New Developments in Industrial Incineration

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Abstract

The paper is a review of improved calculating and design techniques, performance rating of incinerators, and a description of the new open-pit incinerator. Of particular interest is a curve of nitrogen oxide formation with varying excess air and temperature developed from thermodynamic equilibrium data that has been verified by field tests.

Introduction

The field of industrial incineration varies greatly from that of incinerators for municipal waste disposal. Units are generally much smaller. Wastes are more varied. Frequently, the incinerator must be planned before any waste becomes available. Basic data supplied to the designer may be erroneous by orders of magnitude. Consequently, the designer must provide units that will function over a wide range of fuels, calorific values, degrees of impurities, and rates of disposal. This requires substantial design effort and it is the purpose of this paper to show, for industrial incinerators, the main factors involved in selecting good units and to illustrate techniques that can minimize the need for costly trial and error methods.

Combustion Calculations

The prime requirement of any incinerator is good combustion, and a technical analysis prior to design is a necessity. This requires a complete fuel analysis of a representative sample of the waste. If the waste exists only on a flow sheet, any assumptions as to the accuracy of its ultimate characteristics should be pessimistic.

If the waste is of simple chemical structure, combustion calculations are correspondingly simple. If the waste is a complex one containing such things as halogens and metals, or is toxic and corrosive, more complex calculations must be made involving thermodynamic equilibrium data. The necessary calculations are involved but the techniques and data are available. They can easily be computerized and when available in this form, can provide a valuable tool for the incinerator designer.

For example, when faced with the problem of burning a high sodium content waste, the designer must know the form in which the sodium will leave the unit. The writer was rather astounded recently to learn for a contemplated design, that the majority of the sodium would leave the incinerator furnace as liquid sodium hydroxide. A quick review of the vapor pressure tables for NaOH was reassuring that the computer program had not devised some original thinking.

A second example is shown in Fig. 1. How can one dispose of the oxides of nitrogen? What occurs when a liquid containing 10 per cent nitric acid is burned? These questions are, and have been, debated at length. With the computer, we can explore many fuels at many combustion conditions very readily. The answer is very
simple and has been verified by tests. Regardless of the type or nitrogen content of the waste fuel, the level of NO formation under equilibrium or complete combustion conditions is dependent only on excess air and temperature. NO can be disposed of through incineration. Nitric acid can be decomposed safely.

These two examples are only the beginning of the many questions that must be answered as air pollution restrictions quite properly grow. Better computational facilities and practices are the first step towards better incinerators.

**Equilibrium Combustion**

As better incinerators are required, their combustion characteristics must improve. That is, the products of combustion must approach those predicted by thermodynamic equilibrium data. The old standbys of time, temperature and turbulence as the requirements of good combustion, are only qualitative. They do not provide any quantitative yardsticks to measure how well equilibrium is being approached. It is axiomatic that any combustion process that can approach stoichiometric conditions with complete combustion is a process which approaches thermodynamic equilibrium. We must have incinerator burners of this type. Otherwise our sophisticated calculations will be worthless and our incinerators will perform poorly.

We submit then that burners and furnaces capable of equilibrium combustion conditions are the second requirement of a good incinerator.

**Gas and Liquid Incinerators**

Achieving the factors for attaining combustion equilibrium is often easiest with gas wastes. The fuel need not be vaporized. A gas burner system that can be pretested with natural gas or propane and burn completely with 1 per cent or less excess air can be expected to do well with any waste gas when supplied with higher excess air and when adequate temperatures and residence times are incorporated in the design.

The same criteria of low excess air combustion capability can be successfully applied to liquid waste burners. Demonstration of this capability with No. 6 oil incorporates the additional requirement of good atomization for a liquid burner that is necessary. For waste liquids that are more viscous or that are slurries, additional tests with the actual waste should be made. Some of the new sonic atomizers can do an outstanding job in achieving 40 micron or less droplet size combined with a high resistance to plugage from solids.

For a gas or liquid waste burner a third requirement for good incineration is the ability to approach stoichiometric conditions with conventional fuels. The degree of approach without incomplete combustion products can be used to rate burners for performance on unknown wastes.

For liquid waste burners a fourth requirement is the ability to atomize the actual fuel finely. The ability to produce uniform droplets of fine size can be measured and again used to compare atomizers objectively.

**Solid Waste Incinerators**

Intimate mixing of waste fuel and combustion air is not readily achievable with solid waste incinerators be-
cause the fuel usually has a relatively large and discreet particle size. The longer time constants required to achieve temperature equilibrium in solid waste incinera-
tors also makes short test runs at low excess air im-
practical. It does no good to prove that the incinerator is
capable of excellent operation at low excess air if we
melt its walls and render it useless in the process.

The nonuniformity of solid waste fuels and the dif-
ficulty of obtaining continuous feeding devices that work
without excessive power or mechanical maintenance costs
also negate any measurement of meaningful low excess
air performance.

For solid waste incinerators we can, therefore, state
that a requirement of good incineration is demonstrated
performance in a similar unit.

These demonstrations should be intelligent. Professor
Ringelmann's charts may be old, but a dark stack caused
by carbon emission represents something less than op-
timum. Solid particulate emission measurement is meaning-
ful and can lead to intelligent specifications. The small
test unit shown in Fig. 2 is representative of larger open-
pit type incinerators. It allows test burning and sampling
with small quantities of waste at minimum costs.

Two examples of solid waste incinerators that are
novel and completely different will be described. Both
have desirable performance characteristics. Neither is a
panacea. First is the two-stage unit developed by
Gordon Hoskinson, which is shown in Fig. 3. It can
excel in burning cellulose wastes without smoke or
particulate emission. Its unique feature is controlled incomplete combustion in the large chamber. Since burning is without agitation (either mechanical or aerodynamic), only gases leave the primary chamber. Temperatures are kept acceptably low during the periods of incomplete combustion, although they may become excessive during charge burnout. The fuel-rich gases are mixed with air and ignited in the stack by a pilot burner. This two-stage unit has been criticized for its low capacity per unit furnace volume since the combustion rate is reduced by the lack of turbulence. This criticism is not valid if performance when burning general trash is the criterion. However, its performance of many noncellulose products such as synthetic fibers or plastics, leaves something to be desired.

An entirely different concept is the open-pit incinerator that has been developed within the author's company for its own use. No proprietary interest has been taken and outside interest has resulted in hundreds of descriptive bulletins being distributed. Since it was first described in public (1), a number of improvements have developed.

The basic unit is shown in Fig. 4. This unit has two novel features. The omission of the incinerator top permits radiation of the flame to the sky. This provides the necessary heat loss to limit the maximum attainable temperature to values that will make damage to refractories negligible. Open-end units have not yet been successfully operated, and the ends are closed. The high velocity air nozzles supply all air from their overfire position, and produce maximum turbulence and recirculation of the combustion gases. The air nozzles should be located as shown in Fig. 5. A single air manifold and row of air nozzles has been found most effective when aimed at a 30 degree angle from the horizontal.

Published nozzle penetration data have also been found to be erroneous for larger size nozzles. The actual penetration of a 5 inch nozzle was found to be only 25 per cent of that indicated. For the 8 ft width shown in Fig. 4, the nozzles can be spaced every 6 in. with alternate 2 and 3 in. pipe sizes. Recommended air pressures are shown in Fig. 5.

The overfire high velocity jets have also been applied to units with roofs with success, but the rate of firing must be more carefully controlled.

For solids with high calorific values and solids that tend to melt, such as waxes, nylon or polyethylenes, its combustion rate and performance are high. If the waste
tends to become airborne, the emission of solid matter may become objectionable and a mesh screen must be installed to prevent carryover. Steel mesh of No. 2 size has been found to give good service. The unit shown in Fig. 2 demonstrated that stacks were feasible and one unit is under construction abroad with a 40 ft stack.

No thermal damage has occurred in several years of operation, but severe mechanical damage has. This mechanical damage has occurred from heavy rolls of material being dropped against the walls or careless use of unloading equipment. For this reason, newer units have heavier walls that are secured with metal tie rods. It has also been found necessary to use some structural steel for dimension stability on early units that had free standing walls.

Conclusions

For improved industrial incinerators the following new developments offer steps toward better design and performance.

1. More sophisticated calculation facilities and more reliable thermodynamic equilibrium data are available, and their use in design calculations is the first step toward improved incineration.

2. Good incinerators should have good combustion characteristics that operate at or near equilibrium conditions.

3. Gas and liquid waste incinerators can be evaluated by their performance at or near stoichiometric conditions.

4. Liquid waste incinerators require good atomizers and the new sonic types offer improved performance with some wastes.

5. Solid waste incinerators must be evaluated individually. Small test models may be used but each waste must be carefully evaluated.

6. Two novel incinerators have recently been developed, which are of widely different characteristics that perform well in specified areas. Neither has all the advantages of the other.

References