Introduction

The utilization of the heat energy released by the incineration of refuse is attracting increasing attention, since the energy is produced as a byproduct of another process. This paper presents a summary of the experience obtained in the operation of a municipal refuse incinerator with waste heat recovery and utilization, as a case study. Some of the items discussed are specifically related to this plant, while others are related to the process and therefore have general application.

Description of Plant

The Merrick Incinerator was built by the Town of Hempstead in the years 1950 to 1952, and was placed in service in August, 1952. One of the conditions imposed upon the use of the site was the prohibition of a tall stack.

The plant was designed by the late Henry W. Taylor to incinerate 600 tons of refuse per day, with three-shift operation. The incineration equipment consists of two groups each of 300 tons per day capacity, with each group composed of two circular furnaces discharging to a common combustion chamber, a single pass boiler, multi-cyclone type fly ash arrester, induced draft fan, and stub stack. The initial design was based upon refuse composed of 30 per cent combustible material, 20 per cent non-combustible, and 50 per cent moisture.

The initial plant design included the following major units:

Refuse Storage Pits - Two 950 cubic yards (approximately 160 tons) each
Traveling Cranes - Two 5 tons capacity with 2½ cubic yards refuse grapples
Furnaces - Four 15-foot inside diameter, batch feed, nominal capacity 150 tons per day each
Combustion Chambers - Two 5946 cubic feet each
Boilers - Two 57,800 pounds saturated steam per hour at 250 psig
Fly Ash Arresters - Two multi-cyclone with 143-9 inch tubes each
Induced Draft Fans - Two 100,000 cfm at 700 F. each
Stacks - Two 5 foot-diameter to 12 feet above roof
Residue Conveyors - Two collecting conveyors under each furnace group, and two sloping conveyors to elevated residue hopper
Turbine Generators - Two 1,000 kva, 440 volts, each
Diesel Generator - One 279 kva, 440 volts
Pressure Condensers - Two 60,000 pounds per hour

The general arrangement is shown in Fig. 1.

The plant was designed to be operated on a self-sufficient basis with no connection to any external source of electric power. Sufficient refuse storage was provided so that at least one of the two boilers would be in operation at all times with power continuously available from the waste heat utilization system. The diesel-generator unit was of sufficient capacity to provide power to start up one of the two incinerator groups, providing care was
exercised to avoid simultaneous starting of large motors. The startup of the second group was normally withheld until waste-heat generated power was available from a steam turbine generator.

During the initial years of operation, each group would be shut down on alternate weekends for maintenance and inspection, with plant power during such periods maintained by the other group.

At the time the plant was being designed, it was hoped that the power generated from the waste heat could be sold to a nearby commercial user, but this hope was not realized. Accordingly, steam not required for plant power generation was condensed in saltwater cooled pressure condensers with the condensate returned as boiler feedwater. Cooling water was wasted, except for incidental uses within the plant.

**Plant Modifications**

In the past six years, the plant was modified in several respects, as follows:

- a) Refractory replaced in furnaces, combustion chambers, and boilers with suspended walls in combustion chambers;
- b) Fly Ash flushing system installed in combustion chambers;
- c) Refuse storage capacity increased by 1700 cubic yards (300 tons approximately);
- d) Over-fire air inlets installed;
- e) Fly ash arrestor replaced with units of greater capacity;
- f) Boilers completely retubed;
- g) Induced draft fans replaced with units of greater capacity;
- h) Gas turbine generator set installed;
- i) Pressure condensers replaced;
- j) Main electrical installation modified; and
- k) Retractable soot blowers installed in place of stationary blowers.

The modifications also included other minor revisions which did not affect the heat utilization processes significantly.

The modifications listed were precipitated by an increase in the heat content of the refuse over that used in the design. The increased heat content of the refuse raised temperatures above those for which the various units were designed, and the equipment was modified to suit the changed conditions. The retubing of the boilers was necessitated by tube failure due to other causes.

The introduction of over-fire air increased the total volume of gases, requiring higher volumetric capacity in the fly ash arresters and induced draft fans.

The plant is presently operated continuously, since routine maintenance may be accomplished under normal operating conditions. Major maintenance requires shutdown of the equipment group involved, and each such shutdown is accompanied by general inspection and preventive maintenance procedures. The increased storage volume permits operation of both equipment groups over a typical weekend, and permits the burning operation to proceed at a reasonably constant rate.

In the program of improvements to the Merrick plant it was found necessary to increase the capacity of the standby power generating equipment for several reasons. The original diesel standby was of limited capacity, such that only half of the plant could be started using that power. The plant improvements increased the total power load by installing induced draft fans of greater capacity, enlarging the primary air fans, and installing additional ventilation and a number of minor additions.

With the larger power load the situation in case of failure of a steam turbine under full plant operation became more critical. In addition, the standby generators may be used to supplement the steam turbine generators when steam production is low.

The Refuse Disposal Plant is presently supplying electric power to a Town park adjacent to the Plant buildings and to the Department of Sanitation offices and garage on the plant site.

**Waste Heat Utilization**

The effective utilization of waste heat requires the ability to meet the demand of the customer or a use for the heat such that the heat can be used as produced. This second condition is sometimes met when an incinerator is located adjacent to municipal buildings or...
plants using steam or power.

With the varying quantity and widely varying characteristics of the fuel burned at an incinerator, the first requirement means that the base demand to be met must be considerably below the maximum rate of production. Much of the heat produced must therefore be wasted.

A 600-ton per day capacity incinerator releases large quantities of heat energy, and some means of disposing of the energy which cannot be used should be included in the design. At the Merrick Plant, excess heat is dissipated by condensing unused steam in pressure condensers. The steam system is designed to discharge excess steam to the condensers automatically, so that variations in steam production and use do not affect the utilization equipment. A heat-sink device of some type will generally be required in any design which produces heat energy without dependence upon the demand for it, and the heat-sink device for an incinerator should be capable of disposing of all the heat energy produced. The Merrick Plant now utilizes some 30 per cent of the available waste-heat energy for operation of the plant and adjacent applications, with the remaining heat energy dissipated in the steam condensing system.

For effective waste heat utilization, a high degree of reliability should be built into the system. In general, system reliability is enhanced by the use of duplicate units for all critical functions. The duplicate units may be either full or partial capacity. For extremely critical functions full capacity standby units are desirable. For other critical functions standby units at partial capacity may be satisfactory. The degree of reliability required is primarily dependent upon local conditions and should be determined as part of the design. At the Merrick Plant each of the two major equipment groups may be operated independently; in addition, either steam turbine generator may operate independently to provide sufficient power to operate the entire plant. Auxiliary equipment such as cooling water pumps are provided with full-capacity standby. Standby capacity is not provided for certain elements, however; the cooling water intake pipeline, for example, is a single line and its failure would cause shutdown of the entire plant. The original main power distribution panel was set up with a single bus system fed by all generating units, but this panel was modified at the time the gas turbine generator set was installed to minimize maintenance problems. In general, the smaller items of equipment may be duplicated at full capacity without excessive cost or difficulty; but the larger items cannot normally be duplicated at full capacity without eliminating the economies waste heat utilization is intended to achieve.

The pursuit of reliability in a plant of this type must be extended to many minor functions. Proper operation of the plant depends upon proper operation of a large number of elements, and the failure of any element will interfere with or require shutdown of the process. The failure of a small and apparently insignificant element may produce results which are entirely out of proportion to the cause, unless the system has been carefully designed to eliminate such possibilities.

It is difficult to utilize municipal incinerator produced waste heat efficiently due to the characteristics of the process. Normally incinerators are designed to burn refuse at a rate related to the rate at which it is received. At Merrick, the large refuse storage capacity permits the rate of burning to be relatively constant and independent of daily delivery rates, so that in this case waste heat production may be maintained at a reasonably uniform level for extended periods. Assuming that the available waste heat could be delivered continuously at a uniform rate, optimum efficiency could be achieved if it could be used continuously at the same rate. This type of operation, however, may be difficult to achieve in small plants.

The variation in heat content of the refuse from day to day also operates to reduce the available efficiency, since the actual utilization would normally be limited to the heat produced under less than optimum conditions. The additional heat produced on an optimum day would be difficult to use efficiently, and would normally be dissipated in some manner. This limitation of efficiency is to some extent inherent in any heat producing system using a variable heat content fuel.

The Merrick plant was initially designed for refuse with a lower heat content than that now being burned, and major components were designed for those conditions. The subsequent modifications were directed to permit the plant to burn the design quantities of present refuse having a higher heat content, with minimum revisions to the plant. Accordingly, temperatures were controlled and heat dissipated by increasing the excess air quantities above those normally used, allowing continued use of the furnaces, combustion chambers, and boilers originally installed. Thus a comparison of the steam produced per pound of refuse burned at Merrick with a plant designed for a specific fuel will only demonstrate that the excess air reduces steaming efficiency, as it was intended to do. In this case, improvement in steaming efficiency would either reduce the incineration capacity or require an increase in boiler and condenser capacity, neither of which is presently desirable. In the event the energy now wasted in this manner could be utilized, improvements in steaming efficiency would be economically justifiable.

Another factor which tends to limit the efficiency of incinerator produced waste heat is the fact that to date the refuse incinerator is an isolated producer sensitive to each of several varying conditions. Such a plant would be far more efficient as one element in a system, with the fluctuations in energy demand absorbed by the other elements; in this manner, the incinerator could be ef-
ficiently operated as an energy producer with minimum limitation on refuse disposal operations.

The objective of incinerator waste-heat utilization is to secure an economic benefit from energy which would otherwise be wasted. The above discussion is predicated upon the general conditions affecting the Merrick plant, in which there is no provision for storage of the energy produced. If this energy could be used to produce a salable product, the product itself could be stored, and the energy used at a high level of efficiency. One such product is fresh water, which may be produced from seawater in reasonable quantities by means of evaporation equipment. While it is desirable to draw upon previous experience in steam and power installations, incinerator waste-heat applications should not be limited solely to processes based on the use of purchased fuel. The availability of inexpensive energy allows greater latitude in its application, which should be exploited.

It should be understood that the Merrick plant was designed for a specific purpose and to suit specific conditions. The method of waste-heat utilization best fitting those conditions was the production and use of steam-generated electric power, and the plant itself was a logical user of this power. Thus the plant is totally self-sufficient for all electrical power requirements, requiring a high degree of reliability. There are other methods of utilizing waste heat, and the controlling conditions may differ from those which operate at Merrick. The operating experience at Merrick demonstrates the value of a thorough analysis of the specific requirements of the process and the objectives of the design in order to insure a satisfactory installation.