Research Article
Mathematical Modeling of Solid Waste Incinerators

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Abstract: Population growth, technological progress and changes in consumption patterns in recent years have led to an increase in the solid waste. On the other hand, limit energy resources and raw materials caused waste to be considered as a waste material and also recyclable at the high level of scientific and applied research. In solid waste management, waste burning is regarded as one of ways for eliminating waste. In this study, municipal waste in one of the districts of Tehran was taken into account for a case study. Also, in special systems which need special care of temperature such as the system for controlling the temperature of the furnace fuel of burnable solid waste in temperature 950°C. Fuel requirements for design were also calculated. At the end of the project, fluent software was used to confirm the findings obtained from the city incinerator furnace design.

Keywords: Combustion, fluent, heat transfer, incinerator, landfill

INTRODUCTION

As a large amount of waste materials is regarded as hazardous waste, it is unavoidable to burn these wastes completely in so far as nothing remains in all areas. Based on this background, the study of burning hazardous wastes in such a way that nothing remains about these wastes has taken into account in this study. In addition, emitted gases from incinerator were considered for further research in this study.

In this project, the waste was considered as a vital part of everyday life, especially in the heat of the incinerators and thermal kiln design as an important part of this industry. Due to the need to eliminate the release of hazardous waste and hazardous materials and waste volume control (for lack of emissions), it is the basis for the design in this study.

Hazom has obtained an empirical relationship of the waste by sorting elemental compositions for HHV information:

$$HHV = 0.339 \ (C) + 1.44 \ (H) - 0.139 \ (O) + 0.105 \ (S) \quad \frac{MJ}{kg}$$

$$HHV = 145.7 \ (C) + 619 \ (H) - 59.8 \ (O) + 45.1 \ (S) \quad \frac{BTU}{lb}$$

In a more complex case, Wilson (1972) obtained estimated high heating value with the use of thermodynamics, carbon and sulfur heat value, type of carbon and the formation of water:

$$HHV = 0.3279C_0 + 1.504(H) - 0.1383(O) - 0.1484(C_1) + 0.09262(S) + 0.02419(N)$$

$$HHV = 141(C_0) + 647.8(H) - 59.48(O) - 63.82(C_1) + 39.82(S) + 10.4(N)$$

According to Lee and Lin (1999), C1 is the percentage of fixed carbon mass in waste and C0 is the percentage of carbon which will be emitted from waste compounds.

An example of an equation that is based on analysis of urban waste for estimating the high heating value of municipal solid waste based on flammability of components, paper, plastics and food (as they are collected) is the method used by Kahn and Abu-qarareh (1991) as follows:

$$HHV = 0.0535[F + 3.6CP] + 0.372 \ PLR \quad \frac{MJ}{kg}$$

$$HHV = 23 \ [F + 3.6CP] + 160 \ LR \quad \frac{BTU}{lb}$$

In this equation, HHV is the high heating value, F is the mass percent of food materials, CP is mass percent of study and cardboard and PLR is mass percent of plastic and leather in dry waste compound (Bruner, 1991).

In additin, Ettouny *et al.* (2005) in their study entitled "Control of thermally integrated incineration-waste heat recovery systems: A case study in 2005", did their study on hospital waste. The project initially developed based on the Fig. 1:

Then, he developed his design based on the following formula and developed the temperature of waste elimination at 1473°K:

$$\sum \int_{T_{ref}}^{T_{mix}} (n_j C_J \, dT) = \sum \int_{T_{ref}}^{T_i} (n_i C_i \, dT)$$

By considering that the temperature at the point of 10 should be 1223°K, Q is obtained in accordance with the following formula:
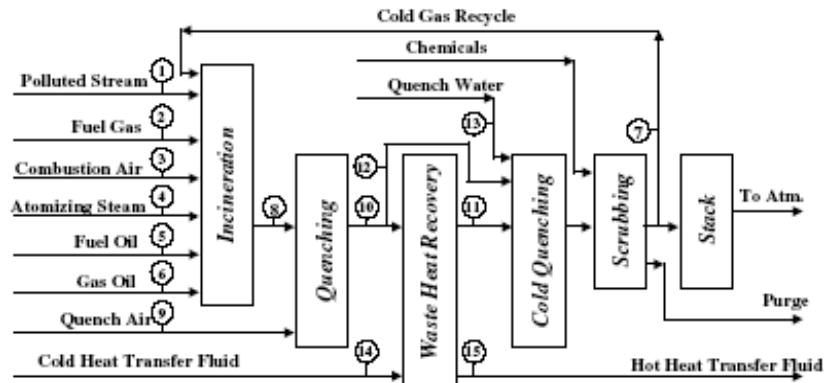
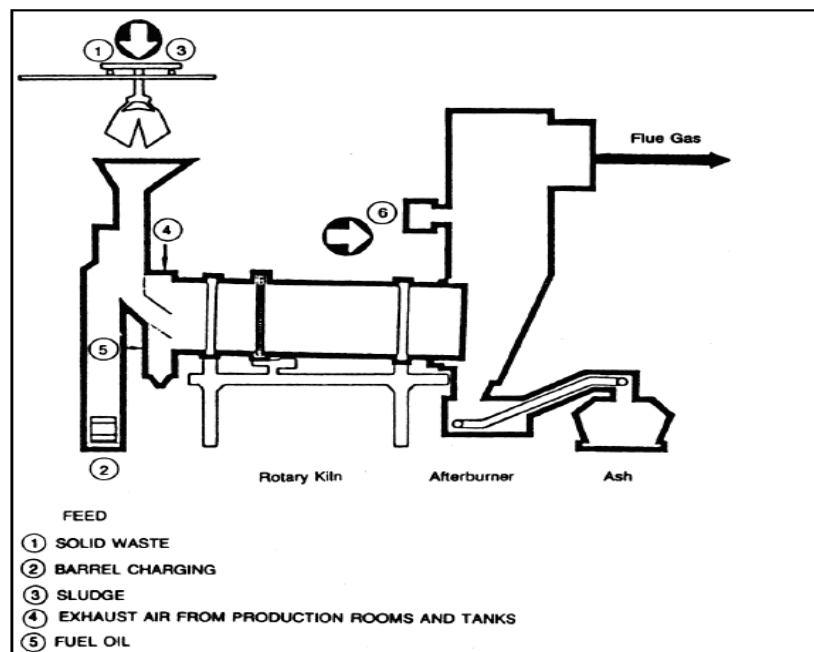Fig. 1: Control of thermally integrated incineration-waste heat recovery systems (Ettouny *et al*., 2005)

Fig. 2: Rotary kiln system

$$\sum \int_{T_{11}}^{1223} (n_i C_i dT) = Q$$

Based on this system, we can determine Q and Qmax and Qmin regime and different amount in each equation can be obtained. Then, we can enter data in an analog computer for the purpose of decreasing or increasing the amounts mentioned.

By considering the above background, the main objective of this study is to complete the combustion of hazardous wastes by the aforementioned instrument was done for one sample from hazardous wastes in Tehran, which has been regarded as one of the reasons for polluting environment and as a danger for human life. Two methods of combustion calculations and the accuracy of essential temperature for the purpose of removing the waste was validated by using Computational Fluidity Dynamics (CFD) and Fluent software.

TYPES OF INCINERATORS

Municipal, commercial and hospital Incineration can be classified into different categories by their size (depending on capacity) and its use. Rotary kiln technology can be regarded as one of the most famous. The rotary kiln incineration system is the most applicable incinerator which has various uses in burning waste in the form of liquid, solid and sludge, especially in municipal waste. Overall, the rotary kiln system for hazardous waste landfill fire is shown in Fig. 2. The furnace includes parts littered the entrance and exit of air from burning trash bins for separating gases and ash trash has a place to drain.
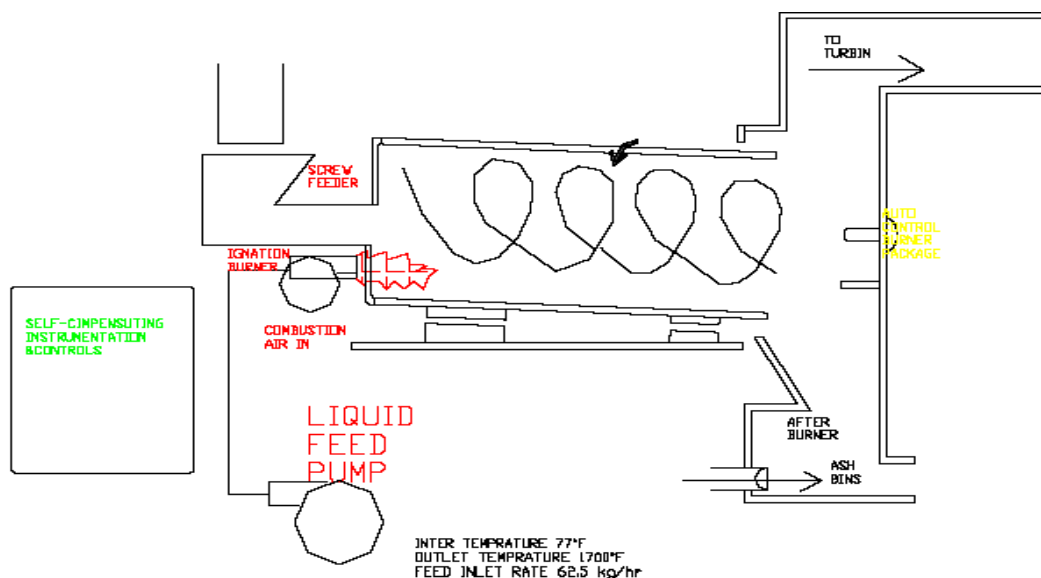
Fig. 3: Proposed form of mathematical simulation of rotary kiln incinerators

Accordingly, the municipal waste is a composition of liquid waste, solid waste and sludge. This type of incinerator is a viable option for this type of design. But, in order to ensure complete burning of waste in the system, the thermal design of the furnace and the amount of fuel needed in this system, designing seems necessary (Lee and Lin, 1999).

MATERIALS AND METHODS

The basics of thermal design incinerators: Incineration is a thermal process that should be measured at the required temperature. We should provide fuel and power for those wastes which are nonflammable and need the energy for combustion. Incinerator design should be started from heat rate calculation. However, based on experiences, for better combustion efficiency, waste heat requirements are proposed as follows:

In wet material, the temperature should be about 110°C, for volatile materials, the temperature should be about 725°C and finally for carbon materials, it should be around 950°C. If we consider the total waste of materials based on percentage, the amount of heat required is based on the percentage of ingredients for hazardous ingredients for the complete destruction of the waste at temperatures greater than 1200°C. The following steps must be done in order to calculate the temperature:

- Identification of waste quality
- Identification of hazardous waste and the need for heat
- Analysis of heat exposure and the estimation of the required temperature

- Analysis of quantity estimate of components and getting the air required for waste combustion
- Measurement of the amount of produced heat
- Getting the required heat in order to provide the needed fuel (Cavaseno, 1980) (Fig. 3)

RESULTS

The main basis for doing this study is on municipal wastes in one of the districts of Tehran, based on recycling Statistics in September 2006. Based on Waste Management Statistics Quarterly, the most waste production in one of the stations in Tehran equals to 150 tons/day. Table 1 show the analysis done based on the combination of wastes sample.

Also, the moisture amount of a kind of municipal wastes is between 15 to 40% that was considered 25% in Tehran. Since most municipal waste contains solid waste, we considered rotary kiln incinerator. However, the design is based on these assumptions. The first assumption is that we do not need fuel. Burning garbage should be done based on the heating value of the fuel, which should be added to heat generated and temperature difference with 25°C (based on HHV fuel definition). Then, if the answer is positive, our initial assumption is not correct while if this value is zero or negative, it shows that the garbage quality is good for destroying completely in burning temperature (Statistics, 2006).

The following formula is used for burning wastes:

$$Q = -(\text{HHV})_{\text{total}} + (H_{\text{sensible}})_{\text{outlet}} - (H_{\text{sensible}})_{\text{inlet}}$$

However, the input enthalpy can be obtained according to the following formula by considering this point that the waste temperature is equal to 77°F.

Table 1: Analysis of waste quality estimation based on the Statistics of waste recycling organization in the Karko, Tehran (Sep 2006)

Carbon	Oxygen	Hydrogen	Sulfur	Nitrogen	Other sectors
44.8	33.8	5.9	0.31	2.06	13.13

Approximate analysis of waste:

Moisture = 25%
Non combustible (inert) = 8.03% (ashes)
Combustible = 66.97%

The final analysis:

C : 44.86 wt %
O : 33.8 wt %
H : 5.9 wt %
S : 0.31 wt %
N : 2.06 wt %
Cl : 13.07 wt %

Fuel:

Natural gas (C: 0.693, H: 0.227, N: 0.08, by mass)
Fractional excess air = 1.75
Flue gas temperature = 1700°F

Regarding the calculation of fuel and waste heating value, Hazom relationship was used as follows:

$$(HHV_{MSW}) = 14545 X_C + 62031(X_H - 0.125 X_O)$$
$$- 760 X_{Cl} + 4500 X_S$$
$$= 14545 * 0.4486 + 62031$$
$$(0.059 - 0.125 * 0.338) - 760 * 0.1307$$
$$+ 4500 * 0.0031 = 7478.52 \frac{btu}{lbm}$$

$$(HHV_{fuel}) = 14545 X_C + 62031(X_H - 0.125 X_O)$$
$$- 760 X_{Cl} + 4500 X_S$$
$$= 14545 * 0.693 + 62031(0.227 - 0)$$
$$= 24160.72 \frac{btu}{lbm}$$

Solution: To solve this problem, trial and error is necessary. We assumed that the additional fuel is not required and the process of Q standard determination will be followed. If Q is less than or equal to zero, our assumption is correct, otherwise, our assumption fails to be true and fuel flow rate should be estimated through trial and error method.

Initially, we suppose that we do not need any fuel. Then, the following steps should be taken:

Step 1: Determination of flow rate, relative humidity, non-flammable materials (Inert) and the rate of Cl, S, N, O, H, C:

$$n_{moisture} = 13778.96 * \frac{0.25}{18} = 191.374 \frac{lb - mole}{hr}$$

$$n_{inert} = 13778.96 * 0.0803 = 1106.45 \frac{lbm}{hr}$$

$$n_C = (13778.96 * 0.6697 * 0.4486) / 12 = 344.96 \frac{lb - mole}{hr}$$

$$n_H = (13778.96 * 0.6697 * 0.059) / 1 = 544.44 \frac{lb - mole}{hr}$$

$$n_{Cl} = (13778.96 * 0.6697 * 0.1307) / 36.5 = 33.04 \frac{lb - mole}{hr}$$

$$n_O = (13778.96 * 0.6697 * 0.338) / 16 = 194.93 \frac{lb - mole}{hr}$$

$$n_N = (13778.96 * 0.6697 * 0.0206) / 14 = 13.57 \frac{lb - mole}{hr}$$

$$n_S = (13778.96 * 0.6697 * 0.0031) / 32 = 0.894 \frac{lb - mole}{hr}$$

Step 2: Calculate the theoretical air:

$$n_{S,O_2} = n_C + \frac{(n_H - n_{Cl})}{4} + n_S - \frac{n_o}{2}$$
$$= 344.96 + (544.44 - 33.04) / 4 + 0.894 - 194.93 / 2$$
$$= 376.24 \frac{lb - mole}{hr}$$

Therefore,

$$n_{S,air} = 376.24 / 0.21 = 1791.61 \frac{lb - mole}{hr}$$

Step 3: Calculate the amount of the actual air based on excess air:

$$n_{air} = (1 + f)n_{S,air}$$
$$= (1 + 1.75) * 1791.61 = 4926.94 \frac{lb - mole}{hr}$$

and

$$n_{N_2} = 0.79 n_{air} = 3899.07 \frac{lb - mole}{hr}$$

$$n_{O_2} = 0.21 n_{air} = 658.41 \frac{lb - mole}{hr}$$

Step 4: Determine the flow rate of gases:

$$n_{CO_2} = n_c = 344.95 \frac{lb - mole}{hr}$$

$$n_{water} = \frac{(n_H - n_{CL})}{2} + n_{moisture} = 447.07 \frac{lb - mole}{hr}$$

$$n_{HCL} = n_{CL} = 33.04 \frac{lb - mole}{hr}$$

$$n_{SO_2} = n_s = 0.894 \frac{lb - mole}{hr}$$

$$n_{o_2} = \frac{n_o}{2} + n_{o_2} - n_C - n_S - \frac{(n_H - n_{CL})}{4}$$

Table 2: Average specific heat

C_{PM} (Btu/lb-mole °F)

T (°F)	Air	O_2	N_2	CO_2	HCL	SO_2	H_2O (g)
77	6.94	7.02	6.94	8.88	6.95	9.97	8.04
100	6.95	7.04	6.95	8.94	6.95	10.06	8.05
200	6.98	7.11	6.97	9.20	6.96	10.44	8.10
300	7.01	7.18	6.99	9.45	6.98	10.78	8.15
400	7.04	7.25	7.01	9.69	7.01	11.07	8.21
500	7.07	7.32	7.04	9.91	7.05	11.33	8.27
600	7.11	7.38	7.06	10.12	7.10	11.56	8.33
700	7.15	7.44	7.09	10.32	7.16	11.76	8.40
800	7.18	7.49	7.12	10.51	7.22	11.92	8.47
900	1.22	7.55	7.16	10.68	7.30	12.07	8.54
1000	7.25	7.60	7.19	10.85	7.34	12.20	8.61
1100	7.29	7.65	7.23	11.01	7.40	12.30	8.68
1200	7.33	7.70	7.26	11.16	7.46	12.39	8.75
1300	7.37	7.74	7.30	11.30	7.52	12.48	8.83
1400	7.41	7.79	7.33	11.43	7.57	12.55	8.91
1500	7.44	7.83	7.37	11.55	7.62	12.61	8.98
1600	7.48	7.87	7.41	11.67	7.66	12.68	9.06
1700	7.52	7.91	7.44	11.78	7.68	12.74	9.14
1800	7.55	7.95	7.48	11.88	7.70	12.81	9.22
1900	7.59	7.98	7.52	11.98	7.70	12.89	9.29
2000	7.63	8.02	7.55	12.07	7.70	12.97	9.37

Mean specific heat (C_{PM}) of various flue gas species (Reference temperature 77°F)

$$= 658.42 \ \frac{lb-mole}{hr}$$

$$n_{N_2} = \frac{n_N}{2} + n_{N_2} = 3899.07 \ \frac{lb-mole}{hr}$$

Step 5: Calculate Q:

$$Q = -(HHV)_{total} + (H_{sensible})_{outlet} - (H_{sensible})_{inlet}$$

$$(HHV)_{total} = \sum \{w(HHV)\}$$

Then, we calculate W (inlet flow rate of flammable materials) as follows:

$$dryfeed = 0.75 * 13778.96 = 10334.22 \ \frac{lbm}{hr}$$

$$ash = 8.03\% = 0.0803 * 13778.96 = 1106.45 \frac{lbm}{hr}$$

$$w = dryfeed - ash = 9227.76 \ \frac{lbm}{hr}$$

$$(HHV)_{total} = (9227.76 * 7478.52)_{MSW}$$

$$= 69.0099 * 10^6 \ \frac{btu}{hr}$$

For calculating $(H_{sensible})_{outlet}$ in the following Table 2, we have:

$$C_{pm,CO_2,1700^o F} = 11.78 \ \frac{btu}{lb-mole^o F}$$

$$C_{pm,H_2O,1700^o F} = 9.14 \ \frac{btu}{lb-mole^o F}$$

$$C_{pm,HCL,1700^o F} = 7.68 \ \frac{btu}{lb-mole^o F}$$

$$C_{pm,SO_2,1700^o F} = 12.74 \ \frac{btu}{lb-mole^o F}$$

$$C_{pm,O_2,1700^o F} = 7.91 \ \frac{btu}{lb-mole^o F}$$

$$C_{pm,N_2,1700^o F} = 7.44 \ \frac{btu}{lb-mole^o F}$$

And we assume:

$$C_{pm,inert,1700^o F} = 0.24 \ \frac{btu}{lb-mole^o F}$$

Then, based on the temperature of the water saturation under the pressure of 1 atm equals to 212°F and with regard to thermodynamic tables, we have the followings:

$$@ \ 1atm = 14.696 \ psia \ \Rightarrow \ T_{sat} = 212^0 F$$

$$h_{fg} = 970.4 \ \frac{Btu}{lbm} \ \& \ h_f = 180.15 \ \frac{Btu}{lbm}$$

$$\begin{aligned}
(H_{sensible})_{outlet} \\
= \sum \{nC_{pm}(T-77)\}_i + n_{water}(\Delta H_v)_{water} \\
= \{nC_{pm}(T-77)\}_{CO_2} + \{nC_{pm}(T-212)\}_{H_2O} \\
+ \{nC_{pm}(T-77)\}_{HCL} \\
+ \{nC_{pm}(T-77)\}_{SO_2} + \{nC_{pm}(T-77)\}_{O_2} \\
+ \{nC_{pm}(T-77)\}_{N_2} \\
+ \{nC_{pm}(T-77)\}_{inert} + n_{water}(\Delta H_v)_{water}
\end{aligned}$$

$$= \{344.96 * 11.78(1700 - 77)\}_{CO_2}$$
$$+ \{447.07 * 9.14(1700 - 212)\}_{H_2O}$$
$$+ \{33.04 * 7.68(1700 - 77)\}_{HCL}$$
$$+ \{0.894 * 12.74(1700 - 77)\}_{SO_2}$$
$$+ \{658.42 * 7.91(1700 - 77)\}_{O_2}$$
$$+ \{3899.07 * 7.44(1700 - 77)\}_{N_2}$$
$$+ \{1106.45 * 0.24(1700 - 212)\}_{inert}$$
$$+ \{447.07 * (18 * 180.15)\}_{water} +$$
$$\{447.07(18 * 970.4)\}_{water} = 78.33 * 10^6 \frac{btu}{hr}$$

For (H sensible) inlet in 77°F, we have:

$$(H_{sensible})_{inlet} = \sum \{nC_{pm}(T - 77)\}_i$$
$$= \{nC_{pm}(T - 77)\}_{MSW} + \{nC_{pm}(T - 77)\}_{air}$$
$$= \{nC_{pm}(77 - 77)\}_{MSW} + \{nC_{pm}(77 - 77)\}_{air}$$
$$= 0$$

Thus:

$$Q = -(HHV)_{total} + (H_{sensible})_{outlet} - (H_{sensible})_{inlet}$$

$$= +9.32 * 10^6 \frac{btu}{hr}$$

DISCUSSION

Since Q is positive, the "no fuel required" assumption is false and therefore we should estimate the amount of fuel required by using trial and error as follows:

Assumption: Oil flow rate =5000 lbm/h

Step 1: Determination of relative humidity flow rate, non-flammable materials (inert) and the rate of C, H, O, N, S, Cl and fuel,
For fuel, we have:

$$n_C = (5000 * 0.693)/12 = 288.75 \frac{lb - mole}{hr}$$

$$n_H = (5000 * 0.227)/1 = 1135 \frac{lb - mole}{hr}$$

$$n_N = (5000 * 0.08)/14 = 28.57 \frac{lb - mole}{hr}$$

Therefore,

$$n_{moisture} = 13778.96 * \frac{0.25}{18} = 191.374 \frac{lb - mole}{hr}$$

$$n_{inert} = 13778.96 * 0.0803 = 1106.45 \frac{lbm}{hr}$$

$$n_C = 344.96_{MSW} + 228.75_{fuel} = 633.71 \frac{lb - mole}{hr}$$

$$_H = 544.44_{MSW} + 1135_{fuel} = 1679.44 \frac{lb - mole}{hr}$$

$$n_{Cl} = (13778.96 * 0.6697 * 0.1307)/36.5 = 33.04 \frac{lb - mole}{hr}$$

$$n_O = (13778.96 * 0.6697 * 0.338)/16 = 194.93 \frac{lb - mole}{hr}$$

$$n_N = 13.58_{MSW} + 28.57_{fuel} = 42.15 \frac{lb - mole}{hr}$$

$$n_S = 0.894 \frac{lb - mole}{hr}$$

Step 2: Calculate the theoretical air:

$$n_{S,O_2} = n_C + \frac{(n_H - n_{Cl})}{4} + n_S - \frac{n_o}{2}$$
$$= 633.71 + (1679.44 - 33.04)/4 + 0.894 - 194.93/2$$
$$= 948.74 \frac{lb - mole}{hr}$$

Therefore,

$$n_{S,air} = 948.74/0.21 = 4517.8 \frac{lb - mole}{hr}$$

Step 3: Calculate the amount of actual air based on excess air:

$$n_{air} = (1 + f)n_{S,air}$$

$$= (1 + 1.75) * 4517.8 = 12423.96 \frac{lb - mole}{hr}$$

and

$$n_{N_2} = 0.79 n_{air} = 9836 \frac{lb - mole}{hr}$$

$$n_{O_2} = 0.21 n_{air} = 1660.29 \frac{lb - mole}{hr}$$

Step 4: Determine the flow rate of gases:

$$n_{CO_2} = n_c = 633.71 \frac{lb - mole}{hr}$$

$$n_{water} = \frac{(n_H - n_{CL})}{2} + n_{moisture} = 1014.57 \frac{lb - mole}{hr}$$

$$n_{HCL} = n_{CL} = 33.04 \frac{lb - mole}{hr}$$

$$n_{SO_2} = n_s = 0.894 \frac{lb - mole}{hr}$$

$$n_{o_2} = \frac{n_o}{2} + n_{o_2} - n_C - n_S - \frac{(n_H - n_{CL})}{4}$$
$$= 1660.29 \frac{lb - mole}{hr}$$

$$n_{N_2} = \frac{n_N}{2} + n_{N_2} = 9836 \frac{lb - mole}{hr}$$

Step 5: Calculate Q:

$$Q = -(HHV)_{total} + (H_{sensible})_{outlet} - (H_{sensible})_{inlet}$$

$$(HHV)_{total} = \sum \{w(HHV)\}$$

$$(HHV)_{total} = (9227.76 * 7478.52)_{MSW}$$

$$+ (5000 * 24160.72)_{fuel} = 189.81*10^6 \ \frac{btu}{hr}$$

For calculating (H sensible) inlet in 1700°F, we have:

$$C_{pm,CO_2,1700^oF} = 11.78 \quad \frac{btu}{lb-mole^oF}$$

$$C_{pm,H_2O,1700^oF} = 9.14 \quad \frac{btu}{lb-mole^oF}$$

$$C_{pm,HCL,1700^oF} = 7.68 \quad \frac{btu}{lb-mole^oF}$$

$$C_{pm,SO_2,1700^oF} = 12.74 \quad \frac{btu}{lb-mole^oF}$$

$$C_{pm,O_2,1700^oF} = 7.91 \quad \frac{btu}{lb-mole^oF}$$

$$C_{pm,N_2,1700^oF} = 7.44 \quad \frac{btu}{lb-mole^oF}$$

we assume:

$$C_{pm,inert,1700^oF} = 0.24 \quad \frac{btu}{lb-mole^oF}$$

Thus:

$$(H_{sensible})_{outlet}$$
$$= \sum \{nC_{pm}(T-77)\}_i + n_{water}(\Delta H_v)_{water}$$
$$= \{nC_{pm}(T-77)\}_{CO_2} + \{nC_{pm}(T-212)\}_{H_2O}$$
$$+ \{nC_{pm}(T-77)\}_{HCL}$$
$$+ \{nC_{pm}(T-77)\}_{SO_2} + \{nC_{pm}(T-77)\}_{O_2}$$
$$+ \{nC_{pm}(T-77)\}_{N_2}$$
$$+ \{nC_{pm}(T-77)\}_{inert} + n_{water}(\Delta H_v)_{water}$$

$$= \{633.71*11.78(1700-77)\}_{CO_2}$$
$$+ \{1014.57*9.14(1700-212)\}_{H_2O}$$
$$+ \{33.04*7.68(1700-77)\}_{HCL}$$
$$+ \{0.894*12.74(1700-77)\}_{SO_2}$$
$$+ \{1660.29*7.91(1700-77)\}$$
$$_{O_2} + \{9836*7.44(1700-77)\}_{N_2}$$
$$+ \{1106.45*0.24(1700-77)\}_{inert}$$
$$+ \{1014.57*(18*180.15)\}_{water}$$
$$+ \{1014.57(18*970.4)\}_{water}$$
$$= 187.87*10^6 \ \frac{btu}{hr}$$

For calculating (H sensible) inlet in 77°F, we have:

$$(H_{sensible})_{inlet} = \sum \{nC_{pm}(T-77)\}_i$$
$$= \{nC_{pm}(T-77)\}_{MSW} + \{nC_{pm}(T-77)\}_{air}$$
$$= \{nC_{pm}(77-77)\}_{MSW} + \{nC_{pm}(77-77)\}_{air}$$
$$= 0$$

Thus:

$$Q = -(HHV)_{total} + (H_{sensible})_{outlet} - (H_{sensible})_{inlet}$$

$$= -1.94*10^6 \ \frac{btu}{hr} \ = -604.11 \ kw$$

Now we want to study the effect of pre-heating intake air.

First, we preheat the intake air until 300°F:

$$(H_{sensible})_{inlet} = \sum \{nC_{pm}(T-77)\}_i$$
$$= \{nC_{pm}(T-77)\}_{MSW} + \{nC_{pm}(T-77)\}_{air}$$
$$= \{nC_{pm}(77-77)\}_{MSW} + \{nC_{pm}(300-77)\}_{air}$$
$$= 0 + 12423.96*7.01(300-77) = 19.42*10^6 \ \frac{btu}{hr}$$

Therefore,

$$Q = -(HHV)_{total} + (H_{sensible})_{outlet} - (H_{sensible})_{inlet}$$

$$= (-189.81 + 187.87 - 19.42)*10^6$$

$$= -21.36*10^6 \ \frac{btu}{hr} \ = 6650.4 \ KW$$

$$= 6.6504 \qquad MW$$

Mathematical modeling of waste incinerators by Fluent software: Now, in order to confirm the results, Fluent software was used as follows:

Grading: Then, the problem was garded (Fig. 4) by considering the design of the furnace or kiln as rotational kiln with the speed of 1.5 rad/s and the dimensions of 2 ft 15*5 or with the discharge point in the project and with regard to the assumption that the waste on the furnace is distributed across the surface of kiln and the angle of incinerators to the horizon is 6º, we want to solve the problem, but the simulated form is like the following figure with more than 2 million grids.

Registering data: Due to the fact that our model combustion is complex and we are coping with turbulent flow within the furnace, we utilize specious transport method with "eddy de'll sipation". However, for better modeling of circulating current, we use turbulence as k-ε. Further, considering this issue that radiation space is too large, we use P1 method to be able to model absorbance coefficients.
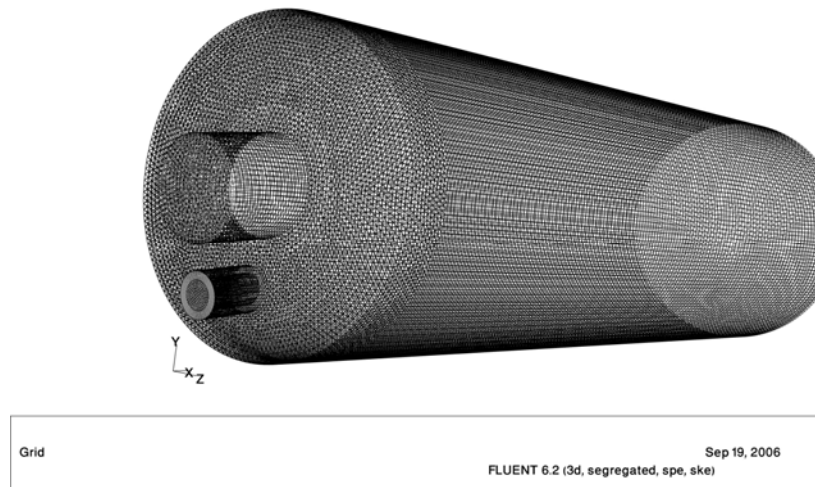
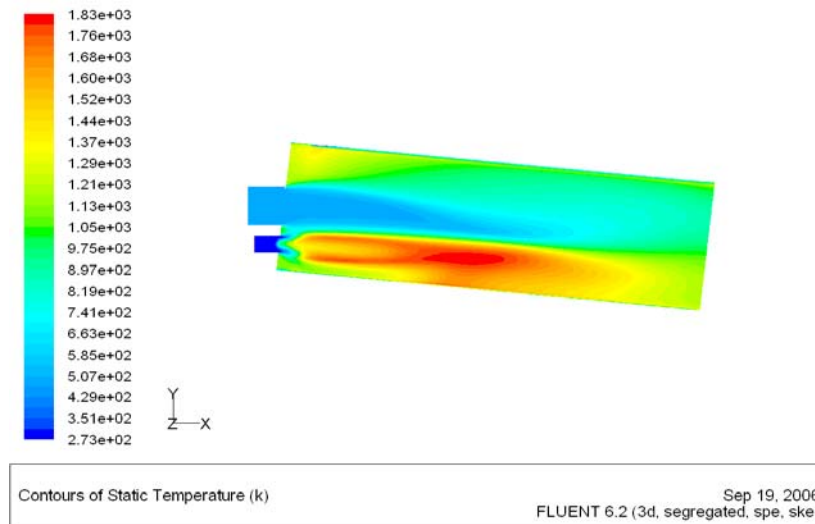Fig. 4: Grade classification based on the rotary kiln combustion requirements

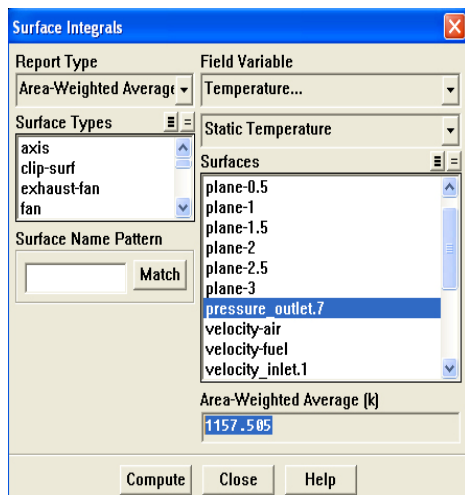Fig. 5: Incinerator outlet temperature mean

Fig. 6: Output temperature contours

So, the problem can be solved by entering the combustion reactions.

Issue output: Through solving the problem, we can come to some interesting results about combustion. The combustion temperature output is exactly the same output that we had used in the initial design. Figure 5 shows the temperature contours and Fig. 6 indicates the mean temperature at the outlet of the incinerator.

Yet, another objective of the simulation is the components flow rate of the incinerator, as it can be seen in the form of the major components Fig. 7 to 10.

CONCLUSION

As shown in the above figures, by considering the reactions and equations of combustion in incinerators, the default temperature of 950°C and overall
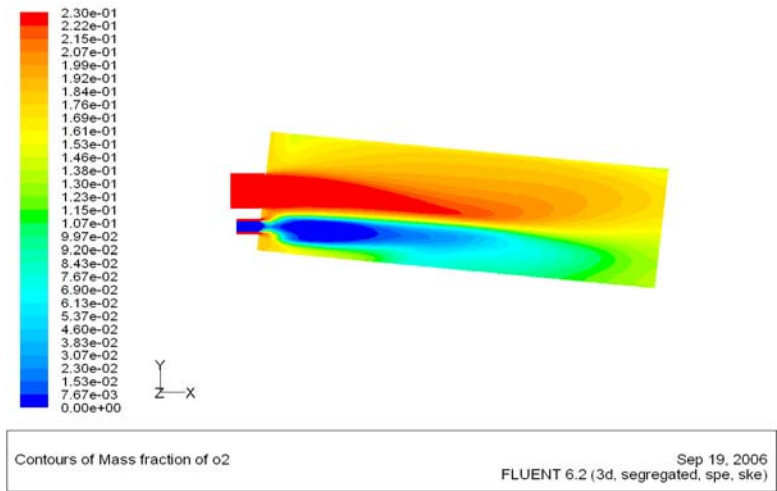
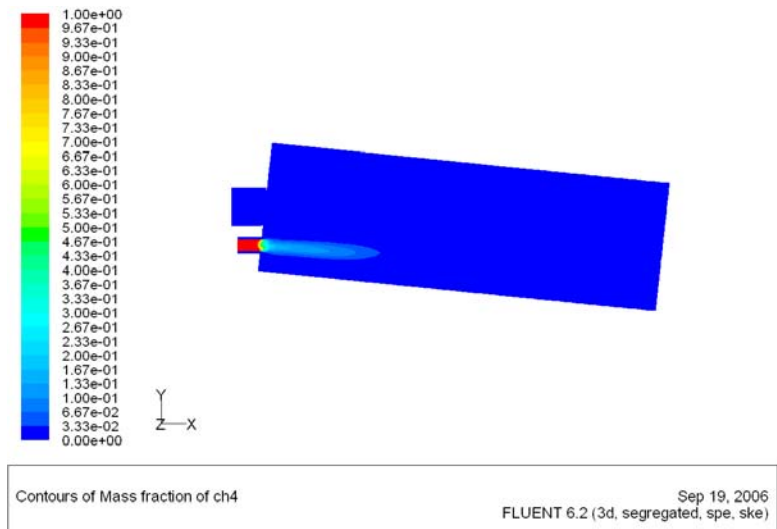Fig. 7: Rate of oxygen distribution in the furnace

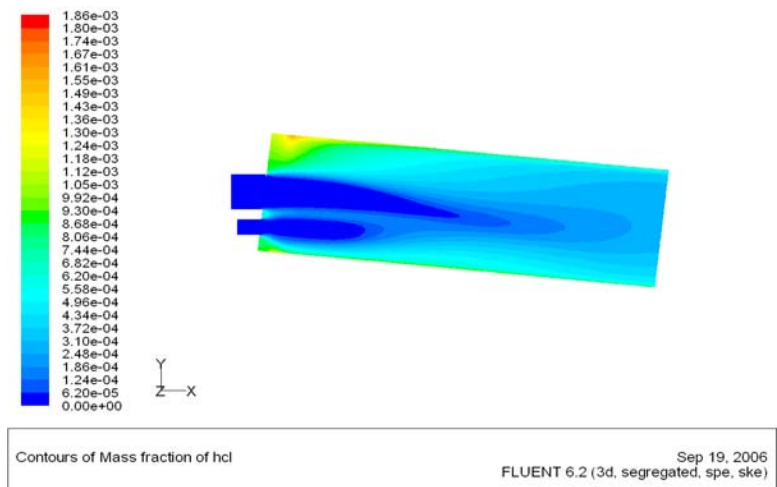Fig. 8: Rate of methane gas distribution in the furnace
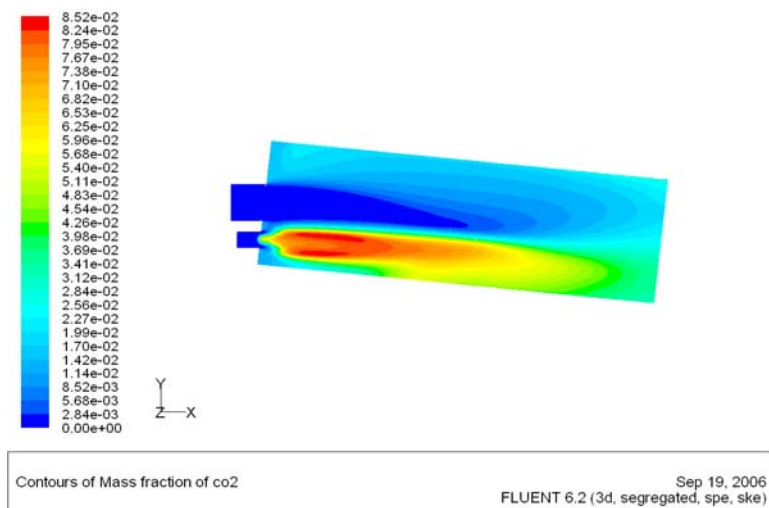

Fig. 9: Distribution rates HCL furnace

Fig. 10: Distribution of the rate of CO_2 gas furnace

atmosphere furnace at 1157 K (884°C) is equal, which can confirm the third hypothesis. In addition, the oxygen distribution according to Fig. 7, the rate of methane in the fuel distribution in Fig. 8 and HCL distribution rate in the furnace of 10, CO_2 gas distribution rates according to Fig. 9 and finally the distribution in the furnace according to Fig. 10, can be regarded as some evidence for complete combustion of fuel and oxygen in the furnace.

However, this system alone cannot be suitable for dangerous hospital waste and an analog temperature controller, mechanical filters and the cleaning fluid are needed for controlling the rate of heat flow every time. This process cannot be possible without using analog or computer-skilled operators that take the effective parameters into account.

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