion environment.

Actual combustion combines hydrocarbons (fuel) and oxygen and yields carbon dioxide, water vapor and heat. Stoichiometric (perfect and theoretical) combustion would therefore be:

CARBON + OXYGEN = CARBON DIOXIDE

HYDROGEN + OXYGEN = WATER

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INCINERATION DESIGN OVERVIEW

The 3 T's of Combustion

The waste streams that we are dealing with obviously contain more elements that just carbon, hydrogen and oxygen. However, these three constitute the largest portion of the waste chemistry, which is why incineration makes sense.

In the real world, perfection is not attainable and it is inevitable that there will be Products of Incomplete Combustion (PICs) and inorganic (non-combustible) products or by-products, present.

The job of the incinerator is to minimize the PICs through complete and thorough combustion.

Inorganic substances and other such uncontrolled emissions, such as acids, metals, dioxins and furans, when present in significant quantities, dictate the need for auxiliary air pollution control equipment (APC), such as scrubbers and/or bag-houses.

As such, there are only three control variables to work with in combustion, the Three "T's" of Combustion:

- TIME
- TEMPERATURE
- TURBULENCE

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INCINERATION DESIGN OVERVIEW

(T-1) TIME

This refers to retention or residence time and applies to both solids and gases. As it relates to solids it is referring to the completed combustion of the waste matter in the primary chamber (where the waste stream is introduced).

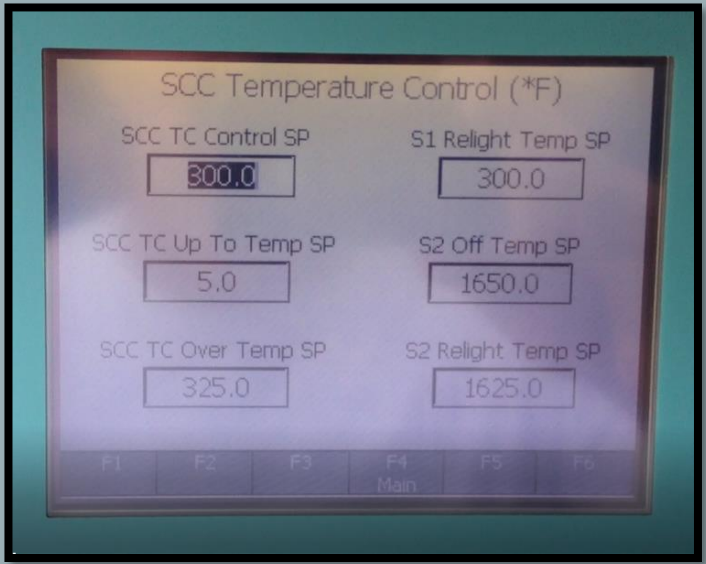
This is critical for good ash burnout and is a function of the incinerator's operational design. In other words, the objective is to consume or drive off all of the hydrocarbons in the primary chamber.

The time required to do this is relative to the design of the incinerator and the size of the primary chamber to support the volumetric flow of gases generated in the combustion process.

Thus the size of the primary chamber determines the combustion capacity of the system. Gaseous retention time is the aspect referred to in most of the new environmental regulations and relates to the duration the gaseous by-products of the combustion in the primary chamber are held in the secondary chamber and is critical to ensure completion of combustion and thermal destruction efficiencies.

Secondary chamber retention time is a volumetric flow function determined by the amount and velocity of the gases in relation to the size of the secondary chamber.

INCINERATION DESIGN OVERVIEW



(T-2) TEMPERATURE

Temperature is a function of heat balance and is typically most critical as it relates to the secondary chamber.

A minimum secondary chamber temperature of 1800° F measured at the furnace outlet is generally required for medical and municipal wastes. This is necessary in order to insure biological destruction.

While primary chamber temperature is not as critical, some regulations are calling for minimums of 1400° F.

Typically VOC applications require 1400-1600° F with a one second retention time.

Temperature would appear to be the easiest of the three T's to control, simply increase burner input to elevate temperatures.

However, it is imperative that all three variables be controlled simultaneously efficiently balance temperatures.

Our systems utilize multiple burners positioned in optimal locations to provide superior flame dispersion to minimize fuel usage. PLC based control systems provide the capabilities to continuously monitor and adjusts all functions to maintain optimal balance of the system.

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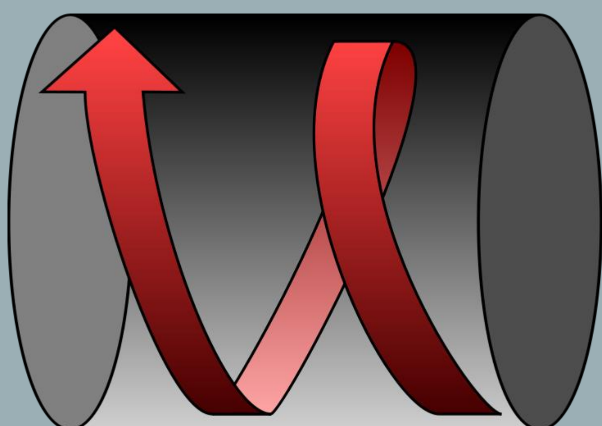
INCINERATION DESIGN OVERVIEW



(T-3) TURBULENCE

Turbulence, relevant to the combustion process, refers to the mixing of the combustion reactants;

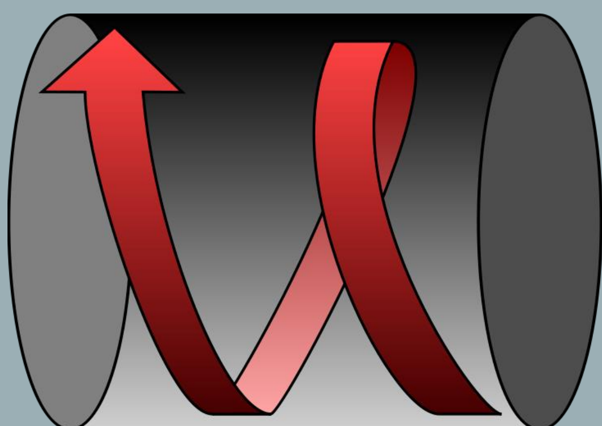
- Hydrocarbons (from the waste)
- Oxygen (combustion air)

Effective turbulence provides for increased combustion efficiencies. There are basically two types of turbulence:

1. **Mechanical:**

   Mechanical turbulence applies to the solids or mixing of the actual waste stream in the primary chamber, for example, like stoking a fire with a poker. However, in their batch configuration mechanical turbulence is not possible in the primary chamber and thus providing adequate aerodynamic turbulence is critically significant to assure proper burn-down of the waste.

INCINERATION DESIGN OVERVIEW



(T-3) TURBULENCE Cont'd

1. Aerodynamic:

Aerodynamic turbulence refers to the mixing of combustion air with the combustibles.

In the primary chamber aerodynamic turbulence is applied directly to the waste bed via controlled under fire injection nozzles, (the same principal as applying bellows to a fire), to assure complete combustion of the waste for unparalleled burn-down.

As the volatilized gases leave the primary chamber, they are injected with secondary, or "over-fire" air to assure completed combustion of the flue gases in the secondary chamber thermal oxidizer.

The bottom line is; if you don't have oxygen present, it won't burn.

Evaluation of a system's flow designs and proper maintenance of combustion air injection systems is critical to maintaining optimal combustion efficiencies.

INCINERATION DESIGN OVERVIEW

The THREE T's are the basis for **all incinerator design** principles.

The factors of waste type, form and composition, heat release rate (Btu/ft3/hr.) and burning rate (Btu/lb/ft2/hr.) are the determinants of primary chamber sizing.

They relate proportionately to the secondary chamber determining factors of retention time (secondary chamber volume/acfm of flu gas), temperature and turbulence as required to meet regulations.

It is a standard practice to run heat and mass balance calculations based on ultimate analysis waste stream composition data to determine chamber sizing and system capacity ratings.

Optimal design practice will capitalize on these factors to provide the best environment for completed combustion, because that is all an incinerator can do.

The design of any Thermal Oxidizer Systems, must be based on direct application of the Three T's of Combustion:

- TIME
- TEMPERATURE
- TURBULENCE

These principles directly apply to the incineration process.

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