Steam Generation From Incineration

Abstract

This paper cites previous predictions of increased evaporation rates and shows why these are possible to attain. Reasons for current low rates are given. A practical furnace-boiler combination is illustrated to show one means of getting useful steam production from incineration. Points of difference in furnace operation between a refuse-fired unit and a normal power boiler are discussed.

At the annual meeting of the American Society of Mechanical Engineers in December, 1958, Mr. Harold G. Meissner gave an excellent paper entitled, "Heat from Incineration - Available Quantities & Utilization." Many incinerator designers were amazed when he predicted that evaporation can be in the range of 3 to 3½ lb of steam per pound of municipal refuse burned. Of course this will vary depending upon steam conditions and heating value of the refuse.

It is not the intent of this paper to repeat the previous paper, but merely to show why the higher evaporation is possible. It is believed that if engineers realized the energy that is available from refuse incineration, more plants would be equipped with steam-generating equipment. The installation of a boiler in an incinerator plant not only provides energy at a comparatively low fuel cost, but also simplifies problems of air pollution by automatically cooling the products of combustion so that a standard commercial dust collector may be used.

There are relatively few applications in this country of waste-heat boilers to municipal incinerators. These installations have been checked to determine steam production. The steam generated is in the range of 1 to 1.5 lb/lb of refuse burned. It is my opinion that there have not been any well engineered incinerator boilers installed up to the present time. Most of the installations have been with batch feed incinerators. One exception is the plant at Atlanta, Georgia. It was reported at the annual APWA Meeting in September, 1963 that this plant generates an average of 1 lb of steam per lb of refuse burned. This is obviously not a good application of waste-heat boilers to incineration. The Betts Avenue plant of the City of New York has waste-heat boilers applied to continuous feed incinerators. Because of conduits between the furnaces and the boilers, there is a large amount of infiltration. For this reason, high evaporation cannot be expected.

In batch-feed incinerators, gas enters the boiler bank at temperatures varying from 700 F to 1200 F (an average entering temperature of about 1000 F). If it is desired to use the steam for efficient power generation, batch-feed plants are not suitable because it is impossible to generate steam having a relatively constant superheat temperature. Municipal refuse is burned with a minimum of 100 per cent excess air to avoid excessive temperatures in refractory furnaces. In batch-feed plants, there is considerable infiltration from air leakage in the combus-
ion chamber and ductwork leading to the boiler. Also the continuous opening and closing of charging doors makes it impossible to control excess air.

One plant reporting relatively good performance is the Merrick Incinerator at Hempstead, Long Island. This plant reported that they are generating approximately 1.6 lb of steam per lb of refuse burned. Steam is generated at 200 psig and 385 F from feedwater at 180 F. The amount of superheat is so small that the value is negligible.

An attempt was made on three separate days to obtain data on average CO2 and gas temperatures entering the boiler. Because of the frequent opening and closing of charging and access doors, the data obtained is of practically no value. For instance CO2 readings as low as 2.5 per cent were obtained; this indicates over 800 per cent excess air. Instantaneous readings as high as 7.6 per cent CO2 were also obtained. The fact that an experienced test engineer was not able to obtain reliable data points up the desirability of further study of the incineration problem.

Fig. 1 shows a design that has been used for years to burn cellulose fuels such as bagasse, bark, and other paper mills waste. Several boiler manufacturers have had sufficient experience to predict steam output quite accurately. Fig. 2 illustrates a continuous-feed incinerator furnace that has been thoroughly established. Note the relatively constant furnace temperature that may be obtained with this type as shown in Fig. 3. These temperatures give the boiler plant designer a reasonable basis for predicting steam output.

Now suppose we put these two established components together to form a refuse-fired steam generator. We'll use the boiler from Fig. 1 and the furnace from Fig. 2. This gives us a unit illustrated in Fig. 4. It is probable that if this unit is used for power generation, it will be necessary to provide a constant steam output regardless of the heating value of the refuse or refuse delivery (which could be interrupted, because of inclement weather). For this reason, oil or gas burners should be installed in the rear wall for auxiliary firing when refuse is not available.

Note the water walls at the rear of the furnace. This surface is exposed to furnace radiation and will absorb a considerable portion of the heat generated. Calculations to determine the radiant pickup are a standard procedure with boiler designers. These calculations indicate that only 35 per cent excess air is required to maintain a maximum furnace temperature of 2000 F. We have not had experience burning refuse in a water-
cooled furnace and it is possible that the mechanics of burning this fuel will require more than 35 per cent excess air. For this reason, present calculations are based on 65 per cent excess air. This is a conservative figure. Compared to the over 400 per cent excess air which we found in the batch-type incinerator furnace previously mentioned, this results in a material reduction in gas flow. Lower gas flow means less air required, lower draft loss, and less power required for forced- and induced-draft fans. It will be noted that the products of combustion are delivered to the water-wall furnace and boiler at 1600°F to 2000°F with practically no dilution from leakage. Operation with low excess air immediately manifests itself in a considerably improved efficiency due to reduction in dry-gas loss.

Fig. 5 is based on the assumption that steam is required at 250 psi and 500°F total steam temperature from feedwater at 212°F. This is also based on burning municipal refuse having a heating value on an “as air fired” basis of 5000 Btu per lb. Since it is common practice to rate incinerators in terms of burning capacities per 24 hours, these curves were prepared to show directly the steaming capacity per 24 hours. Only a small calculation is required to obtain steam generated
per pound of refuse burned. It will be noted that Curve A reflects steam that can be generated in a modern incinerator-fired boiler with a furnace temperature of 1800°F, and that Curve B represents steam generated from a batch-feed furnace with 1000°F entering the boiler bank. 65 per cent excess air was used in preparation of Curve A and 400 per cent excess air for Curve B. It is interesting to note that 2.7 lb of steam can be generated per lb of refuse burned in the modern plant, but that only 1.55 lb of steam can be generated per lb of refuse in the batch method of firing. The difference in steaming capacities illustrated by these curves may be shocking to some engineers whose experience is closely associated with refuse incineration. However, it is believed that these calculations will be readily accepted by the experienced boiler designer.

Of course, the amount of steam generated per pound of refuse burned will vary with feedwater temperature, steam pressure and temperature, and heating value of the refuse. It is believed that 450 psi and 725°F is about the maximum pressure and temperature that should be considered for the fuel under discussion. As the steam temperatures increase, it will become necessary to install excessively large superheater surfaces. These may be impractical from a physical as well as an economic viewpoint, to insure constant design steam temperature under adverse conditions. This will require desuperheating when the furnace conditions are good.

Because of heavy dust loading and nature of the dust, it can be much more difficult to clean the fire side of tubes than in normal firing. For this reason, tubes should be arranged to facilitate cleaning; retractable soot blowers are recommended. Also, it is recommended that openings be provided so that the boiler may be handled if necessary.

Fig. 6 illustrates the Oceanside plant now under construction in Hempstead, New York. This plant follows the pattern illustrated in Fig. 4. It was decided by the consulting engineer that the expense of water walls at the rear of the furnace was not justified. The boiler is of the controlled circulation design. This type was selected because of the difficulty that has been experienced
in cleaning the fire side of tubes. A controlled circulation boiler can be cleaned more readily than a natural circulation boiler. Tubes in the two lower banks are arranged in platen. Tubes are 2-in. diameter on 6-in. transverse centers. The two upper tube banks have 2½-in. diameter tubes on 3-in. transverse centers and 2½-in. vertical centers. It is estimated that gas temperature be reduced to 1180°F when leaving the platen section. Slagging of tube surfaces is not expected at that temperature.

Although this paper has considered only municipal incineration, it should be pointed out that there is a serious refuse disposal problem in many large industrial plants, most of which require steam for various uses. It is suggested that consideration be given to the installation of incinerator-fired boilers adjacent to boiler plants to provide the maximum amount of low cost steam.

A great deal of useful energy is going up municipal incinerator stacks. The decision regarding steam generation should be evaluated by the consulting engineer based on sound economic studies. In the past, most municipal incinerators have been located in sparsely populated areas where there was very little possibility of using the steam. It is believed that as consulting engineers become familiar with the available steam potential that can be obtained with modern incinerating equipment, more plants will be so located that the steam produced may be more easily utilized.