Enclosed Combustor Basics
Prepared by Corey Haney
Applications Engineer, HY-BON/EDI
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Definitions and Terminology

According to the Environmental Protection Agency (EPA), an Enclosed Combustor (EC) is "an enclosed firebox which maintains a relatively constant limited peak temperature generally using a limited supply of combustion air. An enclosed flare is considered an enclosed combustor." (40 CFR 60.751) An EC can also be called a Thermal Oxidizer (TO). According to the NFPA, a Thermal Oxidizer is "an independently controlled, enclosed combustion system whose purpose is to destroy VOC, [hydrocarbon] gases or vapors, or both, using elevated temperature, residence time, mixing, excess oxygen, and, in some cases, catalysts." (NFPA 96, 3.3.46.2) The definition of a TO clarifies how an EC is designed and why it is an effective device in managing VOC hydrocarbon (HC) gases efficiently.

Purpose

As mentioned in the Definitions and Terminology section, the purpose of an EC within the Oil and Gas Industry is to safely and efficiently destroy Volatile Organic Compounds (VOCs). "Combustors are used to control VOCs in many industrial settings, since the combustor can normally handle fluctuations in concentration, flow rate, heating value, and inert species content." (4.3.1.2)

Types

An EC can be divided into many types; however, for our purposes we will only consider the two, most common variations when the EC is eliminating VOC HC from storage vessels. The variation comes from the means in which the air is supplied to the EC.

One method of providing air into the EC is called mechanical draft. In a mechanical draft system, the air is supplied by using a fan or blower. The draft can be forced, induced or balanced. A forced draft is created by placing the fan or blower at the base of the EC. This "forces" the air into the EC by creating a positive pressure at the base of the EC. An induced draft is created by placing the fan or blower near the top of the EC. This "induces" the air into the EC by creating a negative pressure within the stack. The third method is simply a combination of both, which creates a balanced pressure within the stack.

The second method of providing air into the EC is called natural draft. In a natural draft system, the airflow is produced by a driving force (draft) created (naturally) by the difference in density of the hot exhaust inside the EC and the ambient air. The magnitude of the draft is dependent on ambient temperature, ambient pressure, stack height and stack temperature.

Pros and Cons

Mechanical Draft vs. Natural Draft

Safety

A mechanical draft system requires a blower or fan to create a draft in the EC. The natural draft system creates a draft automatically once the operation of the EC begins. Assuming all other variables are equal, the natural draft system is safer because there are fewer moving parts that could cause failure or harm to the system or people.

Cost

A mechanical draft system requires a blower or fan, the associated duct work and power to operate the equipment. Whereas, the natural draft system does not require an extra components or electricity. Depending on the required throughput of the combustors, the natural draft system would have fairly long stack height. It is quite possible, assuming all things being equal, that the initial cost and installation of both types of combustors would be comparable. However, overtime the cost of the mechanical draft would be higher due to the required maintenance of the blower or fan and the cost of the electricity to operate the draft system.

Operation

The amount of air introduced into the natural draft system is greatly affected by the stack height and the environment. This, in turn, greatly affects (limits) the combustor's turn down. A combustor's turn down is the ratio of the highest flow rate to the lowest flow rate. This means that the combustor has a relatively small window of operation because a high stack temperature must be maintained (typically 1400F) to ensure high destruction efficiency. That's a minimum stack temperature. The maximum is primarily a function of safety concerns and temperature ratings for the equipment. Most operators and manufacturers keep the temperature below 2100F. The amount of air into the natural draft combustor is fixed by design and cannot be easily increased.

The mechanical draft system, however, operates independently of stack height and the environment. This means that as the fuel flow rate increases, the mechanical draft system can move more air into the combustor. Forcing more air into the combustor as the fuel flow rate increases allows for the stack temperature to be controlled. Mechanical draft combustors have a higher turndown.

Open Combustor vs. Enclosed Combustor

Safety

To begin, an open combustor is more widely known as a traditional, candle-stick flare. These are very easily spotted during their operation because the combustion process is visible, (possibly) loud, and radiating copious amounts of heat. Depending on the application a large, isolated area must be designated for the flare primarily due to the dangerous amount of radiant heat.

ECs are generally safer than flares because the combustion process is contained.

Cost

Flares are generally much cheaper than ECs. Furthermore, the cost per cubic foot of gas burned is much lower with a flare than with an EC.

Operation

Both combustion devices use a continuous ignition or pilot system to ignite the waste gas stream. However, it has become industry standard to utilize a continuously present pilot system to ignite the gas stream. Because open flares can handle much higher flow rates they are generally used for emergency situations. ECs have higher destruction efficiencies and are typically used in applications where the variables, such as pressure, gas composition and flow rate are all known.

Placement

As mentioned before, the open flare must be placed according to the expected/designed radiation from the waste fuel. This can require significant area and area preparation.

The EC is less demanding in terms of space requirement. The main concern with an EC is that, with all combustion devices heat is released, and combustion air is required. Since the combustion air *could* contain flammable gas mixtures due to a gas leak on location, it is a good practice to place the combustor at least 70-80 feet from the source. This at least reduces the potential for explosions due to gas leaks on location.

Also, within the piping system for the waste gas stream a liquid KO bottle should be placed to collect liquid hydrocarbon that condenses between the waste gas source and the EC. All piping should be sloped towards the KO bottle and NOT towards the EC.

Design

A well-designed EC ought to include the following items as part of the design:

1. Emergency shut-down valve for the waste gas stream
2. Inline flame arrestor for the waste gas stream
3. High-temperature refractory
4. A burner management system
5. Continuous and reliable pilot system

Components

Below is an explanation for the items listed in the Design section.

1. Emergency shut-down valve for the waste gas stream
    a. This valve will control the flow of waste gas into the EC. In the event that the continuous pilot fails, gas should be prevented from entering into the EC. Also, in the event that the internal stack temperature exceeds design specifications the valve should be closed to prevent damage to the EC or potential harm to the environment or personnel.
2. Inline flame arrestor for the waste gas stream
    a. In the event that oxygen is present in the waste gas system, there is the potential for the combustion process to move upstream towards the waste gas source depending on the speed in which the reaction takes place. It is possible for the speed of reaction to exceed the speed in which the waste gas stream is traveling. An inline flame arrestor works by absorbing the heat from the combustion process, which prevents the combustor process from continuing in the direction of the waste gas source. Great care should be taken when considering a flame arrestor because there are many factors that determine the effectiveness of the flame arrestor.
3. High-temperature refractory
    a. During operation the stack of the EC can get extremely hot. To prevent damage to the stack and provide a layer of safety to the environment and personnel, high-temperature refractory should be used to drastically reduce the outside stack temperature.
4. A burner management system
    a. A control system that is specifically designed to manage the operation of the EC should be always be used. A burner management system will ensure that the EC stays within proper operating conditions, which ensures safety for the EC, environment and personnel.
5. Continuous and reliable pilot system
    a. A continuous and reliable pilot system is now an industry standard. As long as the pilot is present, the highest and most reasonable ability to ignite the waste fuel exists. This pilot system should integrate into the burner management system so that the state of the pilot is always known.

Sizing

The sizing of an EC is primarily based on the following:

1. The amount of waste gas
2. The composition of the waste gas
3. The pressure the EC is to eliminate the waste gas stream
4. The desired destruction efficiencies

Troubleshooting

Common issues with ECs is smoking. Smoking occurs when insufficient air is available for the fuel. The following are common reasons:

1. Too much waste gas is entering the EC and the EC cannot provide enough air to facilitate complete combustion.
2. Insufficient waste gas is entering into the system and failing to mix with the available air.
3. In some cases, liquid hydrocarbon makes its way to the burner, which is extremely dangerous (unless the combustion device is designed to handle liquid hydrocarbon). Since our focus is on ECs designed for hydrocarbon gas, it will not burn the liquid hydrocarbon properly, which results in smoke

References

Part 60 – Standards of Performance for New Stationary Sources

https://www.ecfr.gov/cgi-bin/text-idx?SID=37ee7d26880bd0c664b26b7404fe4235&mc=true&node=pt40.8.60&rgn=div5#_top

Control Techniques Guidelines for the Oil and Natural Gas Industry