INFLUENCE OF OPERATIONAL PARAMETERS ON ENERGY-FROM-WASTE PLANT EFFICIENCY

J. P. VANDERPOL
Laurent Bouillet Ingenierie
Paris, France

INTRODUCTION

The purpose of this paper is to examine the main parameters, other than heat content of the waste, which influence the steam production and/or the efficiency of resource recovery installations. All too often people have a tendency to use short cut methods to evaluate various processes. For instance, a system supplier might be asked, "How much excess air do you use," or "What is the efficiency of your incineration plant," with the efficiency being measured by the energy of steam produced divided by the energy in the refuse brought to the plant. Answers to these kinds of questions might be extremely misleading.

In this paper, through a typical case considering a refuse with a fired higher heating value (HHV) of 5000 Btu/lb, it is shown the extent to which a number of parameters influence the heat balance of a household refuse incineration plant.

BASE CASE

The operating base parameters are arbitrarily chosen as follows:

(a) Heat value: (HHV) 5000 Btu/lb

(b) Ultimate composition—(lb/ton)

(1) Combustible—1111.1
(2) Noncombustible—440.0
(3) Water—448.9

(c) Composition of combustible (lb/ton of refuse)

C	584.2
H	71.7
O	441.9
N	11.1
S	0.3
Cl	1.9

(d) HHV of Combustible—9000 Btu/lb

(1)	Ambient temperature.	68°F
(2)	Refuse temperature.	68°F
(3)	Relative humidity.	60%
(4)	Flame temperature.	2337°F
(5)	Boiler entering temperature.	2316°F
(6)	Clinker temperature.	725°F
(7)	Unburnt particles in clinker.	1%
(8)	Excess air.	60%
(9)	Steam pressure.	15 bars (abs)
(10)	Feed water temperature.	212°F
(11)	Blow down.	1%
(11)	Soot blowing.	Mechanical
(12)	Calorific losses.	200,000 Btu

All curves and figures are calculated for one ton of refuse according to Laurent Bouillet-Howard (L.B.H.)

computer programs which include all the parameters mentioned in this study.

DISCUSSION

If one is to compare various processes, one should clearly state the operating conditions in order to be certain that the assumptions of the various suppliers are comparable. Two sets of factors could be considered in such a comparison, as follows:

(a) Exogenous factors
  (1) HHV of refuse.
  (2) Ambient air temperature.
  (3) Feed water temperature.
(b) Endogenous factors
  (1) Total air quantity including air leakage (prior to boiler) at various points of the process.
  (2) Gas temperatures
  (3) Unburnt carbon
  (4) System heat losses.

The endogenous factors are a consequence of the process design and construction and must be consistent and justified. One must therefore analyze the endogenous factors indicated for the various process systems. It is not uncommon at this point to find that nameplate guaranteed steam production is not consistent with the assumed exogenous factors and the selected endogenous factors.

The detailed performance of an incineration plant is the result of mutual interactions of typical parameters. In order to study the influence of these parameters on incinerator plant efficiency, an arbitrary base case was chosen. Then, each parameter was varied individually and seven curves were drawn showing the impact on steam production as each parameter was varied between two arbitrarily chosen limits representing relatively fixed technological or environmental conditions.

The air introduced to the system prior to the heat exchanger will, of course, have a great influence on the quantity of steam produced. However, in discussing air quantities, one must recognize that there are three "different" sorts of air introduced into the system.

(a) First is the air quantity necessary to ensure good combustion. This quantity is the sum of the theoretical or stoichiometric amount and an additional quantity referred to as "excess air". This total air quantity is used as an indication of the efficiency of combustion of a system.

(b) Second is the quantity of air necessary to control flue gas temperatures to a selected temperature. This is a function of the process utilized and of the heat value of the refuse.

(c) Third, after a few years of operation, air leakage can take place in the system prior to the boiler or heat exchanger.

To illustrate, if we assume a process burning a refuse with a heat content of 5000 Btu/lb and using 60% excess air, the flame temperature is 2337°F. At this temperature, the risk of NO_x production is very high. Thus, if the process requires a maximum flame temperature of 2000°F then total air quantity becomes 14,000 lb/ton of refuse (from Fig. 1).

If we further assume that some air leakage takes place, say 2000 lb/ton of refuse, then the total air quantity becomes 16,000 lb/ton (excess air of 120%). We can then see from Fig. 2 that steam production is 6800 lb/ton instead of 7710 for the originally assumed excess air of 60%. There is also a loss of 3.6 points in efficiency.

On Fig. 3, assuming minimal losses in the system and no heat absorption by water walls, the flame temperature of 2337°F is assumed to result in a boiler inlet temperature of 2316°F. Of course, at this temperature most fly ash would be in gaseous or liquid form which would result in deposits sticking to and building up on the boiler tubes. Thus, gas temperatures at the boiler inlet would have to be reduced, resulting in reduction of steam production and thermal efficiency.

Boiler outlet temperature has been set at a minimum of 418°F below which there are risks of acid condensation. Of course, it is physically possible to go below this temperature. It will be noted from Fig. 4 that as boiler outlet temperatures increase, steam production and thermal efficiency decrease.

On Fig. 5, the maximum unburnt carbon limit has been set at 6%, because it is the regulated limit in certain industrial countries. The minimum chosen, 1%, has been achieved in some tests. It will be noted that, as unburnt carbon increases, steam production and thermal efficiency decrease.

On Fig. 6, it will be noted that as feed water temperature increases, steam production increases. However, as feed water temperature increase is realized as a result of using more steam to heat the feedwater, no gain in system thermal efficiency results.

On Fig. 7, the effect of changes in ambient air are illustrated. Thus, if tests are conducted on a cold winter day (assumed temperature 14°F) versus during a very hot summer day, the steam produced by the system, all other parameters being held constant, might range from 6990 to 7260 pounds per ton of refuse, while thermal efficiency could vary from 74.4% to 76.9%.

The Figures show that three parameters might pro-

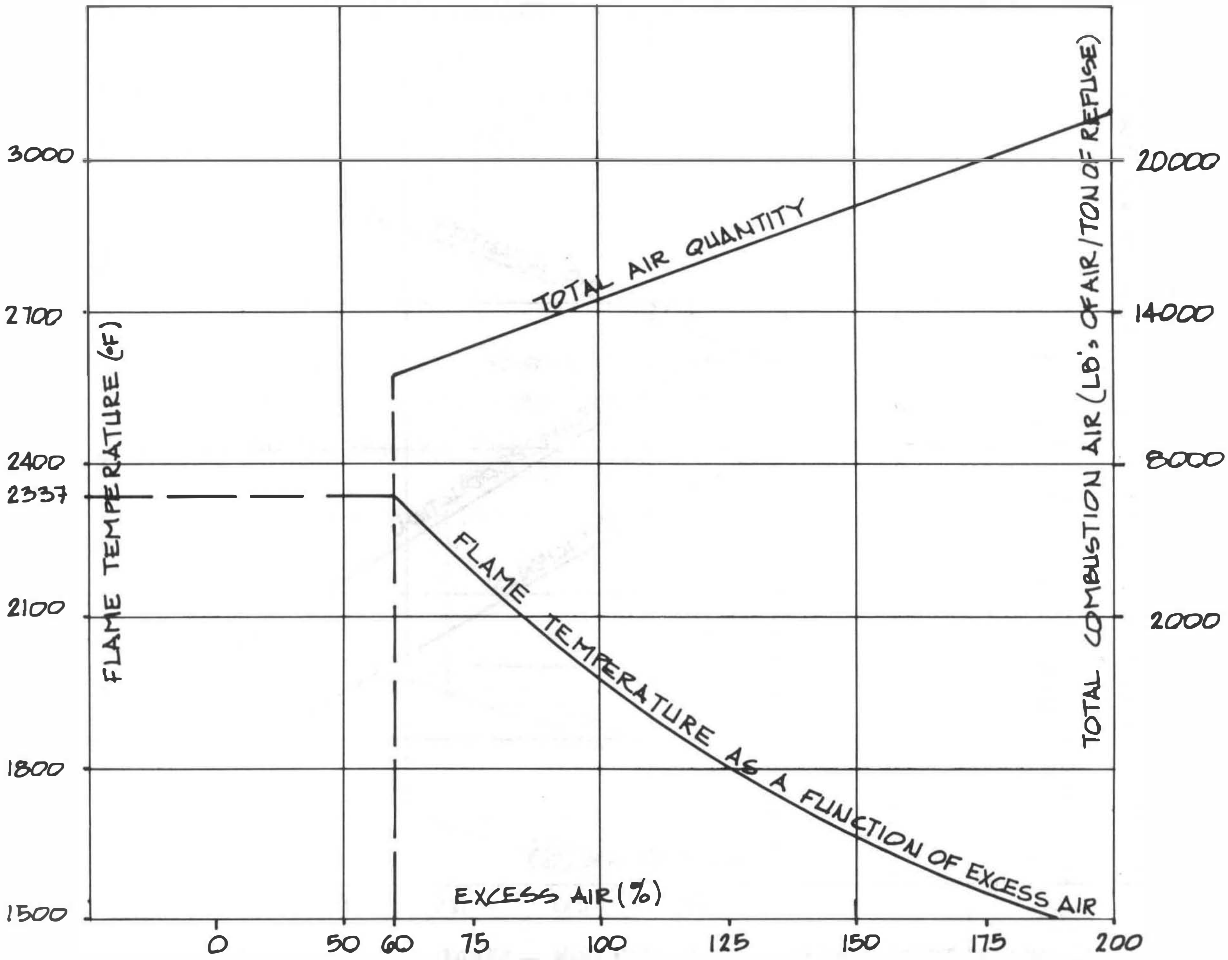

FIG. 1 FLAME TEMPERATURE VERSUS EXCESS AIR STANDARD REFUSE WITH HHV (5000 Btu/lb)

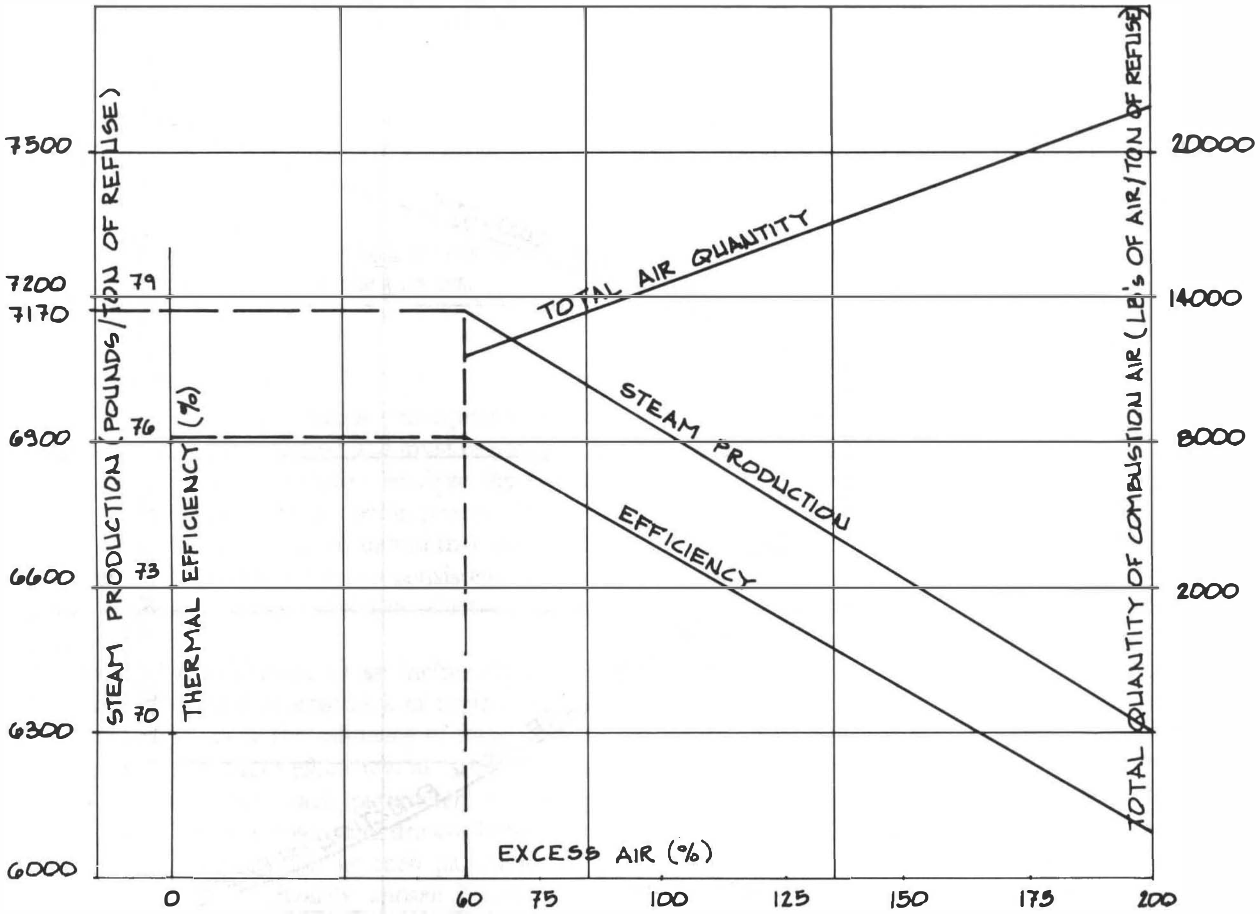

FIG. 2 INFLUENCE OF TOTAL AIR ON STEAM PRODUCTION — STANDARD REFUSE WITH HHV (5000 Btu/lb)

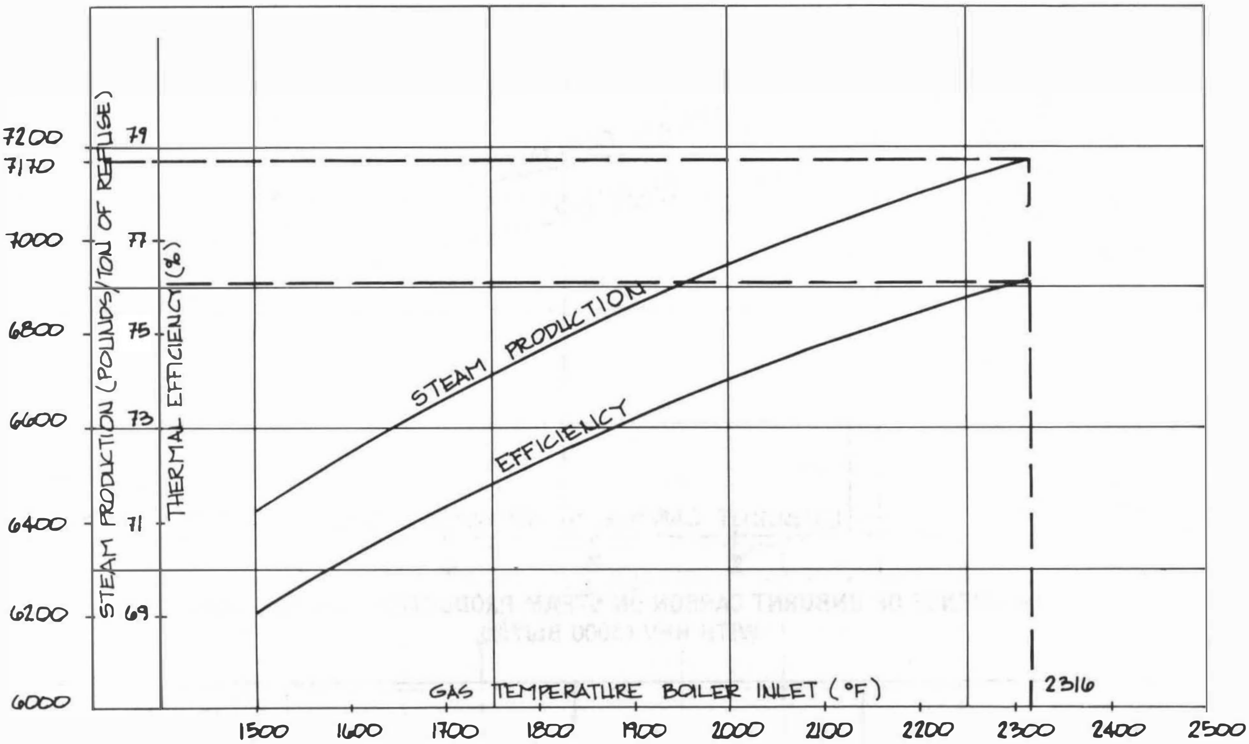

FIG. 3 INFLUENCE OF BOILER INLET TEMPERATURE ON STEAM PRODUCTION — STANDARD REFUSE WITH HHV (5000 Btu/lb)

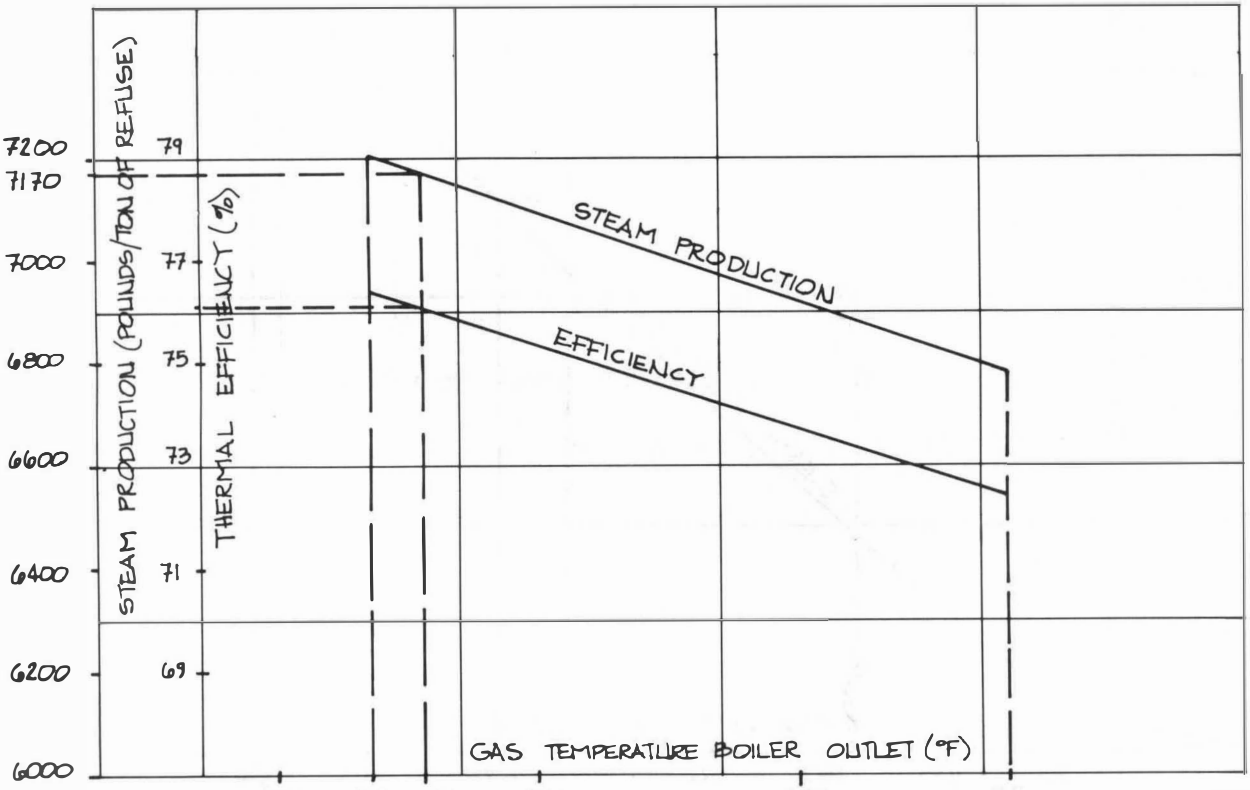

FIG. 4 INFLUENCE OF BOILER OUTLET TEMPERATURE ON STEAM PRODUCTION — STANDARD REFUSE WITH HHV (5000 Btu/lb)

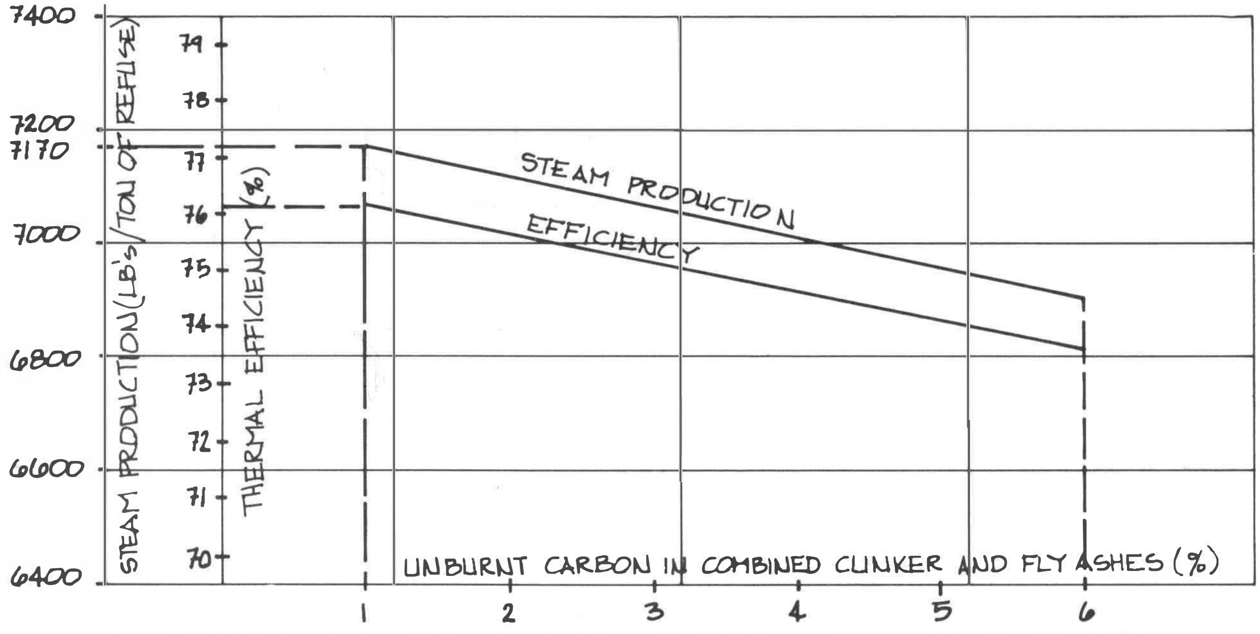

FIG. 5 INFLUENCE OF UNBURNT CARBON ON STEAM PRODUCTION — STANDARD REFUSE WITH HHV (5000 Btu/lb)

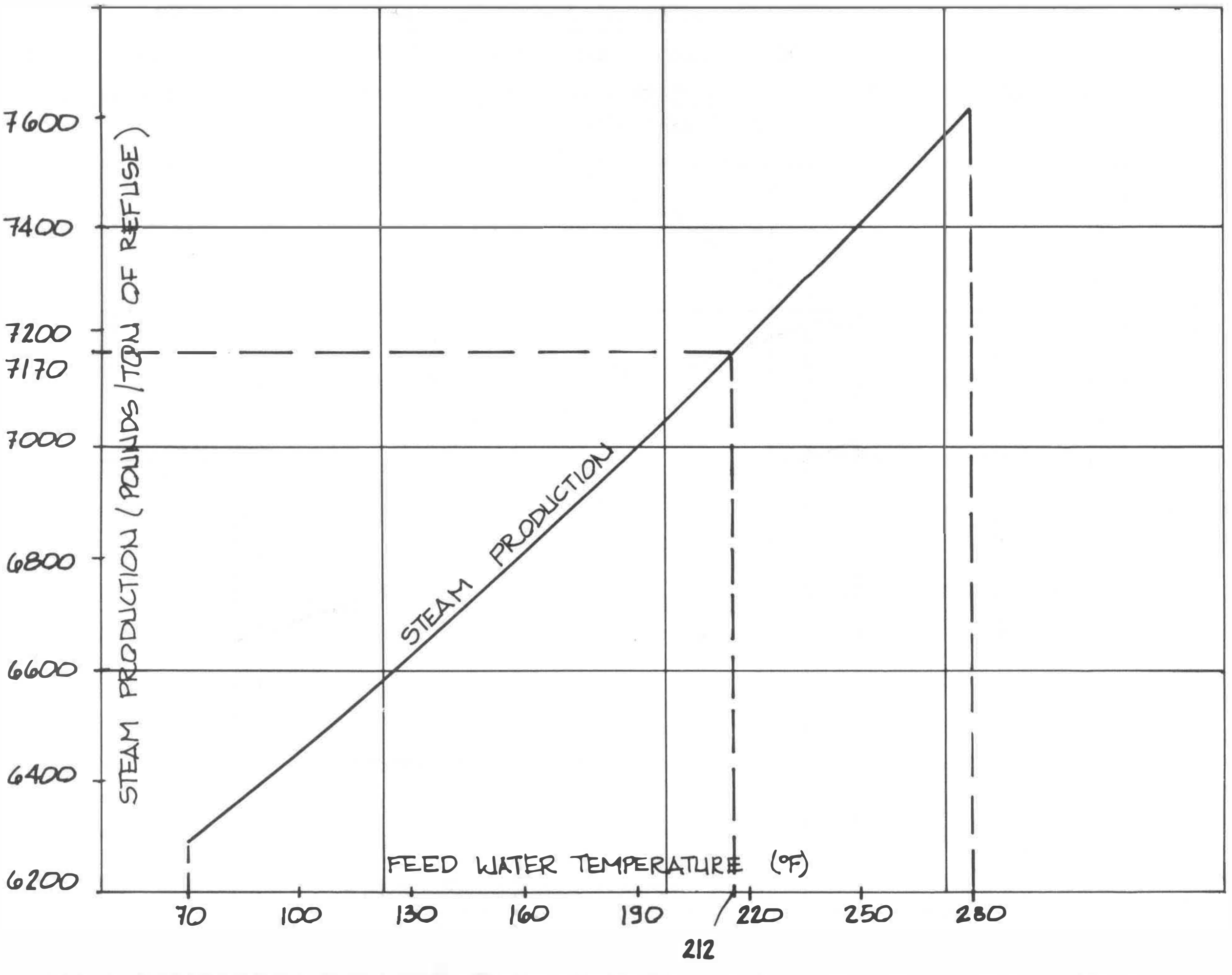

FIG. 6 INFLUENCE OF FEED WATER TEMPERATURE ON STEAM PRODUCTION — STANDARD REFUSE WITH HHV (5000 Btu/lb)

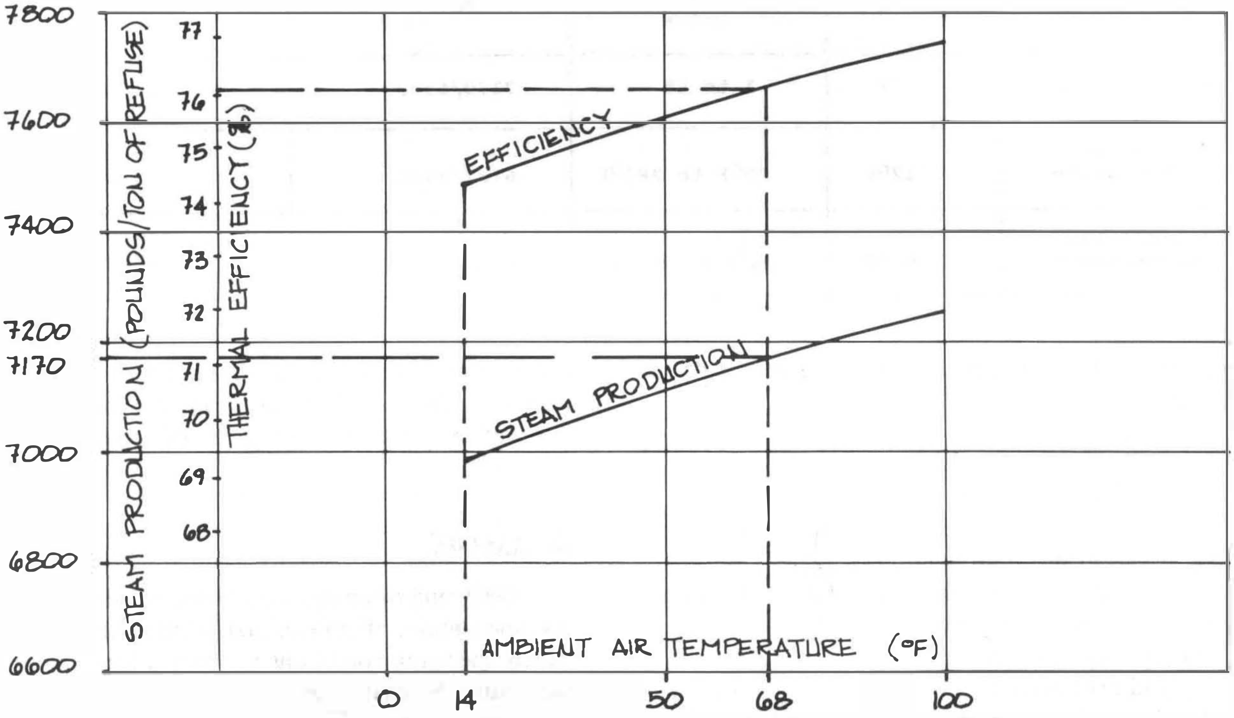

FIG. 7 INFLUENCE OF AMBIENT TEMPERATURE ON STEAM PRODUCTION

TABLE 1 SUMMARY U.S. STANDARD REFUSE (H.H.V. — 5000 Btu/lb)

Parameters	Base Case Study	Variation Range	VARIATIONS	
			Steam Output lbs/ton Compared to Base Study (7,170)	Efficiency as % of H.H.V. compared to base Study
Excess air	60%	60 to 200%	7170/6305	100/87.9
Boiler inlet temperature	2316	2316 to 1500	7170/6429	100/89.6
Boiler outlet temperature	428°F	418°F 540°F	7210/6780	100.5/94.6
Unburnt carbon	1%	1 to 6%	7170/6900	100/96.2
Feed water temperature	212°F	70°F to 280°F	6287/7620	87.7/106.3
Ambient air temperature	68°F	14°F to 100°F	6990/7260	97.5/101.3

duce variations in steam production of over 10%, as follows:

(a) Excess air
(b) Boiler inlet temperature
(c) Feed water temperature.

Variations in boiler inlet temperatures could result in variations in steam production of 5–10%, while two other parameters, as follows, might produce variations of up to 5% in steam production:

(a) Ambient temperature
(b) Unburnt carbon.

Results of these analyses are summarized in Table 1.

Finally, two additional parameters were studied for which diagrams are not presented in this paper, relative humidity of the ambient air and carbon monoxide in the flue gases. Relative humidity variations in the ambient air were found to cause maximum variations in steam production of 0.4% with humidity varying from 0% to 100%. Variations in CO in the flue gases also have a negligible effect on steam production if the installation is properly designed and operated.

SUMMARY

In designing or analyzing a waste combustion process, one should, of course, first of all study the anticipated operating conditions at various heat values for the refuse. Secondly, one should study the effect of both the exogenous factors and endogenous factors as has been presented herein. Next, these factors should be varied simultaneously. In order to conduct a proper analysis, considering instant variations in heat values and exogenous and endogenous factors, the engineer or the designer must have computer programs which take into account all of the parameters indicated in this paper.