Abstract

Control of air pollution from incineration begins in the furnace. Scientific design and careful operation will insure that the generation of pollution will be minimized. Effects of various criteria of design and operating practices are discussed.

Introduction

The importance of furnace design and operation, and their effect on air pollution when burning any type of fuel, but more specifically, the incineration of refuse material, is frequently overlooked or disregarded in the mistaken belief that nothing can be done about the pollution, until the pollutants leave the furnace. Extensive experience in the design and operation of furnaces for many different and varied fuels, including all types of refuse, has shown that the first and most profitable place to reduce all kinds of pollution is at the source, which in the case of an incinerator is obviously in the furnace or primary chamber.

For example, if a piece of paper is burned to ash, there is very little solid particulate left to be discharged as fly ash. When however the paper is only charred, the resultant blackbirds will fly all over the neighborhood, to the annoyance of all concerned.

Again, some chemical constituents in furnace gases are very malodorous, or toxic, when emitted from a relatively cool furnace, but become harmless when completely oxidized in a hot furnace. Carbon and hydrogen, for example, should be completely oxidized to CO and H₂O, which are harmless, rather than to CO and C/H compounds, which can be deadly under certain conditions, and are generally undesirable.

Excess air flow must be carefully controlled, as this can have a major effect on the pollutants emitted, both solid and gaseous. Some excess air is always required, both to assure proper combustion of the refuse, and to avoid excessive furnace temperature, with resultant furnace slagging and high refractory maintenance. The approximate air quantities required for various furnace temperatures as related to heat input and moisture content, are readily calculated. Air flows greatly in excess of these values will cause higher velocities and increased carryover of solid particulate, as well as reduce the furnace temperature to below that required for complete combustion.

Flame Temperature

A fact frequently overlooked is that the flame from the burning refuse, is the hottest element in the furnace and when properly controlled, it will maintain the desired temperature, regardless of the refractory walls or arches. In fact the installation of water walls permits higher furnace temperatures to be carried, by lowering the excess air, without formation of excessive side wall slagging, as has been proven in several installations.

Heat flows only from a higher to a lower temperature level, so that re-radiation from the walls to the furnace interior occurs only when the fire has died down through
lack of refuse or other cause. The function of the furnace walls is therefore primarily to contain the combustion products, and prevent excessive air infiltration. The use of steel cased settings, which can be made substantially air tight, is therefore desirable, and common practice in the well designed incinerators, as well as in many industrial and utility furnaces.

**Fly Ash**

Tests have shown that the fly ash carryover from the refuse on the grate will increase approximately as the square of the air velocity through the grate, so that doubling the air flow, for example, will increase the particulate emission by four times. This is therefore one factor in limiting the combustion rate on the grate, as it is easier and more satisfactory to reduce the emissions leaving the furnace, than it is to remove them from the gas stream, in the flue or stack. Nitrous oxide emission is also increased when too much air is passed through the furnace, as is the conversion of S\(_2\)O\(_3\) into S\(_2\)O\(_4\). The latter may in turn combine with the water vapor to form H\(_2\)SO\(_4\), which is very undesirable.

**Furnace Height**

Flame travel, or the height of the flame above the refuse bed, increases with the combustion rate, as well as with the volatile and moisture contents of the refuse. We have all seen how the flame from the gas burner on a stove lengthens as we turn up the gas, and the same result is noted when more refuse is loaded onto the grate, especially when it is highly combustible, such as paper. The furnace must therefore be large enough to permit burnout of this flame, either in the primary chamber, or in the secondary chambers. When these are too small, the flame may carry over into the flue or stack, resulting in a fire hazard, as well as in incomplete combustion, with undesirable gaseous emissions such as CO or hydrocarbons.

It is generally preferable to provide this flame travel in a vertical direction, so that burnout occurs in the primary chamber. Not only does this assure more complete combustion and reduced carryover, but from the designer's angle, the foundation and arch dimensions are smaller with a relatively high, narrow furnace, than with a spread out shape, at a lower first cost, to the benefit of all concerned.

Air curtains can be used in an incinerator furnace to prevent the passing of undesirable substances, just as they are used in industrial plants to prevent the entrance of hot or cold air, dust, insects, odors or similar elements through doorways. The proper use of overfire air can greatly reduce the carryover of unburned combustible, dust or other pollutants from the burning refuse, by insuring their complete burnout, and when aimed across the furnace and pointed somewhat down, there is a noticeable tendency to knock the fly ash back onto the refuse bed, so that it comes out as residue.

Afterburners serve a useful purpose, in elimination of smoke or other unburned emissions, especially in cases where it is impossible or undesirable to operate the primary furnace at a high enough temperature to prevent their formation at the source. Examples include the removal of upholstery, paint and similar combustible matter from old auto bodies, prior to baling them for scrap, as well as the reclamation of used oil, paint and chemical containers and barrels, by melting and burning out their contents so they can be cleaned and reconditioned.

In above examples the metal would be oxidized and rendered useless at furnace temperatures above a few hundred degrees F, so that the smoke which results from this low temperature, is burned out by passing through the high temperature afterburner chamber, where sufficient combustion air is added to convert the carbon particles to CO\(_2\). Numerous chemical and other recovery processes use afterburners for similar reasons.

Combustion air control is vital to the proper performance of the incinerator, as noted above, and the proportioning of the under and overfire air flows must be carefully considered in the design. More than half of the total combustion takes place above the fuel bed, where the volatile content in the refuse burns as a gas, and where temperature and turbulence are major factors. The overfire air serves therefore in two capacities, first to supply the oxygen required, and second to promote the turbulence necessary for thorough mixing of the gas and air. Properly placed air jets are generally more effective than baffles in promoting required turbulence, as they can be aimed to the area where needed, and adjusted to suit the load and refuse characteristics, with a minimum of cost and maintenance. The required combustion air is therefore supplied where most desirable, so that optimum combustion is assured.

Automatic control of the air flow is greatly facilitated because of the above flexibility of the air jets, and furnace dimensions can usually be decreased because of the quicker and more complete combustion of the gaseous components, without sacrifice in retention time.

Charging the refuse should be done continuously or in small increments, rather than in large batches, to avoid overloading. Mechanical charging is highly desirable, using hoppers or feeders to suit.

The above items cover some of the factors that have been found helpful in designing incinerators on a scientific rather than an empirical basis. Cause and effect follow each other in this branch of engineering as in others, and in the long run a sound design, plus good operation, are bound to produce better average performance than the hit and miss designs too often used in the past.