PROCESS ENGINEERING DESIGN OF TOBACCO WASTES INCINERATOR WITH UTILIZATION OF COMBUSTION GASES HEAT ENERGY

By

ASMAA ELMANSY IBRAHIM IBRAHIM

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
CHEMICAL ENGINEERING

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Title of Thesis:
Process engineering design of tobacco wastes incinerator with utilization of combustion gases heat energy

Key Words:
Summary:
The objective of this thesis is to develop an integrated incineration unit which is technically and economically capable for the efficient handling of tobacco-waste processing plant with the subsequent utilization of the heat content of combustion gases. The incinerator engineering design is based on the composition of solid wastes disposed from the tobacco processing plants of the Eastern Company in 6th October city. The basis of design depends on feeding the incinerator with 1 t/h of solid waste consisting of: 50% tobacco, 20% paper& cartons, 20%wooden boxes, and 10% plastic materials. The remaining ash after the incineration process does not exceed 5% of the original volume of feed stock. The overall material & energy balances reveals discharging combustion gases at mass flow rate of 25490 kg/h with heat content of 20 092 348 kJ. Flue gases energy is utilized either in generating saturated steam or producing hot water. An engineering design is given for: (i) a fired-tube boiler capable to generate 7 t/h saturated steam at 185 ºC & 10 bar, and (ii) 1- 4 shell and tube heat exchanger that produces hot water rated 80 t/h at 85 ºC. The temperature of the exhaust effluent combustion gases vented to the atmosphere is 200 ºC, that proves a highly efficient utilization of their original heat content. The calculated results are in excellent conformity with the data given in the fabricator incinerator manual already installed in the Eastern Company plants.

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Symbols and Abbreviations

NSWMP	National Solid Waste Management Programmer
GDP	Gross Domestic Product
GNI	Gross National Income
EEAA	Egyptian Environmental Affairs Agency
PCDFs	Polychlorinated dibenzodioxins
PCB	Polychlorobiphenyls
HHV	High Heating Value
LHV	Low Heating Value
C.V	Calorific Value
PVC	Polyvinyl Chloride
PP	PolyPropylene
CO_2	Carbon Dioxide
CH_4	Methane
C_2H_6	Ethane
C_3H_8	Propane
iC_4H_{10}	*i*-Butane
nC_4H_{10}	*n*-Butane
iC_5H_{12}	*i*-Pentane
nC_5H_{12}	*n*-Pentane
C_6H_{14}	Hexane
M_{wt}	Molecular weight
M^{C}_{dry}	Mass Flow Rate of Dry Waste
M°_{wet}	Mass Flow Rate of Wet Waste
m°	Mass Flow Rate
V°	Volume Flow Rate
NO_2	Nitrogen Dioxide
SO_2	Sulfur Dioxide
HCl	Hydrogen Chloride

G.H.V	Gross Heating Value
Q°	Heat Transfer Rate
Cp	Specific Heat
H_{fi}^{o}	Standard Enthalpy of Formation
H	Heat of Reaction
A , B, C and D	Constant values
T	Temperature
P.N.G	Primary Natural Gas
S.N.G	Secondary Natural Gas
$M_{c.g}$	Mass flow Rate for Combustion Gases
$Cp_{c.g}$	Average Specific Heat of Combustion Gases
T_g	Temperature of Gases
M_w	Mass Flow Rate of Water
Cp_v	Specific Heat of Water Vapor
T_s	Temperature of Saturated Steam
T_{air}	Temperature of Air
T_w	Temperature of Water
h_{air}	Heat Transfer Coefficient of Air
h_w	Heat Transfer Coefficient of Water
t_{tube}	Thickness of tubes
K_{tube}	Thermal conductivity of carbon steel
A_{tube}	Area of tube
FCI	Fixed-Capital-Investment
PEC	Purchased Equipment
DPC	Total Direct Plant Cost
IDPC	Total Indirect Plant Cost
λ	Rate of Return on Investment
τ	Period of Return

Abstract

The objective of this thesis is to develop an integrated incineration unit which is technically and economically capable for the efficient handling of tobacco-waste processing plant with the subsequent utilization of the heat content of combustion gases. The incineration process is conducted in successive chambers that withstand high temperatures generated by natural gas firing burners. The engineering assembly of the incinerator compartments allow sufficient flying time for the waste-combustion gases to ensure complete the incineration process.

The incinerator engineering design is based on the composition of solid wastes disposed from the tobacco processing plants of the Eastern Company in 6th October city. The basis of design depends on feeding the incinerator with 1 t/h of solid waste consisting of: 50% tobacco, 20% paper& cartons, 20%wooden boxes, and 10% plastic materials. The remaining ash after the incineration process does not exceed 5% of the original volume of feed stock.

The incinerator consists mainly of a primary ignition chamber where whose temperature could reach 850 ºC, followed by secondary combustion chamber in which flue gases temperature is increased to 1200 ºC. The proposed reliable engineering assembly of the combustion chambers will verify flue gases residence time of 2 & 0.5 s in primary and secondary ignition chambers respectively to ensure complete combustion of all waste-components. The heat energy required to reach such high destructive temperatures is supplied by: (i) natural gas burners located in both primary and secondary ignition chambers, and (ii) high calorific values of waste constituents.

The overall material & energy balances reveals discharging combustion gases at mass flow rate of 25490 kg/h with heat content of 20 092 348 kJ/h. Flue gases energy is utilized either in generating saturated steam or producing hot water. An engineering design is given for: (i) a fired-tube boiler capable to generate 7 t/h saturated steam at 185 ºC & 10 bar, and (ii) 1- 4 shell and tube heat exchanger that produces hot water rated 80 t/h at 85 ºC. The temperature of the exhaust effluent combustion gases vented to the atmosphere is 200 ºC, that proves a highly efficient utilization of their original heat content. The calculated results are in excellent conformity with the data given in the fabricator incinerator manual already installed in the Eastern Company plants.

A economic study including profitability analysis has been conducted. The study is based on equipment offers from specialized suppliers for the incinerator and its accessories, together with updated utilities prices. The results prove an annual return on investment of 5 %with a payback period of 8 years. When the environmental return is taken into account the annual return is increased to 20% while the payback time is reduced to 4 years