4.5 INCINERATION

- Incineration, also known as combustion, is most used to control the emissions of organic compounds from process industries.
- This control technique refers to the rapid oxidation of a substance through the combination of oxygen with a combustible material in the presence of heat.
- When combustion is complete, the gaseous stream is converted to carbon dioxide and water vapor.
- Equipment used to control waste gases by combustion can be divided in three categories:
  - Direct combustion or flaring
  - Thermal incineration and
  - Catalytic incineration

1. Direct Combustor

- Direct combustor is a device in which air and all the combustible waste gases react at the burner.
- Complete combustion must occur instantaneously since there is no residence chamber
- A flare can be used to control almost any emission stream containing volatile organic compounds.
- Studies conducted by EPA have shown that the destruction efficiency of a flare is about 98 percent.

2. Thermal incineration

- In thermal incinerators the combustible waste gases pass over or around a burner flame into a residence chamber where oxidation of the waste gases is completed.
- Thermal incinerators can destroy gaseous pollutants at efficiencies of greater than 99 percent when operated correctly.

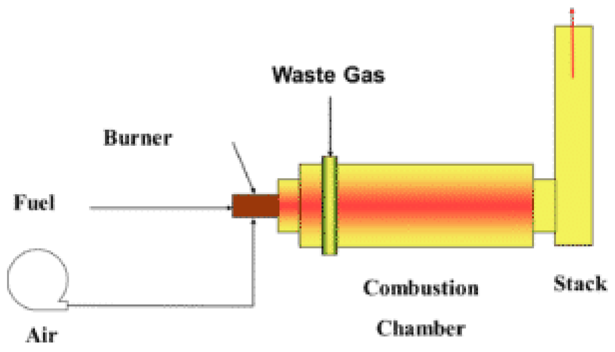

Figure 4.5.1Thermal incinerator

[Source:https://mk0pccgroupd070oma36.kinstacdn.com/wp-content/uploads/thermal-oxidizer-graphic-e1555350485609.png]

3. Catalytic incinerators

- Catalytic incinerators are very similar to thermal incinerators.
- The main difference is that after passing through the flame area, the gases pass over a catalyst bed.
- A catalyst promotes oxidation at lower temperatures, thereby reducing fuel costs.
- Destruction efficiencies greater than 95 percent are possible using a catalytic incinerator.

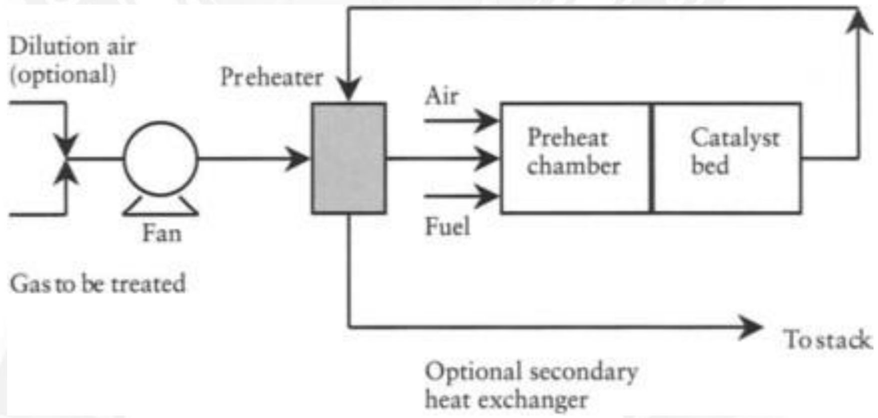

Figure 4.5.2 Catalytic incinerator

[Source:https://ars.els-cdn.com/content/image/3-s2.0-B9780122896767500163-f13-22-9780122896767.jpg]

Performance Equations of Incineration or Oxidation:

Oxidation, or combustion as it pertains to the air pollution control industry, can simply be defined as a rapid combination of oxygen with a fuel (in this case, a volatile organic compound, or VOC). This process will result in the release of energy in the form of heat and, if completed correctly in our world, the process will also release carbon dioxide and water.

The basic combustion reaction looks like this:

$$C_XH_Y + (x + y/4)O_2 + Heat = xCO_2 + (y/2)H_2O + Heat$$

Where, C_xH_y is any hydrocarbon

O_2 is oxygen

CO_2 is carbon dioxide

H_2O is water

The air pollution control industry typically refers to the equipment which performs this process as oxidizers (i.e. thermal oxidizers, catalytic oxidizers, or regenerative thermal oxidizers).

This is because most processes have excess oxygen (excess air), producing a lean mixture or an oxidizing combustion reaction. This blog will only focus on these type of reactions.

So far, we have talked about the end results of the combustion reaction. These end products are the same for all fuels containing different combinations of hydrogen and carbon within their chemical formulas. However, it should be noted that how these end products are achieved can take many different paths or reaction mechanisms. Therefore, different flames, cold spots, or quenching surfaces can produce many varied and unknown intermediate products.

Example:

Carbon and hydrogen atoms may combine and disassociate to form unstable compounds like carbon monoxide and different types of aldehydes.

The types of compounds formed and the speed of their formation and disassociation depend upon the reaction conditions. Other reaction conditions that can affect the combustion process other than temperature are items like pressure, O_2 levels present, and mixing.

Most oxidizers operate at or near atmospheric pressure, so we will not explore that variable in depth. As discussed above, most oxidizers also operate with excess air, oxidizing the atmosphere, which means that the combination of the final products is more dependent on temperature and mixing.

The mixing of the VOC is important to the combustion reaction. This reaction needs a minimum temperature to start the process and efficiently proceed to the desired end products of CO_2 and H_2O. Mixing is very important to provide a uniform temperature to start the reaction. This is key to lowering fuel gas costs.

Mixing is also important with regards to the mixture of VOC and O_2. Every particle of fuel or VOC must contact a particle of oxygen in order for the combustion reaction to take place. Oxygen content and residence time at the combustion temperature is also important.

The reaction rate of the combustion reaction is dependent on temperature; for instance, an increase in temperature actually decreases the amount of time that is needed to convert CO to CO_2.

- A decrease in O_2 concentration would require better mixing, due to the lack of availability of O_2 for the reaction completion.
- Temperature, oxygen concentration, and residence time to reduce CO actually must be controlled in the opposite direction to reduce the amount of nitrogen oxides (NOx) emitted, so raising the temperature isn't always the best solution.

Advantage:

- One advantage of thermal incineration is that the energy and heat produced by the process can be recovered and used to power other processes in the facility.

Disadvantages:

- Thermal incinerators are also not generally cost-effective for low-concentration, high-flow organic vapor streams
- Thermal incinerators are not usually as economical, on an annualized basis, as recuperative or regenerative incinerators because they do not recover waste heat energy from the exhaust gases.