Abstract

The configuration of the furnace is influenced by the type of grates and size of unit to be installed. For small capacity a circular or rectangular batch feed furnace may be used. For capacities of 50 tons per day and over, the tendency is toward the use of continuous feed grates with a rectangular furnace. Types of grates include the traveling, reciprocating and rocking grates. Sometimes a rotary kiln is used as a second stage burner. Factors determining the size of a furnace include burning rate per unit of grate area, heat content of the fuel, operating temperatures, and gas velocities. The character of the fuel calls for attention to facilities for charging and moving the material. Coarse material or rubbish presents problems in charging. Several types of furnace design are described and shown.

Introduction

The purpose of this paper is to present a cross-section of the status of design of municipal incinerator furnaces. The configuration of the various types has been developed to accommodate certain kinds of grates. The design has been dictated to a large degree by the requirements of the grate manufacturers for suitable working space for their particular equipment. The type of grate chosen governs the general configuration of the furnace, which in turn often influences the size and shape of the enclosing building.

The well established types of incinerator furnaces are illustrated in the following paper. Comments are made as to their suitability for plants of large or small capacity as well as their relative efficiency and labor-saving features. New designs which are in limited use or are about to be put on the market also are discussed. The coverage includes the burning of building demolition wastes, commercial and industrial refuse, as well as the usual domestic rubbish and garbage.

For the purpose of this discussion, it will be considered that an incinerator furnace is made up of a charging hopper or opening, an ignition chamber, a device for removing the ashes and residue, and a secondary combustion chamber. The expansion chamber, fly ash subsidence area, the tall chimney or induced draft with stub chimney are omitted from further discussion because these sections of the incinerator enclosure are common to the various types of incinerator furnaces. These various features are identified on the illustrations of the various types of furnaces, Fig. 1 to 9 inclusive.

Choice of Furnace Types

Most of the present day municipal incinerators employ the storage pit, bridge crane and grab bucket for the charging of refuse into the furnaces. The major distinction between types of furnaces is that some are batch fed and others employ a continuous feed [1].

Batch-Fed Furnaces. The batch-fed furnaces are usually those not exceeding 64 tons per hr (150 tons per day) capacity. These employ a hydraulically or elec-
tric motor driven charging gate positioned over the roof of the furnace and are further divided, usually into circular grate or rectangular grate furnaces. End-of-Furnace charging is used in some industrial and municipal rectangular grate furnaces.

The circular grate furnace configuration is shown on Fig. 1. The refuse is dropped when the charging gate is opened and piles up over the rotating cone with its extended rabble arms. The cone provides for the admission of a portion of combustion air, and as the cone and arms slowly rotate, the fuel bed is agitated. The ash dumping gates are located at the periphery of the stationary circular grate. Considerable manual stoking as well as frequent attention is required in addition to the agitation provided by the rotating cone. Stoking doors are provided in these furnaces.

The rectangular grate furnace configuration with roof charge is shown on Fig. 2. The refuse is discharged onto the grate through a charging gate and vertical chute as in the aforementioned circular grate furnace. The fuel bed is agitated by means of hydraulically actuated rocking grates which lift as much as 9-in. The banks of grates are operated alternately and the burning refuse is gradually moved down from near the bridge wall to the ash dumping gates located near the stoking doors. A similar arrangement is sometimes used with reciprocating grates.

A rectangular grate furnace configuration, utilizing end furnace charge by means of a mechanically or hydraulically operated ram, is shown on Fig. 3. The refuse is discharged on to the ends of the grates through a guillotine door whose action may be synchronized with the ram stroke. The conveying action of the reciprocating grates pushes the fuel bed in a cascading flow toward the discharge end. The speed of the continuously reciprocating grates can be adjusted, as well as the stroke length, to suit any change in the character of the refuse.

Considerable manual stoking as well as frequent attention is required on most batch-fed furnaces. On these batch fed types of furnaces overfire air is furnished through small doors or openings near the roof of the ignition chamber over the stoking doors. A secondary combustion chamber, usually with at least twice the volume of the ignition chamber, is provided with the batch-fed furnaces.

The opening of the charging gate in the furnace roof at frequent intervals permitting the inrush of room air has, of course, a very bad effect on the combustion process. The uncontrolled inrush of cold air upsets the combustion balance and furnishes a severe thermal shock to the refractories. The abrasive effect of irregularly shaped hard objects and metals in the refuse often damages the refractory lined openings. The size of the roof charging gates is limited by these and other
considerations usually to not more than 3 ft by 4 ft. This limited opening on occasion makes it necessary to manually push some of the rubbish through.

The continuous feed furnace is not used in small plants primarily because of the difficulty in maintaining a continuous supply of refuse to be burned. If we consider an incinerator for a municipality with a population of 20,000 persons or less, we usually expect a loading of less than 25 tons per day. The common solution is a hatch-fed incinerator consisting of two 50 ton per day furnaces operating on a single shift, 5-day per week basis. Obviously it would be quite difficult to keep a gateless charging hopper filled at all times during such an operation.

Continuous Feed Furnaces. On the incinerators handling above 50 tons of refuse per day, there is an increasing tendency to use furnaces of the continuous feed type. The improvements in refractories and in the furnace equipment are making it possible in many cases to depend on single unit installation. A single 200 ton per day continuous feed furnace operating on a single shift per day basis could efficiently handle the aforementioned loading. This is considered by many to be the minimum practical size for a continuous feed type of furnace, although smaller ones have been built.

Types of continuous feed furnaces are the traveling grate, the reciprocating grate plus rotary kiln type and the continuous or constant flow types using sections of reciprocating or rocking grates with vertical offsets between sections.

Fig. 4 shows the traveling grate type. These are generally of 250 ton or 300 ton per day capacity and the corresponding grate widths are 8 ft or 10 ft. The charging hopper can be the same width as the grate with the other horizontal dimension 4 ft to 6 ft. The chute from the charging hopper to the roof of the furnace is usually about 15 ft in height. This is kept filled with refuse and acts as an effective draft seal.

Fig. 6 shows a continuous feed type of furnace using rocking grates. This is one of the most recent developments. The refuse is carried away from the charging hopper by means of the rocking grates set on an inclined plane. A small drop is provided at the end of the first 2 sections to break up and mix the refuse.

The inclined ignition or traveling grate takes the refuse away from the charging hopper. The radiant heat from the furnace walls causes a rapid ignition of the wastes. The burning material cascades off the end of this first grate onto the horizontal traveling or burning grate which, operating at a faster speed, transports the material towards the ash dump. The speed of the grates is regulated so as to have as complete a burnout of the material as practicable before reaching the residue disposal trough.

Provisions are made for stoking in this type of furnace, although less stoking is required than with batch fed furnaces. Air is supplied through the burning grate and through the furnace walls and roof.

The so-called rotary kiln incinerator is shown on Fig. 5. This is usually a two-stage process consisting of ignition and burning grates utilizing reciprocating grates or rocking grates followed by a rotary kiln. A portion of the hot gases from the ignition chamber rises and passes over the wet garbage and refuse, and then is conducted to the combustion chamber by a separate by-pass duct over the rotary kiln. The rotary kiln makes a complete revolution in three to five minutes, depending upon the characteristics of the material being burned.

No provisions for stoking are provided on the rotary kiln type of furnaces and none is required. A door is provided at the ash removal section to remove any objects which are too large to dump into the ash conveyors.
Incinerator plants are commonly rated on their burning capacity in tons per 24 hr. Thus we speak of 100 ton or 600 ton incinerators. Furnaces also are generally rated in the same manner, but there is a growing tendency to consider them by their hourly rating. A 600 ton incinerator plant might consist of four 150 ton batch fed furnaces, or more likely in a new plant two 300 ton continuous feed furnaces. These furnaces would each be rated at 6-1/4 tons/hr and 12-1/2 tons/hr, respectively.
The size of the ignition chamber in projected plan is dependent upon the burning rate assigned to the particular type of grate used. A check of operation at many municipal incinerator plants a few years ago by a committee of the American Public Works Association revealed that the average burning rate of incinerator grates was about 55 lb of refuse per sq ft/hr. Manufacturers' ratings are generally well above this figure. However, on the APWA rating, a 6-1/4 ton/hr (12,500 lb/hr) furnace would require a grate area of about 228 sq ft.

The dimensions of length, height, and width are usually related to the type of grate used. The total volume of the ignition chamber and combustion chamber is based upon the heating value of the refuse being burned. Rubbish and garbage mixtures as delivered for incineration usually will have heating values ranging from 2500 to 7500 Btu per lb. If we were to assume an average of 5000 Btu per lb, then the heat release in the aforementioned furnace would be 12,500 x 5000 or 62,500,000 Btu per hr, or \( \frac{62,500,000}{228} \approx 275,000 \) Btu per hr per sq ft of grate. Some early designs have provided about 1 cu ft of volume per 12,500 Btu per hr of heat release. On this basis a 6-1/4 ton/hr furnace would require a total of 5000 cu ft of volume in the ignition and combustion chambers. Recently some designers have recommended liberation rates of 20,000 and more Btu per hr per cu ft of furnace volume. There has been no uniform basis of proportioning this volume between the two chambers. The volume of the combustion chamber may be up to 2.5 times that of the ignition chamber, or it may be omitted entirely and the ignition chamber provided with sufficient volume to accommodate the secondary combustion process.

The urge to simplify and to combine the ignition and combustion chambers has been given a strong impetus by the high cost of furnace enclosures. It is not unusual for the costs associated with the refractory walls to run as high as $15.00 per sq ft of enclosed surface area.

It may be well to point out to those uninstructed in combustion processes that the burning pile of refuse enveloped in flames represents only about 35 per cent of the total reduction of the organic matter in the refuse. The volatilized gases rising from the fuel bed possess the remaining 65 per cent of combustible matter. These gases must be mixed with sufficient air at a high enough temperature and over a necessary time interval to permit this combustion to be completed before the flue gases are vented through the chimney to the atmosphere.

The provision of extra volume in the ignition chamber is of little value if the burning gases are permitted to stream directly over the bridge wall into the expansion chamber and fly ash scrubbers. High pressure and low pressure overfire air jets and baffles are used in some of the new furnaces to impart a roll or spin to the burning gases, causing them to remain in the chamber for a longer time interval.

The criteria furnished in the foregoing paragraphs are for the basis of providing a yardstick or sense of magnitude to the following discussion. Actual designs are based upon detailed thermodynamic calculations of heat and mass balances, air volumes, directions and velocities and on permissible operating temperatures. These subjects have been covered excellently by others. [3], [4].

**Charging of Refuse into Furnaces**

Important items which should be kept in mind when considering furnace design are the relative lightness and other characteristics of the refuse being burned, as compared with other fuels. Consider the problem of charging and moving through the furnace the ordinary mixture of corrugated paper, boxes, tin cans, and garbage which often runs 7 cu yd to the ton. In addition the refuse is difficult to move. It will not flow around corners. It has a most uncertain angle of repose and often stands at a considerable height in an unsupported wall.

For these reasons it has been found necessary to place the material directly onto the grates by dropping through vertical chutes or by pushing the refuse into the end of the furnace through a water cooled guillotine door using a dozer or a hydraulically operated ram. This latter method of end charging is not used as commonly as the method of roof charging.

The almost universal method of using a storage pit, bridge crane and vertical charging chute for municipal refuse incinerators is one of the most discussed and severely criticized in the present state of the art. Everyone agrees that there should be a better way, but no one has come forward up to this time with a more acceptable method. Interesting variations are the use of impulse conveyors and hydraulic rams for end of furnace charging at the municipal incinerator at Whitmarsh Township in Pennsylvania, and the use of a floor dump hopper and guillotine door at Winchester, Kentucky and at three new plants in Florida.

Fig. 9 illustrates a 150 ton per day furnace of novel configuration. One plant now in operation and two under construction in Florida each have two 150 ton per day furnaces of this design. As shown in the illustration, the primary furnace area over the grates is rather large and...
features a small reflective arch opening above the feed opening and a long tapering sloped roof toward the rear. A secondary combustion zone which also acts as a settling chamber adjoins the primary furnace. A two level reciprocating grate is used and a continuous drag conveyor running lengthwise of the furnace collects grate siftings, grate residue and fly ash from the elevated gas scrubber.

Several basic design criteria beyond those normally considered have been considered in this design. First is the desire to charge the furnace directly from the refuse truck as well as by overhead crane. The ram feeder assembly has 30 cu yd storage capacity. Second, the high proportion of yard trash in the refuse and its widely varying moisture content indicated the need for maximum combustion of the volatiles in the primary furnace area and a means of making this heat directly available to the refuse charge. The large furnace volume provided was to permit substantially complete combustion and the reflective arches to aid in ignition and burnout of the refuse. Controlled overfire air jets are installed to provide additional turbulence and limit the furnace temperature build-up with dry refuse.

The secondary chamber is arranged for low velocity, vertical travel of the gas to allow the heavier fly ash to drop out at this point. The reversal of the gas flow in this chamber is also deemed beneficial in this regard.

The problem of charging building demolition wastes into an incinerator has not been met successfully. The buildings are knocked down by a clamshell bucket sent crashing through the roof. The twisted timbers and debris are then loaded into huge trailer trucks. The result is a 30 ft long, 7 ft wide and 7 ft high package of large and small timbers as well as assorted debris. Labor costs of separating and cutting this material up so as to pass it through the usual incinerator hopper have been so high as to make the operation impracticable. Some attempts have been made to charge this material through a large guillotine door at the end of the furnace.

Further description of charging arrangements are furnished in the preceding descriptions of furnaces as identified by the type of grate used. The burning rate of heavy timbers requires a much greater retention time in the furnace than other debris. This further complicates the problem. Many designers are working in this field and it is the hope a satisfactory solution will be forthcoming soon.

Recent Developments

There have been several interesting recent developments in design of incinerator furnaces both in this country and abroad. The Europeans have been concerned primarily with more efficient steam generation from the waste heat, including the use of supplementary fuels. They also have introduced an interesting series of rotary grates and have developed several different furnace configurations. [5-7].

Some interesting recent developments in this country have been:

1) The design of a continuous feed furnace housed in a longitudinal steel cylinder with a thin refractory lining but utilizing the incoming combustion air for cooling the exterior of the furnace walls. This is similar to furnaces used in the chemical industry. No prototype has been constructed at this time.

2) A specially constructed incinerator for the burning of demolition materials at a Philadelphia salvage yard. The furnace utilizes a single traveling grate and a guillotine gate for end charge. The novel arrangement of air jets for rotating the burning gases and air jets and water sprays for removal of fly ash from flue gases as well as the very short stack without resorting to induced draft fans make this a most interesting plant.

3) The design of a rotary kiln incinerator without the use of ignition and burning chambers but utilizing the kiln itself as a single unit furnace. The combustion air is supplied through wind boxes encompassing the rotary kiln supports. No plant has been constructed using this equipment.

References


