Considerations in the Construction of Large Refuse Incinerators

F. NOWAK
Technische Werke der Stadt Stuttgart
Stuttgart, Federal Republic of Germany

METHODS OF REFUSE DISPOSAL

For industrial nations and especially for congested areas such as large cities and districts as the "Ruhrgebiet," refuse becomes an increasingly serious problem for municipal politicians. Unplanned dumping, the method of refuse disposal practiced for centuries, is still employed. However, unplanned dumping systems are slowly being changed to planned dumping systems, first to save space and second to prevent unnecessary pollution of the ground water. At the same time, there are composting installations where fermentable substances contained in the refuse are being converted into a form acceptable for use in agriculture. This, of course, means that an adequate demand for the compost exists locally.

Burning of refuse has also been practiced for decades in order to reduce its volume considerably and, above all, to enable the dumping of residue as a harmless ash without danger to water and the atmosphere. A reduction to 10 to 15 percent of the initial unpressed volume of refuse prolongs the availability of the dumping sites. Associated with burning is the danger of air pollution in the neighborhood. This problem does not exist in dumping and composting operations. Therefore, incinerator plant operators are obliged to filter or to wash the dust-laden exhaust gases in order to comply with regulations concerning the maximum level of atmospheric pollution. In West Germany, 150 mg/m³ of dust is permitted in the cleaned gas. It is not easy to meet this requirement since we are concerned with fuels having an ash content of up to 60 percent.

During the washing process, large quantities of mechanically and chemically polluted water are inevitably produced that, in this condition, may not be discharged into the sewerage system. The required quantities of water are very large. Only large chemical concerns use the washing process in order to bond the hydrochloric acid resulting from the combustion of large quantities of PVC (polyvinyl chloride). The wet and aggressive drain discharge has a very strong corrosive effect on the flue gas ducts and the chimney. Water particles carried over can be dangerous to vegetation in the neighborhood near the combustion site.

For dry filtering of the dust, methods can be used that are customary with conventional boilers burning coal, for example, mechanical or electrical filters. However, a prerequisite for the use of these filters is that the gas temperatures are sufficiently reduced to prevent thermal damage. Temperatures of 900 to 1100°C occur during combustion, but in the filters the temperatures cannot exceed 300°C to prevent damage to the filter and for optimum dust removal. The necessary cooling can be achieved by three different methods. The first cooling method utilizes water sprays, resulting side effects of which have been described previously. The second way is by mixing with cold air, which is injected into the flue gas by means of fans. It is easy to see that a much greater quantity of air than of flue gas is required, and, therefore, very large fans are necessary. These fans consume a considerable amount of power and generate an unpleasant noise level. Therefore,
in Western Europe a third method has been adopted to reduce the gas temperature to the desired level. The heat is utilized for steam generation using an associated boiler as a heat exchanger. Although our primary concern is the proper incineration of the solid wastes, if the heat contained in the refuse can be put to beneficial use, we have achieved a fringe benefit. Sale of this recovered heat can result in a considerable reduction in the operating cost of the overall plant.

However, this method of disposal of refuse also has its special problems. The flue gases mixed with dust must pass the heating surfaces in order to transfer their heat. According to experience, approximately 90 percent of the ash content melts into clinker on the combustion grates, while the remainder is carried by the flue gases through the boiler passes. Because of the heterogeneous composition of refuse, the remaining ash consists of various substances that influence each other chemically. Therefore, contrary to experiences with coal-fired boilers, a completely different melting behavior of the ash particles takes place; they maintain their stickiness and sinter at temperatures as low as 300°C, thereby fouling the heating surfaces very quickly. One of the effects of this fouling at the primary superheater tubes can be seen in Fig. 1. Cleaning is rather difficult because the deposits sometimes stick very hard.

Another extremely disagreeable problem is the corrosion at various tube areas, which is caused by aggressive flue gas and dust. The designers and operators of refuse incinerators producing steam must take these difficulties into consideration and must look for methods to reduce these effects to an acceptable level in order to make the operating time as long as possible and to keep the operating cost within acceptable limits. The term “boiler availability,” well known in boiler design, is also used for these incineration plants. Thus, refuse-fired boiler availability is between 60 and 80 percent according to load and type and depends especially on the circumstances previously described.

What are the possible ways to reduce these sources of danger? First, the manufacturer should endeavor to arrange the heat-recovery surfaces with wide, in-line tube spacings to ensure effective cleaning. Spacings of 180 mm and more are common. The choice of a lower flue-gas velocity in the combustion chamber also has some influence in preventing large quantities of dust particles being carried over. Whereas formerly velocities of 6 m/sec for the rising gases were considered proper, they have been reduced to 3.5 m/sec in the new units. Therefore, with the same grate sizes, combustion chambers become wider, which can be seen in Figs. 2 and 3, for boilers with the same refuse throughput capacity of 20 t/h. Since fouling cannot be completely avoided, sufficient cleaning provisions must be considered. Until now, soot blowers or vibrators have been most suitable for this purpose.

The layout of the heating surfaces must be designed in such a way that flue-gas temperatures of approximately 350°C in front of the air heater are not exceeded. Experience has shown that fly ash at this temperature becomes sticky and has a tendency to build up. The narrow tube passages in the air heater lead to undesirable fouling of the tubes and make cleaning very difficult.

**CORROSION AND PREVENTATIVE MEASURES**

Corrosion causes similar difficulties on the heating surfaces. This corrosion occurs especially in the combustion chamber, but metal wastage can still be observed at the primary superheater tubes. There are a number of causes for this metal wastage. It is due partly to the reducing atmosphere in the combustion
Fig. 2 Refuse Furnace with Martin Reverse-Acting Reciprocating Grate for 20 t/h Capacity
chamber, partly to the molten, complex alkali compounds, of which several components have a corroding effect, and partly to oxides and sulfates of the heavy metals such as lead, tin, zinc, barium, etc. Finally, chlorine also has a corroding effect. Chlorine can be found in refuse in the form of chloride, as, for instance, common salt or as contained in PVC.

Tests to restrict the influence of these constituents by use of additives have so far failed. Therefore, the operators must make every effort to keep the sources of danger to a minimum by main-taining optimum firing conditions. This state can be achieved by several different means.

First, it can be effected by a good mixing of the refuse before feeding it into the furnace. The fluctuations in the calorific value — especially if residential and industrial refuse are supplied at the same time — require a regular mixing to prevent formation of areas of refuse with high calorific values next to areas with low calorific values on the grate.

Secondly, it can be achieved by means of the refuse feeder to ensure an even distribution of refuse on the grate. A continuous feed at a constant

**Fig. 3 New Concept of Refuse Furnace with Drum Grate for 20t/h Capacity**
height of refuse on the grate makes consistent burning possible, which is a criterion for preventing stratification of the gases generated during combustion. Moreover, there are grates that are designed for redistribution of refuse after feeding to prevent formation of refuse piles on the grate.

Finally, air control can also be of assistance in that the necessary oxygen must be supplied if refuse is charged in excess of the normal amount. Normally, the operator will not constantly observe the furnace bed but will operate with an air supply that has already been accepted as advantageous, according to the season and the specific character of the refuse.

All these measures can never avoid irregular proportioning of heat availability and air supply. Inevitably, operation will take place with zones having a large or small excess air quantity resulting in formation of gas stratification, which is characterized by high oxygen contents or by the presence of CO. Fig. 4 illustrates the flue-gas composition in the combustion chamber of the unit shown in Fig. 2. Attention is called to the irregular fluctuation of the CO-concentration, which sometimes reaches values of up to 1 percent. The \( \text{SO}_2 \)-concentration of the flue gas, shown in Fig. 4 to range between 300 to 400 mg/m\(^3\), is far below the limiting value of 3 to 4000 mg/m\(^3\) for the Stuttgart area required to meet the maximum ground level concentration of 0.4 mg/m\(^3\), the limit set by the federal government. (There are no officially prescribed maximum-emission values, only maximum-emission concentrations.)

On the heating surfaces near the grates, especially within the range of the flame tips, reduction processes take place that are comparable to the blast-furnace process in which oxide layers on the tube surface are constantly removed by reduction, which goes hand-in-hand with a continuous metal loss. Prior experience has shown that this reduction process is the main reason for corrosion, which is one of the most frequent causes of breakdowns. Plant availability can be reduced considerably by this kind of problem. A tube that has been removed from the combustion chamber, shown in Fig. 5, gives an impression of this corrosive effect. Boiler designers and operators have been considering how to correct the inhomogeneous flue-gas atmosphere resulting from unsatisfactory combustion. There are two different ways to make these corrections.

Fig. 5 Metal Wastage of Evaporator Tube in Combustion Chamber

One way is by selecting a combustion chamber design that enables turbulence to take place following gasification of the refuse so that gas stratification, which creates reducing conditions, is kept to a minimum. Optimum shape factors were determined from model tests carried out by boiler manufacturers. These factors will be applied for the first time in a new plant soon to be erected. The test installations can be seen in Fig. 6. Water was used as a flow medium, because water in relation to air has a similar kinematic viscosity to hot flue gases. To show the flow conditions more clearly, air was injected. This air has nothing to do with the combustion air supplied through the grates or into the combustion chamber. The result of these tests was a
Fig. 6 Model Test for Determination of Optimum Combustion Chamber Configuration

The result is shown in Fig. 7. Instead of excess air quantities of 70 to 80 percent, which have been customary until now, one will have to operate with 100 to 150 percent in the future. Furthermore, approximately 25 percent of the total air will have to be injected as secondary air. An increase in the flue-gas heat losses is inevitably connected with this and must be accepted, because it is more important to maintain trouble-free operation than to have a boiler plant with a high efficiency. The results of the model tests have been applied in the design of the boiler illustrated in Fig. 3.

In spite of the measures described, there will always be zones where combustion is not completed and where the tube material is automatically endangered. The most suitable measures for restricting this danger have proved to be studding and plastic refractory lining of the lower combustion chamber zone. If Sicromal 10 is used, 2,500 studs per m², with a stud length of 16 mm and 10 mm in diameter, are sufficient to hold the refractory lining. Sicromal 10 is a heat-resisting steel that will withstand temperatures up to a maximum of 1050°C and attack by gases containing sulphur. Normally more studs are necessary for boilers with a slag-tap furnace, because of the higher, specific furnace heat capacity. A good material for plastic refractory lining proved to be a mix of clay, chemical binder, and 50 to 80 percent of SiC. These materials are all characterized by good heat conductivity. Since SiC-substances now available on the market are already chemically bonded at ambient temperatures, a sufficient abrasive resistance at the relatively cold tube walls of the refuse furnace chamber is guaranteed. The lining should extend beyond the possible flame tips. The boiler pressure parts must be designed for the reduced heat liberation in the combustion chamber.

Up to now, metallic spraying has not been satisfactory because the surface remains porous and corrosion begins at these holes in the spray coating.

Fig. 7 Model Test for Determination of Secondary (Overfire) Air
Highly corrosion-resistant tube materials have not yet been used because such tubes are too expensive compared to the carbon steel tubes presently used.

Provided that the mentioned constructional aspects are taken into account, the burning of dangerous waste, i.e., waste with a high calorific value, which is sometimes supplied, will be possible. The result of several series of experiments in which synthetic resin was added to the ordinary domestic waste shows that grates are not endangered thermally; temperatures of the grate bars always remain far below the limiting value permissible for the selected material. In Fig. 8, temperatures of the second roller of a VKW grate can be seen. The continuous temperature fluctuations are due to the slow rotation of the grate. Danger exists only for the boiler pressure parts if the mixing of waste components was not satisfactorily carried out or if the heat emission exceeds the value calculated for the boiler. It is possible that the permissible material temperatures will then be exceeded and that the long-time creep strength of steel of the superheater or of the headers will suffer. The component parts of the boiler must be designed to stand up under these possible excess stresses over a short period in order to avoid an over-stressing of the tube material by thermal influences, in addition to the inevitable difficulties due to fouling and corrosion.

CONCLUSIONS

For large municipalities the modern method for waste disposal is incineration. It produces a sterile residue and at the same time reduces the waste volume. In large incinerators the trend is increasingly to utilize the heat produced for steam generation that reduces plant operating cost but with danger of fouling heating surfaces and corrosion. With large flue-gas passages and low gas velocities and by using soot blowers or vibrators, the fouling of heating surfaces can be maintained within acceptable limits.

For proper operation of the furnace it is necessary to have good mixing of the refuse prior to charging, control of the rate of feed of the mixed material into the furnace and to provide proper control and distribution of the combustion air. In order to reduce the likelihood of metal wastage due to the formation of areas of a reducing atmosphere, the waste gases generated in the burning of the refuse have to be thoroughly mixed by the creation of turbulence from the furnace configuration and by the proper use and introduction of overfire air. In the design of a new furnace, the configuration is found by model studies. The endangered zones in the furnace can be protected by lining with plastic refractory.

![Fig. 8 Grate Bar Temperatures on Drum Grate](image-url)