

Sept. 9, 1969

H. R. AMUNDSEN

3,465,696

OPEN PIT VORTEX INCINERATION ARRANGEMENT

Filed Feb. 26, 1968

4 Sheets-Sheet 1

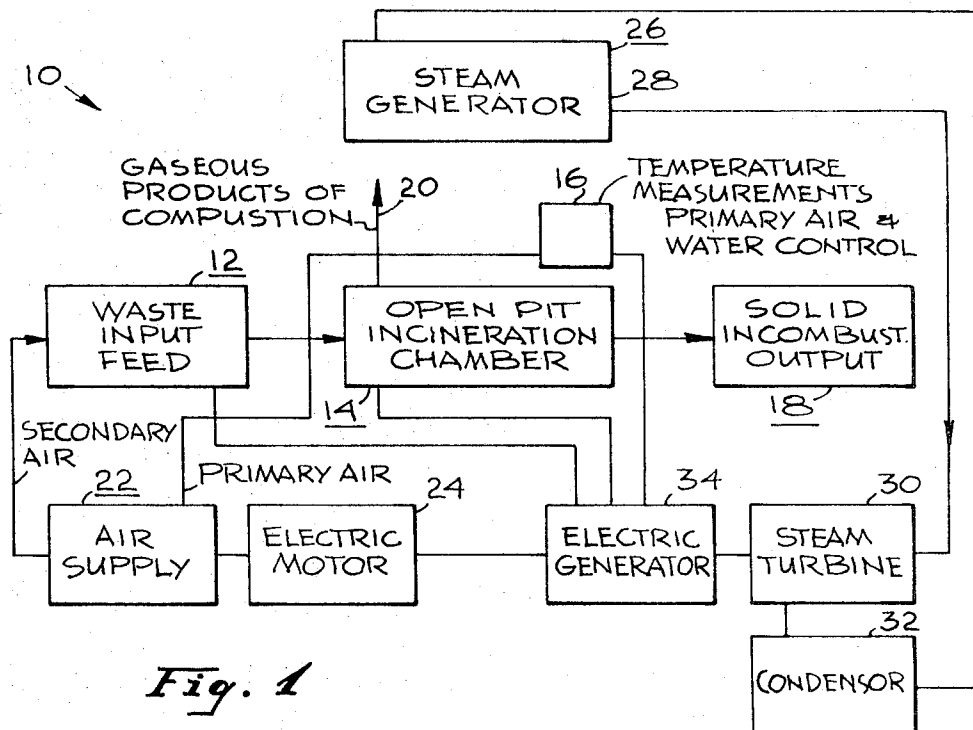


Fig. 1

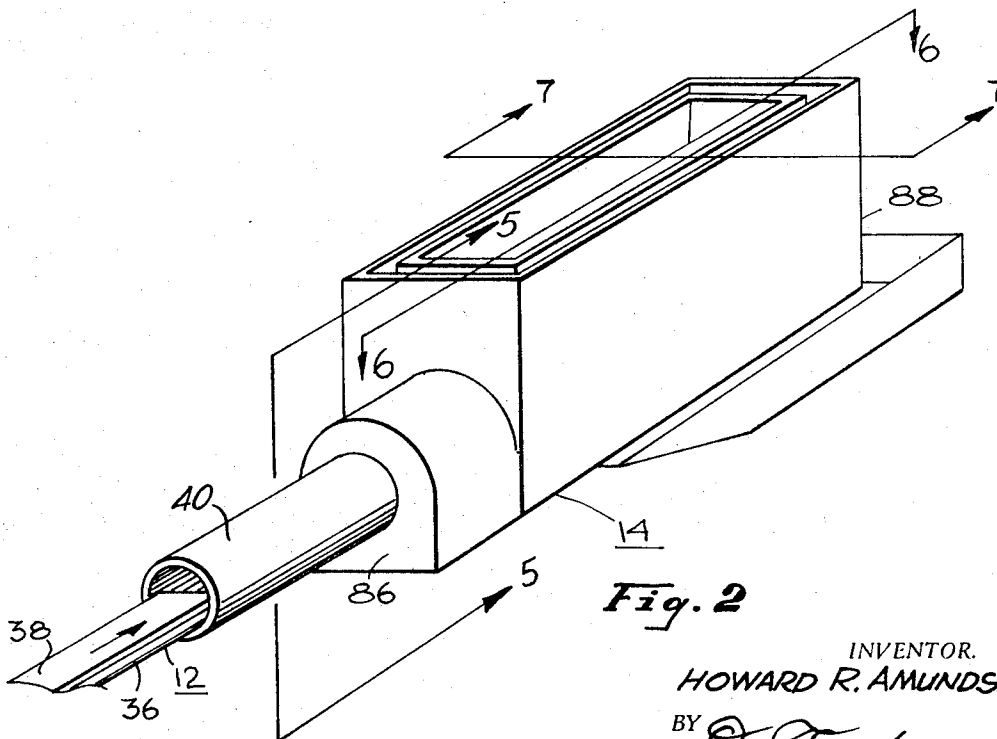


Fig. 2

INVENTOR.
HOWARD R. AMUNDSEN
BY *Don Timmelstein*
ATTORNEY

Sept. 9, 1969

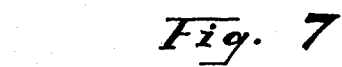
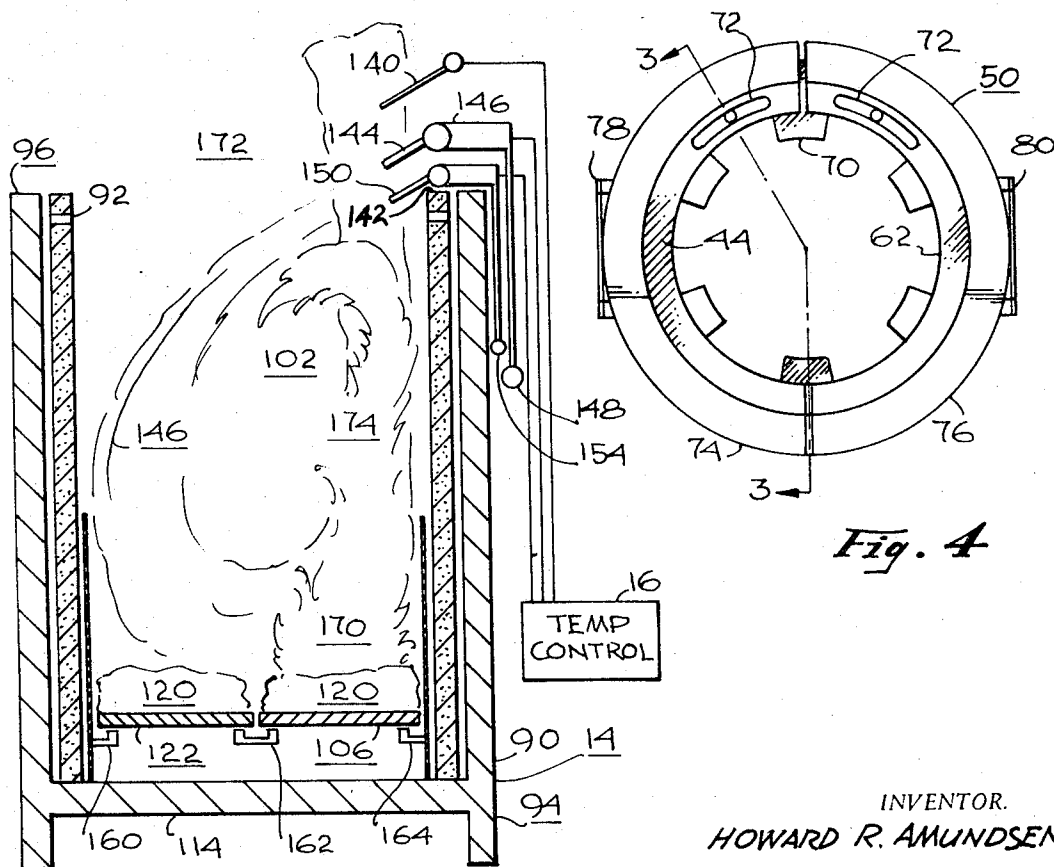
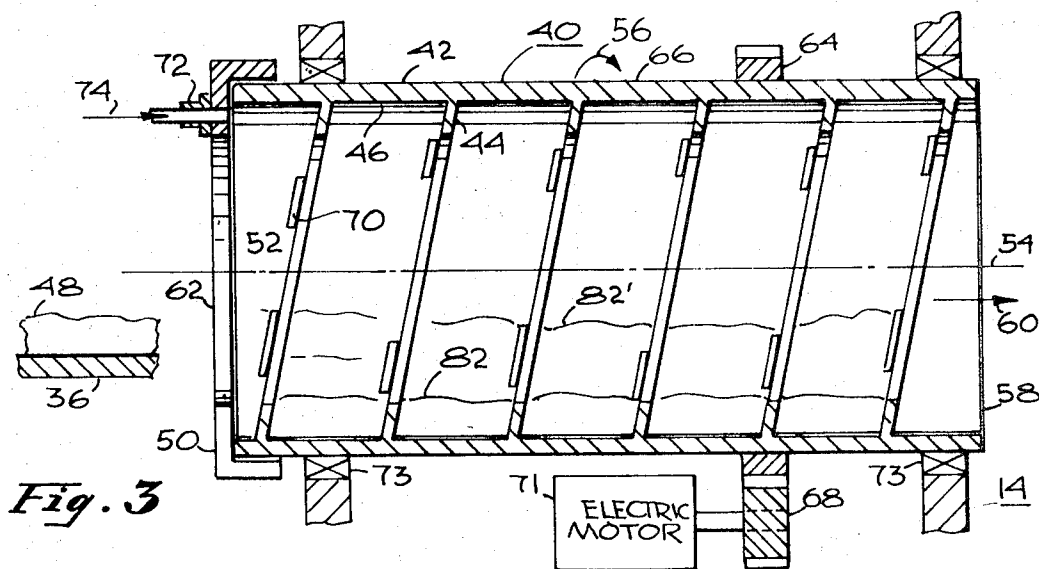
H. R. AMUNDSEN

3,465,696

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4 Sheets-Sheet 2



INVENTOR.
HOWARD R. AMUNDSEN
BY *Don Finkelstein*
ATTORNEY

Sept. 9, 1969

H. R. AMUNDSEN

3,465,696

OPEN PIT VORTEX INCINERATION ARRANGEMENT

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4 Sheets-Sheet 3

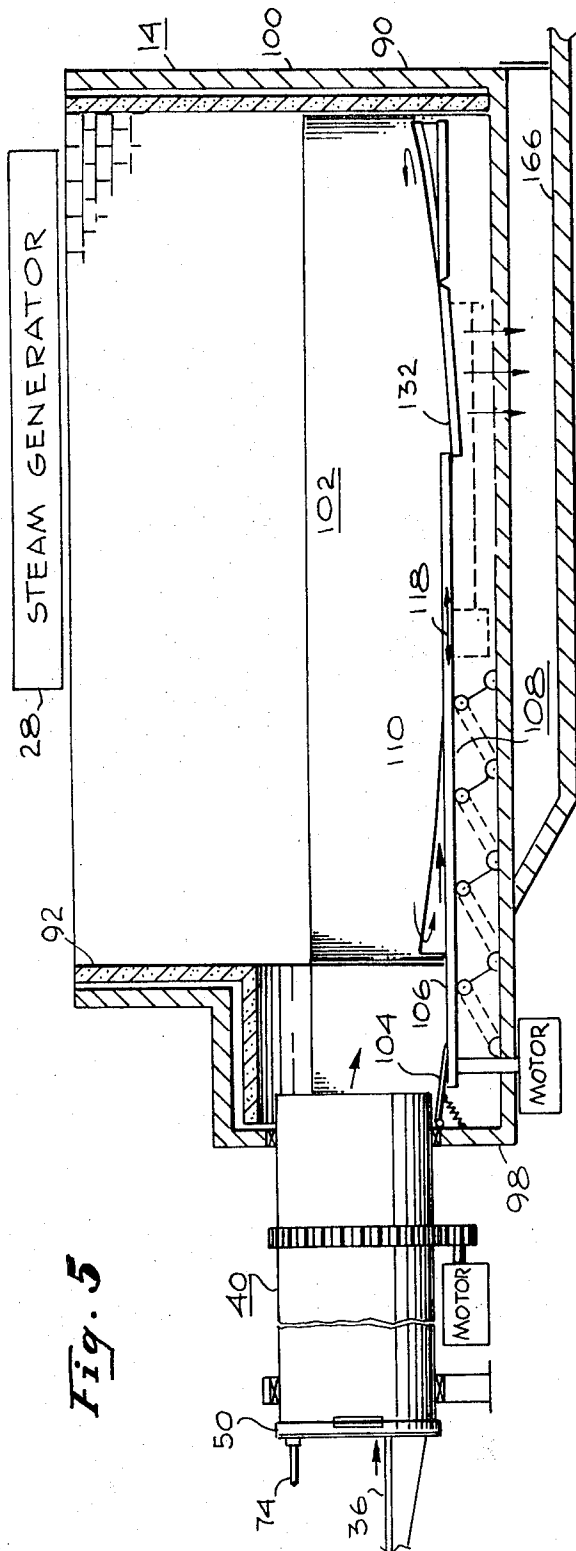


Fig. 5

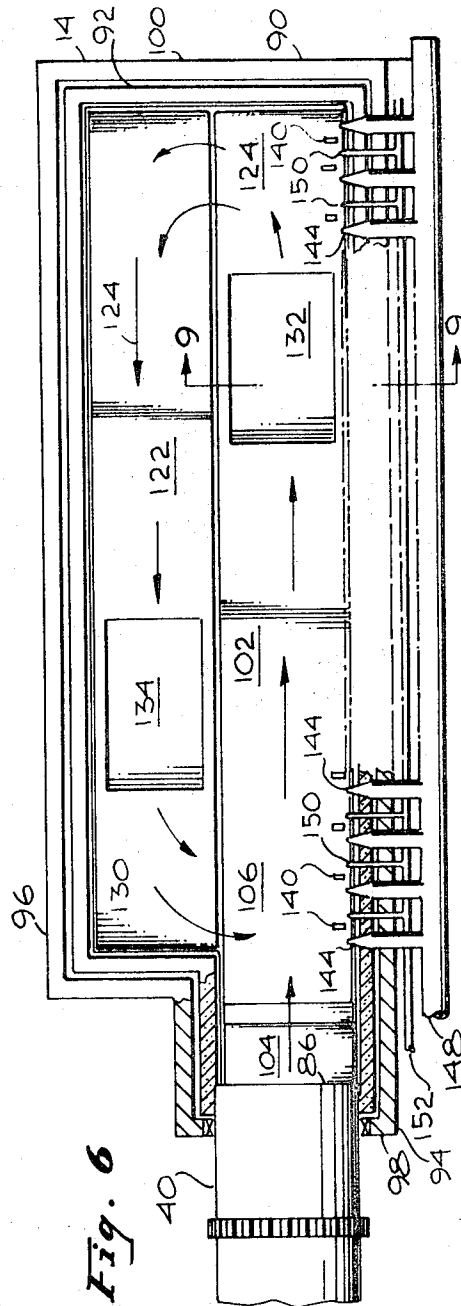


Fig. 6

INVENTOR.
HOWARD R. AMUNDSEN

BY

BY *Don Finckelstein*
ATTORNEY

Sept. 9, 1969

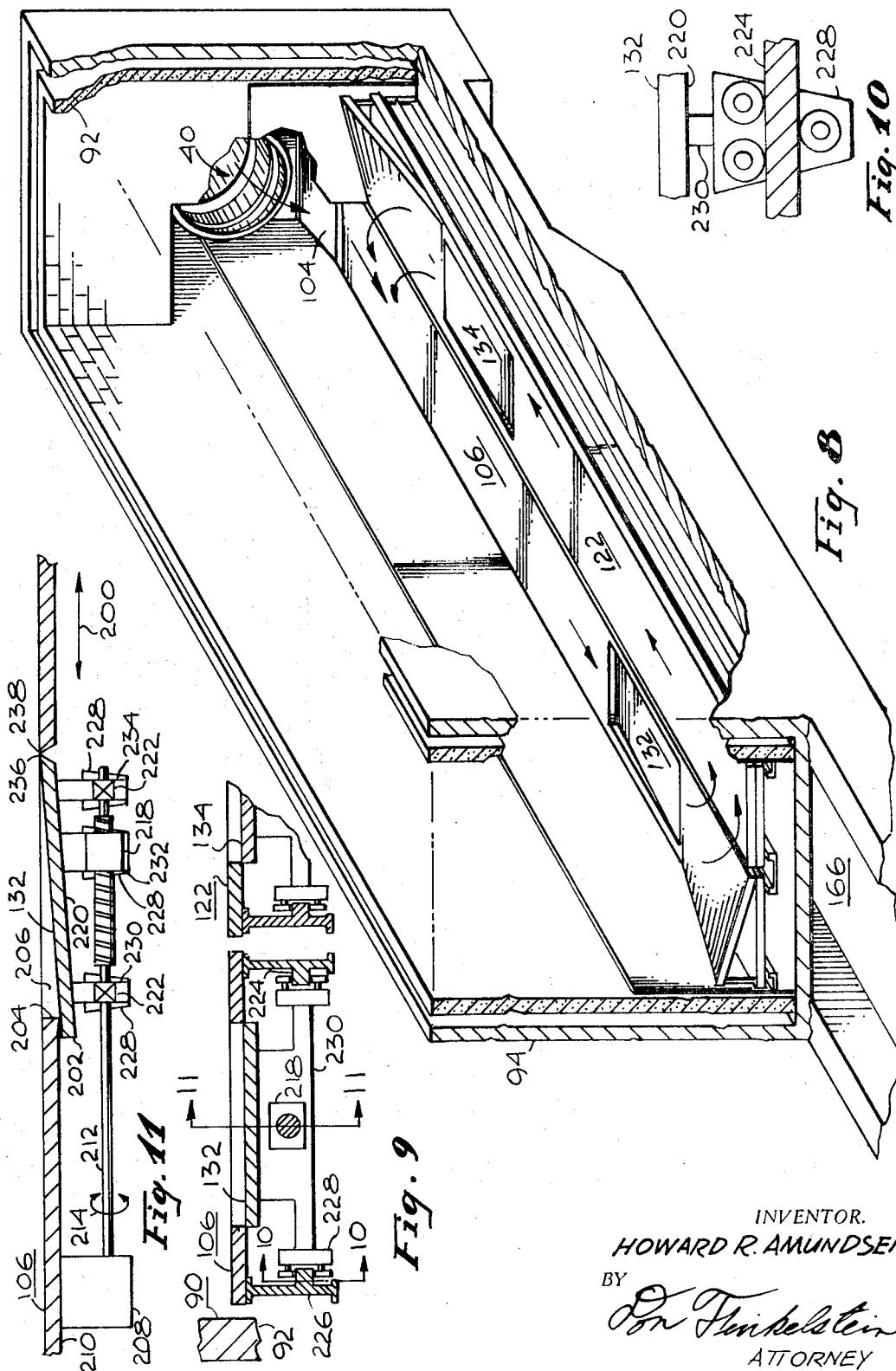
H. R. AMUNDSEN

3,465,696

OPEN PIT VORTEX INCINERATION ARRANGEMENT

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4 Sheets-Sheet 4



INVENTOR.
HOWARD R. AMUNDSEN
BY
Don Fenkelstein
ATTORNEY

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3,465,696 OPEN PIT VORTEX INCINERATION ARRANGEMENT

Howard R. Amundsen, 6782 Homer St.,
Westminster, Calif. 92683

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U.S. Cl. 110—8

8 Claims

ABSTRACT OF THE DISCLOSURE

There is disclosed herein an open pit incineration arrangement for heterogeneous waste and refuse such as that collected through the world by various municipalities and private organizations for disposal. In this incineration arrangement the heterogeneous refuse is fed into an open pit incineration chamber where it is transferred throughout the length thereof by an oscillating hearth. Solid materials not converted into gaseous products of combustion in this first traversal are recirculated within the open pit incineration chamber in the opposite direction by a second oscillating hearth and automatically returns to the first oscillating hearth adjacent the input to the incineration chamber. Such continuous recirculation continues until the material is substantially rendered into a state of incombustible solids. Grates or other waste removal devices are provided within the incineration chamber to allow removal of the solid incombustible materials left in the incineration chamber. Thermodynamic control is exercised to measure the flame temperature within the open pit incineration chamber. The flame temperature is controlled so that a gas producer zone is provided adjacent to the oscillating hearths, wherein the waste is, in general, burned to products of incomplete combustion. Primary air is directed into the open pit incineration chamber from regions adjacent to top thereof to establish a vortex having an axis substantially parallel to the direction of the travel of the waste on the oscillating hearth by a plurality of individually controlled air nozzles. A plurality of thermocouples or other temperature sensing devices are also provided to monitor continuously the flame temperature adjacent to each nozzle and through appropriate control means the air flow to maintain the flame temperature within a predetermined temperature range is controlled. As products of incomplete combustion from the gas producer zone move upwardly in the vortex to the furnace zone within and above the air jets they are burned to products of complete combustion. Secondary air flow is also provided through the feed mechanism in directions parallel to the axis of the vortex so that materials having a large surface area to mass ratio may be burned with great rapidity to products of complete combustion and/or gasify with increased rate into other carbon and hydrogen reactions. Many materials in this category will contain oxygen up to 30 percent.

Water spray through nozzles are used as auxiliary flame temperature control and are located adjacent to the primary air nozzles to provide a dousing stream of water for lowering the flame temperature in the event that the flame temperature should suddenly rise to a value greater than the predetermined temperature range. The heat of flame is diluted in the conversion of water to steam. The heated gases of the products of complete combustion may be utilized as the heat source in a conventional steam generator-steam turbine power plant for providing electrical energy to drive the air compressor for the primary and secondary air flows as well as the mechanical power necessary for the feed and transfer mechanisms.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to the incineration art and more particularly to an improved arrangement for burning heterogeneous waste products to products of complete combustion.

Description of the prior art

Waste and refuse disposal is presenting increasing problems substantially throughout the world as the number of people in the world increase, as the concentration of people in limited geographic areas increases and as in the industrial civilization level rises throughout the world. Thus, the disposal of both solid and liquid refuse and/or waste products that are inevitably generated can no longer be handled in the traditional methods of waste disposal. That is, inefficient incineration cannot be utilized since the inefficient incineration often gives rise to smog or highly odoriferous gases emitted from the place of incineration. Land fill processes whereby solid and liquid waste and refuse is utilized to fill land which subsequently may be utilized for other purposes at best has only a limited applicability since the amount of land conveniently adjacent to the source of the waste and refuse is constantly dwindling as the population density increases and, further, the 40 to 50-year wait in time before such land is structurally stable can be utilized, for example, for buildings of one nature or another is often impractical. Additionally, the constant emission from such filled land of various gases adds to the smog problem as well as emitting noxious gases. Thus, the land is not stable or fit for human habitation until the end of 40 to 50 years when all organic materials have broken down.

For example, in certain areas of California, filling land with solid wastes has been shown to produce more smog, higher temperatures and more frequent and denser winter fogs and the loss of rain fall. Summer temperatures, in certain areas, could rise by approximately 5° and drop by approximately 2 to 3° in winter. The summer temperature rise would result in a reduction in winds bringing relief to the western shores of the United States. Smog would increase because new land masses would produce more frequent temperature inversion which hold smog captive at ground levels.

The disposal of garbage by upstream water users has reached the point where water pollution as well as air pollution is a major problem. For example, in the city of San Francisco approximately eight pounds per person per day of garbage is generated and San Francisco has traditionally dumped this garbage in the Brisbane area tide lands. The growing population in the Brisbane area has now made such dumping practices controversial and subjected to court litigation.

Additionally, the nature and characteristics of the waste and refuse is constantly changing. For example, waste and refuse once consisted primarily of garbage and ashes. However, now, it may include dead animals, industrial wastes, demolition and construction refuse, old appliances, junk automobiles and machinery, glass containers and the like. Thus, the waste and refuse may contain anything from a bed spring to a watermelon rind; from an automobile to a telephone pole with climbing cleats attached. While a 165,000,000 tons of solid waste was discarded nationally in 1966 in the United States, it is estimated that this amount will reach 260,000,000 tons by 1976. Further, the many important inorganic materials such as metals and the like, must be recoverable from the waste disposal arrangement in order that shortages in such materials do not become prevalent. For example, by the year 2000 in the United States population will be

consuming an estimated 33.7 million tons of canned foods and beverages each year, compared to only 16.7 million tons consumed in 1960. If most of these containers are not reprocessed, the can makers will run short of the primary can materials. In the year 2000, in the United States, it is estimated that some 474,000,000 tons of paper and paperboard will be used annually for packaging and there will be 3.2 billion pounds of rigid or molded glass or plastic used in packaging materials. Such glass or plastics are far more difficult to process efficiently in traditional waste disposal methods.

Accordingly, it is necessary to burn the combustible materials to their products of complete combustion and leave the incombustible materials for further reprocessing to extract any desired material therefrom in as efficient and economic a process as possible. While the composition of both the solid waste as well as the liquid waste may be variable, the constituents thereof, though the percentage change, will be substantially the same. Therefore, by an analysis of the typical components on a weight basis from a large sample in any metropolitan area, it may be determined what the percentage of such constituents would be.

When such a material is burned in an incineration arrangement, desirably the residual would only be non-combustible inorganics and the products of complete combustion, namely ash, carbon dioxide, water and accompanying inert nitrogen. As noted above, however, traditional incineration arrangements generally resulted in incomplete combustion with the resultant emission of smog producing gases that may also be odorous and/or noxious. Such incineration arrangements were often economically impractical since the investment in operational costs approached that of a manufacturing operation but in which no end product for subsequent sale is provided.

It is known, of course, that complete combustion of gaseous fuels is readily achievable at atmospheric pressure, though complete combustion of solid and liquid fuels is not so readily attained at atmospheric pressure since they require, in general, higher pressures to achieve complete combustion. Thus, in an attempt to incinerate efficiently the heterogeneous waste and refuse, it has often been proposed to provide a chamber operated at greater than atmospheric pressure. The very inconsistency of solid wastes may either preclude its introduction into such a chamber or require the homogenization of the wastes by grinding or the like into fine enough particles so that such wastes may be rendered substantially uniform in nature. Such grinding, as well as a pressure chamber for combustion is, of course, economically expensive and of limited size capabilities. Further, the control of both the temperature in turbulent mixing within the chambers can only be generally exploited for a specific and consistent homogeneous mixture.

Therefore, it is desirable to provide an incineration arrangement operating as an open pit or essentially at atmospheric pressure wherein heterogeneous liquid and solid waste and refuse may be economically fed and in which the combustible products thereof are, ultimately, burned to products of complete combustion.

SUMMARY OF INVENTION

Accordingly, it is an object of applicant's invention herein to provide an improved open pit incineration arrangement.

It is another object of applicant's invention herein to provide an incineration arrangement in which heterogeneous liquid and solid waste and refuse may be fed without prior classification or processing for incineration therein.

It is another object of applicant's invention herein to provide an improved incineration arrangement in which combustible products are burned to products of complete combustion.

It is yet another object of applicant's invention herein

to provide an incineration arrangement that is economical to construct and operate.

The above and other objects are achieved, accordingly to one aspect of applicant's invention herein, by providing both the structural elements utilized for an open pit incineration arrangement as well as appropriate thermodynamic control thereof.

In one embodiment of applicant's invention a waste and refuse input feed arrangement which, in this embodiment of applicant's invention, may comprise an oscillating conveyor for receiving the heterogeneous waste and/or refuse from appropriate collection vehicles such as garbage trucks, trash collection trucks and the like, and the feed oscillating conveyor transfers the heterogeneous waste and refuse as received into a screw feed structure for transfer into an open pit incineration chamber. In the preferred embodiment of applicant's invention, the screw feed arrangement is an Archimedean screw conveyor for transfer of the material from the feed oscillating conveyor into the open pit incineration chamber. The utilization of solid surface oscillating conveyor and Archimedean screw principles of conveyance are used because these conveying mechanisms are not subject to being stopped by mechanical interference from any material conveyed upon or within the confines of their conveying surfaces. Both motions also have material classifying characteristics, reverse and vanning classification. Classification of material entering the incinerator is conducive in this design to exploiting the high gasification rate of the bulk of material which statistically has a high surface to mass ratio. The characteristics of classification, also performs load-leveling for denser material, thereby forming a cohesive and consistent fire bed in the incinerator which is favorable to the exploitation of specific heats of materials and the gasification of combustible solids. Both reverse and vanning classification assist in settling the ash out of the burning bed. The introduction of solid waste into the incinerator in the above described manner will reduce the quantity of particulate matter emitted in the flue gas because much of the finer and denser material is never airborne and furthermore is subjected to greater cohesion and adhesions in the fire bed due to the more intense temperature experienced in this design than used in traditional incineration.

The cohesion and adhesion of particulate matter to the body of the fire bed is the result of almost invariable stickiness of both organic and inorganic material at temperatures in excess of 2000° F.

The open pit incineration chamber is essentially bounded by four walls and has an open top and a base. The base comprises a transfer arrangement of a solid surface oscillating conveyor hearth for moving the heterogeneous waste and refuse from the Archimedean screw feed discharge to the remote end of the open pit incineration chamber.

The conveyed burning waste material is delivered through the means of oscillating motion of the hearth up to a remote end of the solid surface oscillating conveyor hearth at the remote end of the chamber. When the conveyed load has advanced to the remote chamber end wall and can advance no further and when it can no longer assume an angle of repose, it must then transfer into another area offering less resistance to movement or displacement. The area offering the path of least resistance is an adjacent and parallel solid surface oscillating conveyor hearth conveying in the opposite direction. The transfer is assisted by the use of a banked curve that is incorporated in the surface of the oscillating conveying hearth at the approach to the chamber end wall. The transferred conveyed burning material is then conveyed in the direction from whence it entered the incinerator. The conveyed burning bed is then transferred in the manner previously described into the path of the incoming unignited waste material and thereby, provides the initial ignition for unburned waste material at its inception into

the incinerator. The remote or discharge ends of both solid surface oscillating conveyor hearths in the incinerator are identical in design and function. Any or all burning material and residue will automatically remain in recycle until removed.

It is assumed that a part of the solid waste introduced in the incineration chamber will not be completely reduced to incombustible products by the time it has reached the remote end of the chamber. Thus, the design of applicant's improved incineration arrangement permits the recycling of the unconsumed solid combustibles on the bed until they are completely reduced. Such solid products may be removed by a sliding grate that is incorporated into each section of the solid surface oscillating conveyor hearth. The sliding grate can be mechanically actuated to open or close to any desired opening size. The sliding member in either open or closed position is housed within the frame and support of the solid surface oscillating conveyor hearth. The sliding member is closed by moving in the same direction as the conveyed material while moving to closed position. The sliding member can move much faster in closing than can the rubbish being conveyed on it during closing movement. Therefore, because of the difference in the respective speeds of closing and conveying, the sliding member can, without interference, achieve a complete closure with the fixed end of the solid surface oscillating conveyor hearth in which it is housed.

The two sliding grates can be operated either separately or simultaneously to any predetermined or controllable aperture size desired. Any object that can be introduced into the furnace can be discharged from it without any mechanical interference.

The above short summary of the structure of applicant's invention indicates the feed, transfer and discharge arrangements preferred by applicant for his improved incineration arrangement. However, in order to achieve the proper combustion results, that is, the burning of the combustible materials to products of complete combustion, requires the thermodynamic considerations of the combustion characteristics of the waste and refuse.

Many disciplines in thermodynamics are required in burning the heterogeneous mass of combustibles in solid waste to a product of complete combustion one, among the many disciplines required, is the utilization of recuperative heat.

The incinerator is a combination of a gas producer and a gas furnace and therefore utilizes recuperative heat in order to achieve the highest degree of efficiency in synthesis and production rate of gas. Heat is stored in the incinerator chamber walls, refractory lining and in the fire bed on the hearth consisting of the ash and other non-combustible solid waste. The specific heats of non-combustible materials are exploited in order to sustain ignition temperatures of combustible materials and assist in maintaining temperature ranges required for the synthesis of gas from carbohydrates and hydrocarbons in the solids and liquids to the extent that common limits of inflammability can be established. This is required in order that a common fuel to air ratio can be established that will, ultimately, burn all of the component gases to a products of complete combustion.

The importance of exploiting the specific heat of materials is based upon the heat transfer relationship that when hot and cold bodies are put in contact, the hot body transfers heat to the cold one until both reach the same temperature.

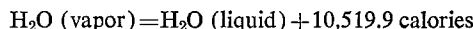
Many of the source materials for recuperative heat that are in solid waste have a low specific heat. This means that these materials gain heat and lose heat slowly. Therefore, when such materials are ultimately heated, they provide a constant source of heat for a considerable period of time. Through contact, such a heat source is able to raise the temperature of most combustibles to a point where ignition occurs.

Examples of specific heats are as follows:

Water	1
Iron	113-118
Stone and brick	.192-.197
Paper and wood	approx. .600
Ash	.200-.250

There are other factors effecting the production of a product of complete combustion from heterogeneous solid and liquid waste; i.e., the reactions that take place in the gas producing phase within the open incinerator gas generator chamber are producer air gas and water gas reactions.

Water when present is in the liquid form. The heat of condensation of steam to water at 25° C. is represented by the equation:



A positive sign indicates that heat is evolved and a negative sign that heat is absorbed. The values are for the reactions at a constant pressure.

TABLE I.—GAS REACTIONS INVOLVED

Reaction:	Heat of reaction, calories
$\text{C} + \text{O}_2 = \text{CO}_2$	+94,051.8
$2\text{C} + \text{O}_2 = 2\text{CO}$	+52,831.4
$\text{CO}_2 + \text{C} = 2\text{CO}$	-41,220.4
$200 + \text{O}_2 = 2\text{CO}_2$	+135,272.2
$2\text{H}_2 + \text{O}_2 = 2\text{H}_2\text{O (liq.)}$	+136,634.8
$\text{C} + \text{H}_2\text{O (liq.)} = \text{CO} + \text{H}_2$	-41,901.7
$\text{C} + 2\text{H}_2\text{O (liq.)} = \text{CO}_2 + \text{H}_2$	-42,583.0
$\text{CO} + \text{H}_2\text{O (liq.)} = \text{CO}_2 + \text{H}_2$	-681.3

It should be noted that in order to have a reaction it is necessary that there be a physical union between the elements, i.e., in making CO_2 , C must be in the intimate presence of O_2 . This establishes the requirement for turbulence.

From the above data, it is obvious that heat must be stored in order to achieve practical incineration.

There are, under given physical conditions, both "lower" and "upper" composition-limits of inflammability. Within, but not outside these limits, self-propagation of flame will occur, once ignition has been effected.

The approximate limits of inflammability of the pertinent gases, at ordinary temperatures and pressures are subject to these fuel to air ratios in producing a product of complete combustion in the furnace zone.

TABLE II.—FLAMMABILITY LIMITS

Gas	Percent by volume	
	Lower Limit	Higher Limit
Carbon monoxide (CO)	12.5	74
Carbon-disulfide (CS_2)	1.25	44
Hydrogen (H_2)	4.0	75
Methane (CH_4)	5.3	14
Ammonia (NH_3)	5.1	70
Producer water gas ¹	7.0	72
Producer (air gas) ¹	17	70
Blast furnace gas ¹	35	74
Mond's gas ¹	4.0	72

¹ All of the above component gases in the make up of air and water gases have similar practical operating ignition characteristics with the exception of methane (CH_4).

The presence of moisture in solid waste will generate methane (CH_4) unless elevated temperatures are used. The fuel to air ratio for methane is not compatible with carbon monoxide (CO) and hydrogen (H_2) and therefore the methane must be changed to $\text{C} + 2\text{H}_2$ through elevated temperature in order to achieve the same fuel to air ratio required for burning carbon monoxide (CO) and hydrogen (H_2) to a product of complete combustion.

TABLE III.—PRODUCER GAS EQUILIBRIUM
[$2\text{CO} \rightleftharpoons \text{CO}_2 + \text{C}$]

Temp., ° F.	Percent CO_2	Percent CO
1,110.....	68.55	31.45
1,200.....	53.35	46.65
1,290.....	36.60	63.40
1,380.....	21.25	78.75
1,470.....	13.70	86.30
1,560.....	6.23	93.77
1,650.....	2.22	97.78
1,740.....	1.32	98.68
1,920.....	0.37	99.63
2,010.....	0.15	99.85
2,190.....	0.06	99.94

TABLE IV.—METHANE EQUILIBRIUM
[$\text{CH}_4 \rightleftharpoons \text{C} + 2\text{H}_2$]

Temp., ° F.	Percent CH_4	Percent H_2
930.....	63.9	36.1
1,110.....	37.9	62.1
1,290.....	16.3	83.7
1,380.....	13.0	87.0
1,470.....	7.5	92.5
1,560.....	4.5	95.5
1,650.....	3.6	96.4
1,830.....	2.0	98.0
2,010.....	0.8	99.2

The incinerator operating temperature range will be maintained between 2000° F.—2500° F.

Within this temperature range any air-fuel ratio can be maintained that is required to reduce any producer air or water gas to a product of complete combustion, i.e., blast furnace gas or Mond's gas.

Flame temperature vary with heat value of materials and the moisture content. When water is added into combustion processes or exists in the combustible material, flame temperature is reduced to the extent that heat is absorbed in changing water to steam. Air in relationship to flame has similar characteristics. If flame temperature is to be increased, the quantity is reduced. If flame temperature is to be reduced, the air and/or water quantity is increased.

The control of flame temperature within the incinerator is not only important from the rate of production and the cost of maintenance aspects, but it also determines the constituency of the gases in both the producer and furnace zone.

For all gases, the maximum flame temperature is obtained when less air is used than required for stoichiometric or complete combustion.

This is illustrated in the following table showing some examples:

TABLE V.—MAXIMUM FLAME TEMPERATURES OF GASES IN AIR

Gas	Percent of gas in gas-air mixture giving maximum flame temperature	Maximum flame temperature, ° F.
Carbon monoxide.....	34.00	3,542
Hydrogen.....	31.60	3,716
Methane.....	10.00	3,410
Acetylene.....	9.00	4,225

Flame temperatures, just like solutions, can be diluted. The effect of dilution can be illustrated as shown on Table VII: "Data Derived From the IT Enthalpy-Temperature Diagram." In the translation of maximum flame to flame temperatures shown in the material of Table VII, it should be recognized that maximum flame temperature has approximately 90%–95% of the air that is the theoretical amount required for complete combustion. N=1.2 excess air is an excess of 14%.

The control of temperature in the incinerator chamber is important because at elevated temperatures, there occurs a reaction that defeats the achievement of a product of complete combustion during incineration.

The reaction is "dissociation." At high temperature, the combustion of fuels is rendered incomplete because dissociation of carbon dioxide and of water vapor takes

places, there being an equilibrium between CO_2 , CO and O_2 and between H_2O , H_2 and O_2 on the other hand.

As temperatures increase above 2550° F., the CO_2 gradually, at an increasing rate, reverts to CO and O_2 and the H_2O reverts to H_2 and O_2 .

Therefore, temperatures within the furnace zone of the incinerator should be held below 2500° F., if not, carbon monoxide and hydrogen will start to comprise much of the waste gas that is emitted into the atmosphere. The degree of emissions of products of incomplete combustion will be shown in Table VI.

TABLE VI.—DISSOCIATION OF CARBON DIOXIDE AND WATER VAPOR

Temp., ° F.	CO_2 , pressure atmosphere		Water vapor (H_2O), pressure atmosphere	
	1 atm.	0.5 atm.	1 atm.	0.5 atm.
	Percent dissociated	Percent dissociated	Percent dissociated	Percent dissociated
2,550.....	0.2	0.25	0.08	0.10
2,730.....	0.4	0.5	0.15	0.20
2,910.....	0.8	1.0	0.3	0.4
3,120.....	1.5	1.8	0.5	0.6
3,300.....	2.5	3.0	0.8	1.0
3,480.....	3.9	4.9	1.2	1.6
3,660.....	6.0	7.5	1.9	2.4
3,840.....	8.9	11.1	2.8	3.4
4,020.....	12.7	15.7	3.8	4.8
4,200.....	17.5	21.4	5.1	6.4
4,380.....	23.2	28.1	6.8	8.5
4,560.....	29.8	35.7	8.8	10.9
4,740.....	37.0	43.7	11.1	13.8
4,920.....	44.5	51.7	13.7	16.9
5,100.....	52.0	59.3	16.6	20.4
5,280.....	59.3	66.3	19.8	24.2

The completion of the chart "Data Derived From the IT (Enthalpy-Temperature) Diagram" is based on two facts:

(1) Statistical relationships exist among the net calorific value of all industrial fuels, their air requirements and the volume of combustion gas which they produce. These relationships render stoichiometric calculations based on ultimate analyses unnecessary and permit direct derivation of the initial enthalpy of any combustion gas.

(2) For all industrial fuels, equal enthalpies of the theoretical net combustion gas, per unit volume, correspond to equal temperatures. Hence, the gas temperature may be directly derived from the enthalpy of the combustion gas or vice versa without recourse to the composition or specific heat of the gas.

The accuracy of calculations based on IT diagrams suffice for all practical purposes since the deviations are smaller than the errors inherent in technical sampling, in the determination of calorific values, analysis of gases, and in the measurement of temperatures and volumes.

In the use of IT diagrams for the designing of combustion and auxiliary appliances, an excess-air factor must be assumed. In test plants, the factor must be calculated from the composition of the flue gas or derived in some other manner.

If only the gross calorific value of a fuel is known, the net value may be obtained from a table that is based on the results of the correlation of the gross and net values of a large number of solid and liquid fuels and is considered to be accurate to within ± 1 percent.

In order to demonstrate the application and formation of "Data Derived From the IT Diagram" which includes the gas temperatures derived from formulas for enthalpy-temperature diagram for combustion gases, a relationship will be shown between "Typical Components of Representative Solid Waste—percent of 1 Ton" Table VIII and "Properties, Analysis and Formulas Pertinent to Solid Waste."

Properties, analysis, and formulas pertinent to solid waste

A calorific analysis of typical combustible material in a solid waste dump reveals that on an average over a long period of time that

i.e., vegetable matter and asphalt. In the separate determinations of the heat value in the components of combustible waste, the percentage of paper and wood, generally constituting on the order of 67.5% of the approxi-

TABLE VII.—DATA DERIVED FROM IT ENTHALPY-TEMPERATURE DIAGRAM

Solid waste, B.t.u. per lb., 6,700 C gr. (gross) B.t.u., 6,000 C _n (net) B.t.u.	Percent of excess air (solid fuel), N	Air reqd., ft. ³ /lb. fuel, A	Vol. of wet combustion gas, n ft. ³ /lb., V	B.t.u./ft. ³ of combustion gas, I C _n /V	Temp., ° F. combustion temperature	Calorific value of gas, B.t.u./ft. ³ C _n	Air reqd., ft. ³ /ft. ³ gas mix, A
Air factor: ¹							
N=1.....		A	V ₀	I ₀			A ₀
N 1.2 excess.....	14	62	73.5	81.5	3,210	81.5	.567
N 1.4 excess.....	25	74.5	86	70	2,970	70	.680
N 1.6 excess.....	33	87	98	61	2,670	61.1	.775
N 1.8 excess.....	41	99	110	54.5	2,470	54.5	.883
N 2. excess.....	46	112	123	49	2,215	49	1.083
		125	136	45	1,870	45	1.243
Solid waste, B.t.u. per lb., 6,700 C gr. (gross) B.t.u., 6,000 C _n (net) B.t.u.	Wet combustion gas volume, n ft. ³ /n ft. ³ fuel, V	Ratio: air volume to gas volume, A/V	Enthalpy of combustion gas, B.t.u./ft. ³ , I CN/V	Temp., ° F. combustion temp. of mix	Percent of excess air to gas, N	Air for secondary combustion, ft. ³	Total air for product of complete combustion ft. ³
Air factor: ¹							
N=1.....	V ₀		I ₀				
N 1.2 excess.....	1.460	.38	55.7	2,570	N1=—	44.5	106.5
N 1.4 excess.....	1.591	.43	50.1	2,370	N1.2=7	62	136.5
N 1.6 excess.....	1.650	.47	45.3	2,155	N1.4=12	87	174
N 1.8 excess.....	1.782	.50	41.9	2,010	N1.6=18	110	220
N 2. excess.....	2.007	.54	38	1,750	N1.8=22	123	235
	2.182	.57	32	1,535	N2=26	180	305

¹ n-1=Theoretical air required to burn 1 lb. solid fuel (6,000 B.t.u./lb.)

The above units apply also to liquid fuels including creosote and tar mixtures.

Units under furnace applies to gas fuels.

NOTE.—No pre-heat of air or fuel involved. No dissociation of gases involved.

TABLE VIII.—TYPICAL COMPONENTS OF REPRESENTATIVE SOLID WASTE, PERCENT OF 1 TON

	Components of solid waste, percent of 1 ton and weight	Solid product of combustible (ash) and non-combustible inorganic residue	Calorific value B.t.u. per lb. of combustible material that is convertible into gas through a combustion process	Density of material. NOTE.—Water specific gravity of water=1 62.5 lbs. per ft. ³
Organics:				
Paper.....	62%.....	(ash) 2%—		
	1,240 lbs.....	24.8 lbs	6,600	.3-1+
Rags.....	0.5%.....			
	10 lbs.....	(ash) 1%—0.1 lb.	6,000	.3-.6
Wood.....	5.5%.....			
	110 lbs.....	(ash) 1%—1.10 lbs.	6,800	.3-1.5
Garbage, tree trimmings, vegetation, etc.....	7%.....			
	140 lbs.....	(ash)—1.40 lbs.	5,500	.2-.6
Organics, total.....	75%.....	(ash)—27.4 lbs.		
	1500 lbs.....			
Inorganics:				
Metal containers.....	4%.....			
	80 lbs.....	80 lbs.		
Plastics ¹	5%.....			
	100 lbs.....	(ash) 1%—1 lb.	5,000/15,000	.1-1+
Unbroken bottles.....	3.5%.....			
	70 lbs.....	70 lbs.		2.5
Concrete.....	2.5%.....			
	50 lbs.....	50 lbs...		2+
Sand, brick fines, broken glass, dust, etc.....	150 lbs.....	150 lbs.		1.5
Non-ferrous metal.....	.5%.....			
	10 lbs.....	10 lbs.		3+
Asphalt.....	30 lbs.....	(ash) 1% 0.3 lb.	14,000	.7
Rubber ¹	10 lbs.....	(ash) 2% 0.2 lb.	10,000/15,000	.25-.55
Inorganics, total.....	25%.....			
	500 lbs.....	361.5 lbs.		
Grand total.....	100%.....			
	2000 lbs.....	389.45 lbs.		

NOTE.—(ash)—Al., Si, Fe., Mg., Mn., Ca., etc.

¹ Plastics and rubber both organic and inorganic.

² A.V.=.550.

the calorific value is approximately 6700 b.t.u. per pound.

In determining the heat value of solid waste, due consideration is given to the fact that there is a great difference in the calorific value of its combustible components, 75

mate 82% total combustibles, indicated that the value of paper and wood represents the average calorific value of the total combustibles in solid waste.

Average properties of combustibles in solid waste as described above will be:

TABLE IX

Moisture -----	percent----	15
Ash -----	do-----	2
Carbon -----	do-----	41.5
Hydrogen -----	do-----	5.1
Nitrogen and sulphur -----	do-----	0.9
Oxygen -----	do-----	35.5
Volatile matter -----	do-----	80
Calorific value, B.t.u./lb.:		
Gross -----		6700
Net -----		6000
Theoretical air requirement per lb. -----		11.24
Ft. ³ air 30° F., 760 mm. Hg (1 atm.) -----		62.24
Waste gas—ft. ³ wet waste gas at 32° F., 760 mm. Hg per lb. of fuel -----		74.32
CO ₂ content of dry waste gas -----	percent--	20.3
Wet waste composition:		
CO ₂ -----	do-----	17.1
H ₂ O -----	do-----	15.6
Oxides of N and S -----	do-----	0.2
N ₂ -----	do-----	67.1

With less moisture in the fuel, the composition of wet waste gas may be as follows by volume:

CO ₂ -----	percent----	17.5
H ₂ O -----	do-----	8.7
N ₂ -----	do-----	73.8
Dew point ° F. -----		130

Somewhat higher values were assigned to sulphur and nitrogen in solid waste to have a basis for describing the chemical reactions that will take place in incinerating material that may have sulphur and nitrogen content.

The properties of combustibles in solid waste were determined by consulting charts on average properties of solid fuels, other than coal. The charts are based on the facts that natural solid fuels have properties depending on their carbon and hydrogen contents and that so many of the properties are so interrelated that from a knowledge of two suitably chosen properties of any individual fuel, the others may be deduced with considerable accuracy:

Among these properties are:

- (1) Volatile matter content
- (2) Calorific value
- (3) Moisture in air-dried fuel
- (4) Combustion characteristics: namely, air requirements, volume, enthalpy, water-vapor content and carbon dioxide content of the flue gases and flame temperature.

It is essential that temperatures prevail at the furnace zone that exceed the minimum spontaneous ignition temperature of the gases that are to be burned to a product of complete combustion.

The gases generated in the producer zone will have the following approximate minimum spontaneous ignition temperatures at atmospheric pressure and within the proper mixtures with air:

TABLE X

	Ignition temperature (° F.)
Carbon monoxide -----	1060
Hydrogen -----	1040
Methane -----	1190
Ammonia -----	1200
Carbon disulphide -----	250
Hydrogen sulphide -----	560

Most solids that will be reduced to a gaseous state in the producer zone of the incinerator chamber will have relatively low ignition temperatures, i.e., 600 to 900° F. The minimum temperature for efficient combustion is probably 1000° F.

In order to achieve this predetermined temperature, in the preferred embodiment of applicant's invention, appli-

cant provides, in a predetermined spaced array, a plurality of temperature sensing means, such as thermocouples, adjacent the top of the side wall of the incinerator chamber along the path of the first transfer oscillating conveyor. Adjacent to each of the thermocouples, there is provided a primary air nozzle for directing a predetermined amount of air inwardly and downwardly into the open pit incinerator chamber to establish a vortex air flow pattern therein. The vortex established by the primary air has a substantially horizontal axis, that is, aligned in a direction parallel to the direction of travel of the transfer oscillating conveyors. The amount of air flowing from each nozzle is individually controlled by the adjacent temperature measuring means in order that in each of the zones between the screw feed and the remote end of the open pit incineration chamber the flame temperature is maintained within the predetermined temperature range.

Further, in the thermodynamic considerations of applicant's invention, the transfer oscillating conveyors contain a fire bed comprising a predetermined thickness of waste and refuse in various states of combustion. That is, for example, such a bed may be two feet or so thick and comprised of incomcombustibles, ash, and combustible materials that have only been partially burned. Emanating from the fire bed, of course, is the flame in the open pit incineration chamber and it is the flame temperature that is measured by the thermocouples or other temperature measuring means provided. The fire bed and the flame together, may be considered a gas producing zone and in this zone it is desired to provide gaseous products of incomplete combustion from the solid combustible materials contained within the waste and refuse that is fed into the open pit incineration chamber.

While conventional gas producers attempt to maintain comparatively low temperatures so that combustible gases are produced thereby, in applicant's invention, of course, materials having a high surface-to-volume such as newspaper sheets or the like, may be conveniently burned to products of complete combustion in the gas producer zone. However, of course, material such as tree stumps, telephone poles and the like will, in general, according to the principles of applicant's invention herein, not be combusted into products of complete combustion within the gas producer zone but, rather, will be burned to products of incomplete combustion regardless of the number of passes through the open pit incineration chamber required. This is achieved by maintaining the temperature of the flame at such a value that a commonality of fuel-to-air ratio may be predicted based upon the statistical analysis of the contents of the waste and refuse and therefore the air flow adjusted to a predetermined amount in order that the flame temperature is maintained within this predetermined temperature range.

The furnace zone, wherein the gaseous products of incomplete combustion from the gas producer zone are burned to products of complete combustion may be considered as both within the upper portions of the primary air stream that generates the vortex and also the regions over the primary air stream. Within this zone the air flow from the nozzles is such that the commonality of fuel-to-air ratio is achieved since the statistical analysis of the constituents of the trash have indicated what the majority of materials contained therein will be.

Therefore, as described below in greater detail, for the present statistical analysis of waste and refuse products applicant prefers to provide a flame temperature in each region of the open pit incineration chamber as determined by the plurality of temperature measuring means within a range of 2000° F. and 2500° F. Above this temperature, it is indicated, there will be disassociation of certain of the products of combustion. Below this temperature, of course, the products of complete combustion will not be generated but rather products of incomplete combustion will be allowed to be emitted into the atmosphere.

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In certain embodiments of applicant's invention, applicant prefers to provide a conventional steam powered electric generator arrangement for providing energy to power the compressor needed for the air supplies, the control arrangements, and the energy needed for operating the various mechanical structures. Heat exchangers, deriving heat from the incinerator flue gas, provide the steam source. The steam power generator may drive other power sources such as electric motors.

BRIEF DESCRIPTION OF THE DRAWING

FIGURE 1 is a block diagram of applicant's approved incineration arrangement;

FIGURE 2 is a perspective view thereof;

FIGURES 3, 4, 5, and 6 are sectional views of portions thereof;

FIGURE 7 is an end sectional view thereof;

FIGURE 8 is an isometric view thereof; and

FIGURES 9, 10, and 11 are sectional views of portions thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGURE 1 there is shown a block diagram of one embodiment of applicant's improved open pit vortex incineration arrangement. The block diagram in FIGURE 1 indicates both the flow characteristics as well as the thermodynamic and structural arrangements necessary in the practice of applicant's invention herein.

As shown on FIGURE 1, there is an open pit incineration arrangement generally designated 10, according to one aspect of applicant's invention. There is provided a refuse and waste input feed arrangement 12 that transfers a heterogeneous mass of waste and refuse into an open pit incineration chamber 14. The waste and refuse within the open pit incineration chamber 14 is subjected to predetermined thermodynamically controlled combustion as controlled by the temperature measurement primary air and water control means 16. The open pit incineration chamber 14 is also provided with a solid incombustible material output 18 for removal of solid incombustibles from the open pit incineration chamber. Further, gaseous products of complete combustion generally indicated by the arrow 20 leave the open pit incineration chamber.

An air supply 22 which, of example, may be an air compressor, is utilized to supply both primary air to the temperature measurement primary air and water control 16 as well as secondary air to the waste and refuse input feed arrangement. In this embodiment of applicant's invention an electric motor 24 is utilized to drive the air supply 22 and power for electric motor is provided by a conventional steam generator-stem turbine arrangement indicated at 26 comprising the steam generator 28, the steam turbine 30 and the condenser 32 for driving an electrical generator 34 that provides the electrical energy to drive the electric motor 24 as well as for all internal control arrangements and mechanical drives as required by the input feed or in the open pit incineration chamber 14. It will be appreciated, of course, that the arrangement shown for the embodiment of applicant's invention illustrated in FIGURE 1 is substantially independent of any outside source of power. That is, the completely self-contained unit may be conveniently located wherever desired without reference to appropriate power supply requirements.

In order to more fully understand and appreciate applicant's invention herein, applicant will describe first the structural elements comprising applicant's improved open pit incineration arrangement and then will describe the thermodynamic controls imposed thereon for burning waste and refuse.

The waste and refuse input feed

There is shown, referring now to FIGURE 2, a perspective

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view of a schematic representation of applicant's improved open pit incineration arrangement. As shown on FIGURE 2 the waste and refuse input feed means 12 is comprised of a feed oscillating conveyor 36 that receives on the upper surface 38 thereof unclassified and heterogeneous liquid and solid waste and refuse from the appropriate collection vehicles. It is important to the economical practice of applicant's invention herein that such waste and refuse may be fed directly into applicant's improved incineration arrangement without prior classification, homogenization, or the like.

The feed oscillating conveyor 36 transfers the waste and refuse to a screw feed 40. While it will be appreciated that many types of screw feeds may be conveniently utilized in applicant's invention herein, applicant has found particular economic operation with an Archimedean screw for the screw feed means 40. That is, within the internal diameter of the screw means 40 there is provided a spiral wall and the screw means 40 is then rotated so that material is transferred within the internal diameter thereof. It is, of course, necessary that any solid waste introduced into the incinerator arrangement 10 be positively conveyed into the incineration chamber 14 by the input feed arrangement 12. It is highly improbable that representative heterogeneous solids waste and refuse can be conveyed without stoppage through any feed system having an opening through which the heterogeneous solid waste must be forced. That is, such opening will, invariably, at one time or another clog to restrict or stop the flow of solid waste into the incineration chamber 14. For example, representative solid waste and refuse may contain anything from a telephone pole with climbing cleats attached thereto to a portion of a truck frame. While the input feed arrangement 12 may readily accept the telephone pole, it may become clogged because the climbing cleats can hook onto the feeding arrangement 12. In the event that this occurs, any solid waste behind the telephone pole must be removed before the telephone pole can be withdrawn. Similarly, in the case of a truck chassis or portion thereof, the aperture may be just too small to accept that large a piece of waste or refuse.

Applicant has found that an Archimedean screw conveyor is less subject to blockage and stoppage than most other types of conveyors and, accordingly, applicant prefers to use an Archimedean screw in the conveyance of the waste and refuse from the input oscillator conveyor 36 to the open pit incineration chamber 14. The Archimedean screw conveyor conveys material through a revolving tubular cylinder in which there is provided an internal screw or ribbon mounted on the internal surface thereof. Such a conveyor can easily transfer material at the same level, to a greater level or a lower level than the input. It will be appreciated that the Archimedean screw conveyor provides a positive displacement up to the depth of the spiral ribbon or screw thread therein and provide surface contact conveyances for material resting above the height of the ribbon. Therefore, it is apparent, in the Archimedean screw that it can carry and convey material in either direction depending upon the direction of rotation thereof. A typical Archimedean screw conveyor 40 is illustrated in FIGURES 3 and 4. As shown on FIGURES 3 and 4 the Archimedean screw 40 comprises a cylindrical wall 42 having a screw thread or rivet 44 at a predetermined pitch and predetermined height coupled to the interior surface 46 thereof.

Waste and refuse to be burned within the incineration chamber 14 is conveyed into the Archimedean screw 40 by the input feed oscillating conveyor 36. The waste and refuse may be generally indicated as at 48 and passes through an entrance ring 50 to the interior 52 of the Archimedean screw 40, which rotates about an axis 54. Rotation of the Archimedean screw 40 in the direction indicated by the arrow 56 will transfer the waste and refuse 48 from the entrance ring 50 to the discharge end

58 thereof that is positioned within the incineration chamber 14.

The Archimedean screw conveyor provides highly economical operation when combined with applicant's improved incineration arrangement. That is, the structure of an Archimedean screw conveyor minimizes the down time or inoperative time due to clogging or jamming. For example, if a telephone pole complete with climbing cleats is pulled into the conveyor by its rivet screw action, the operator of the conveyor can, if he desires, reject the pole by reversing the direction of rotation. The climbing cleats cannot stop this reversal as it can with other types of screw feed arrangements and, consequently follow the contour of the rivets. Therefore, the resistance to reverse drive cannot be greater than the resistance to drive from the entrance ring 50 to the discharge 58. Since the climbing cleats follow the contours of the rivet screw 44, it is easily rejected by reverse rotation. Similarly, such reversal to drive the hypothetical telephone pole in a backward direction opposite to the direction indicated by the arrow 60 which is the normal feed direction, will also move any solid waste and refuse that is behind it, over it or under it.

On the other hand, if a truck chassis has a small portion that moves from the feed oscillating conveyor 36 into the interior 52 of the Archimedean screw 40 and then has a dimension larger than the aperture 62 in the entrance ring 50 the operator can merely reverse the direction of rotation of the Archimedean screw 40 to reject the truck chassis. For example, the Archimedean screw 40 may be driven through gear means 64 coupled to the external wall surface 66 of the wall 42 by matching gear 68 rotated by electric motor 70. The electric motor 70 is preferably operated in either direction so that the direction of rotation of the Archimedean screw 40 may be comparatively easily changed.

The Archimedean screw also uniquely controls the feed rate of material into the incinerator chamber 14. That is, by the depth of the rivet or screw thread 44, its pitch, and the peripheral speed of the Archimedean screw 40, uniquely define the feed rate. It will be appreciated that the pitch of the rivet or screw thread 44 may be varied throughout the axial length of the Archimedean screw 40. This may provide, if desired, different speeds, heights of travel and agitation during the transfer.

Paddle 70 may, if desired, be attached to the rivet or screw thread 44, or to the interior wall surface 46, to increase the lifting travel height of material beyond their respective normal angles of repose. Further, such paddles often aid in reverse classification which, by definition, is the lifting of material of lowest specific gravity on top of the material of higher specific gravity. That is, in reverse classification the less dense material is on top and the more dense material is on the bottom. For example, if a brick is resting on a piece of paper between portions of the rivet or screw thread 44 and adjacent to the interior wall surface 46, during rotation the paper must continue to climb along the side of the surface 46 so long as the brick rests on it. The brick cannot climb higher nor further than the paper under it. Once the brick loses its angle of repose, the paper is then free to fall backward and, in general, will fall backward on top of the brick and the paper is not inclined to get under the brick again because it does not have the ability to penetrate a denser mass to get under it. As the paper falls away from the periphery of the wall surface 46, and goes toward the interior of the interior 52, it is removed from that part of the Archimedean screw conveyor 40 with the greatest peripheral speed, hence the greatest climbing rate. Thus, free paper will tend to remain in the center resting on the top of the denser material because it has been displaced from the confines of positive physical agitation provided by the spiral rivet 44 or the lifter paddle 70.

If desired, the entrance ring 50 may be provided with air ports 72 through which secondary air indicated by

the arrow 74 is fed into the interior 52 of the Archimedean screw 40. It will be appreciated that while applicant shows the secondary air being directed through the entrance ring 50, it may be also supplied at any axial station along the Archimedean screw 40. The secondary air flow 74 tends to feed the lighter material such as paper which may be readily airborne, into the incineration chamber at a rate faster than the normal feed rate of the Archimedean screw 40 and, further, aid in the rapid combustion of such materials to products of complete combustion within the incineration chamber, as described below in greater detail.

As noted above, the Archimedean screw may be driven by the electric motor 71 and supported in bearings 73.

In the preferred embodiment of applicant's invention, the entrance ring 50 is a split ring construction comprised of a first half 74 and a second half 76 each of which are hinged, respectively, by hinges 78 and 80 to appropriate supporting structure so that they may swing outwardly when desired to allow for comparatively easy reverse flow operations when the Archimedean screw conveyor 40 is operated in reverse.

Since the lighter material such as paper, as noted above, tends to remain along the upper surface 82 of the material contained within the interior 52 of the Archimedean screw conveyor 40, or the surface 82 which would be the level with the paddle 70 attached, it is conveyed into the open pit incineration chamber 14 by surface contact and therefore the secondary air flow 74 can accelerate the rate of travel of such materials through the feed structure.

The incineration chamber

The incineration chamber 14 as shown on FIGURE 2 has an input end 86 and a remote end 88. The Archimedean feed screw 40 transmits the waste and refuse material into the input end 86. The open pit incineration chamber 14, within the confines thereof, burns the waste and refuse, in the manner hereinafter described, to products of complete combustion.

FIGURES 5, 6, and 7 illustrate various sectional views of the incineration chamber 14 and FIGURE 8 is a perspective view, partially in section, thereof. Referring, then, to FIGURES 2, 5, 6, 7, and 8, it can be seen that the incineration chamber 14 is comprised of an outer shell 90 which, according to applicant's invention herein, may be concrete. Spaced apart inwardly therefrom is a liner wall 92 of ceramic tile for thermal refractory purposes. Thus, the incineration chamber 14 may be considered to be comprised, even though of a double wall construction, of a pair of parallel spaced apart side walls 94 and 96, an input end wall 98 and a rear wall 100. The Archimedean screw 40 is positioned to transmit waste and refuse into the interior 102 of the incineration chamber 14 through the feed wall 98 adjacent to feed end 86. The waste and refuse leaves the Archimedean screw feed 40 and, except for those airborne portions thereof that are blown into the interior 102 of the incineration chamber 14, fall upon plate 104 which, in turn, transmits the solid waste and refuse to the first oscillating conveyor hearth 106 forming a portion of the base 108 of the incineration chamber 14. The oscillator conveyor hearth 106 may be of the type manufactured by Link-Belt Company under the name of "Flexmount," "Coilmount," or "Torqmount" oscillating conveyors. The oscillator conveyor hearth 106 moves the waste and refuse in a direction indicated by the arrow 110 from the front wall 98 to the rear wall 100. Reciprocating motion of the oscillating hearth 106 in the direction indicated by the double ended arrows 118 continually move the waste and refuse in the direction indicated by the arrow 110 due to the continuous feed of waste and refuse into the incineration chamber 14 from the Archimedean screw 40. A fire bed 120 is maintained on the oscillating hearth 106 and the material falling thereon and moving

in the direction indicated by the arrow 110 is adapted to be burned within the confines of the incineration chamber 14. If the material is not burned to gaseous products and incombustible products after the first traversal of the incineration chamber 14 on the first oscillating hearth 106 it is recycled in a direction opposite hereto by the second oscillating hearth 122. The second oscillating hearth 122 may be similarly constructed to the first oscillating hearth 106. Similarly, the feed oscillating conveyor 36 may also be similarly constructed.

At the end of the oscillating hearth 106 adjacent to the rear wall 90 there is provided a banked turn 124 so that the normal angle of repose of the material as it is forced therearound by the continuous feed forces the as yet unburned material from the oscillating hearth 106 to the second oscillating hearth 122. The second oscillating hearth 122 moves the material in the direction indicated by the arrow 124 towards the first wall 98 where there is provided a second banked turn 130 that redirected the unburned material onto the first oscillating hearth 106 in regions adjacent the end of the plate 104. Material contained upon the oscillating hearth 106 and 122 are thus continuously recycled within the open pit incineration chamber 14 until they may be removed, as desired, through grate portions 132 in first oscillating hearth 106 or grate portion 134 in second oscillating hearth 122. The dynamics of the movable grates 132 and 134 is described below in greater detail in connection with FIGURES 9, 10, and 11.

As shown in detail on FIGURES 9, 10, 11, each of the oscillating hearths 106 and 122 are provided with movable grates 132 and 134, respectively, to allow removal of material from the chamber 14 as may be desired. The grate 132 is mounted for reciprocating movement with hearth 106, for example, and is also mounted for reciprocating movement in the direction indicated by the arrow 200. As depicted on FIGURE 11, the grate 132 has a first end 202 adjacent on edge 204 of an aperture 206 in the hearth 106. A motor 208 is coupled to the underside 210 of the hearth 106 and rotates screw drive shaft 212 in the directions indicated by the arrow 214. The screw drive shaft 212 has a threaded portion 216 engaging a nut 218 coupled to the underside 220 of the grate 206. The screw drive shaft 212 is rotatably supported in the bearings 222. Rotation of the screw drive shaft 212 moves the grate 132 in the directions indicated by the arrow 200 to open and close the aperture 206 in the hearth 106 as desired. Operation of the motor 208 may be manually controlled.

As shown in FIGURES 9 and 10, the grate 132 is supported on flanges 224 of supports 226 by wheeled guides 228. The guides 228 are coupled to cross members 230, 232, and 234 on each side thereof to control the path of movement of the grate 132.

When the grate 132 is opened, the end 236 thereof moves away from edge 238 of aperture 206 in hearth 106 and towards the edge 204 as close as desired to open up as large a portion of the aperture 206 as desired. Thus, any solid material burned to product of complete combustion or anything else in the fire bed 120 or 134 may be removed in removal pit 166.

As indicated on FIGURE 9, the grate 134 may be similar to the grate 132.

A plurality of temperature measuring means such as thermocouples 140 are positioned in spaced apart relationship adjacent the top portions 142 of the side wall 94 of the incineration chamber 14. As described below in greater detail, the thermocouples 140 measure the flame temperature and control the primary air flow into the interior volume 102 of the incineration chamber 14. The primary air flow is directed into the interior volume 102 through the plurality of nozzles 144 and, as can be seen, is downwardly and inwardly directed from the side wall 94 toward the side wall 96 at an angle approximately 30° to generate the vortex 146 therein. The temperature control 16 receives the signal from the thermocouple 140

and controls the nozzle 144, for example by means of a motor operated valve 146 to control the amount of primary air injected into the volume 102 thereby. Air is supplied to each of the nozzles 144 from air header 148.

Additionally, a plurality of water spray nozzles 150 are provided adjacent each of the primary air nozzles 144 for directing a stream of water into the interior 142 of the incineration chamber 14. These water nozzles 150 are supplied by water header 154 that are utilized as an emergency condition to prevent any exceptionally high temperature from causing damage to the structure. For example, if a load of magnesium happened to be contained within the waste and refuse on the oscillating hearth 106, the sudden combustion of the magnesium could be deleterious to the structure without proper cooling efforts.

As gutters 160, 162 and 164 are positioned adjacent the longitudinal edges of the first oscillating hearth 106 and second oscillating hearth 122 as indicated in FIGURE 7. These may be arranged to empty into removal pit 166 where the materials from the grates 132 and/or 134 are dumped so that they may be removed therefrom for further processing to recover any desired constituents thereof.

For clarity, the steam generator system 26 has been omitted from FIGURES 2, 5, 6, and 7. However, as indicated by the block 56 on FIGURE 5, the heat exchanger for steam generator may be positioned above the open pit incinerator 14 so that water flowing therethrough may be converted into superheated steam for operation of the steam turbine 30, as shown on FIGURE 1 and as described above.

The above description of the structure associated with this embodiment of applicant's invention is combined with a predetermined thermodynamic control to achieve the economic combustion to products of complete combustion of the combustible matter within the waste and refuse.

Thermodynamic zones of combustion

As shown most clearly on FIGURE 7, according to applicant's invention herein, there are provided two zones of combustion in applicant's invention. That is, there is first provided a gas producer zone generally designated 170 and a furnace zone generally designated 172. The gas producer zone is a zone in which, primarily, the highest specific gravity combustibles contained within the waste and refuse fed into the incineration chamber 14 are combusted to gaseous products of incomplete combustion and solid incombustibles. That is, for example, a tree stump which is a rather massive combustible that may be contained within the waste and refuse has a fairly low surface area to mass ratio and, consequently, will make several cycles through the incineration chamber 14 before it is combusted. In the gas producer zone 170 this tree stump, for example, is burned to products of incomplete combustion and to residual ash. The gas producer zone may be considered to be comprised of the fire bed portion 120 and the flame portion 174. It can be seen, of course, that the flame portion 174 protrudes upwardly beyond the upper limits of the side walls 94 and 96. The thermocouples 140 are positioned to measure the flame 174 temperature and to control the primary air flow through primary air nozzles 144 in response thereto to maintain the flame temperature within a predetermined temperature range as described below. It will be appreciated, however, that the lighter combustible products fed through the Archimedean screw that may be airborne due to the secondary air flow 74, normally, will comprise light papers, light rags or similar very high surface area-to-mass ratio elements which are in general burned directly to products of complete combustion within the gas producer zone. Thus, applicant can equally provide a controllable different rate of progress between the fast burning and slow burning solid combustible waste and refuse during progress through the incineration chamber 14. In any event, however, both slow and fast burning

solid wastes may be simultaneously reduced to mixed gases that are amenable to complete combustion when mixed with the proper amounts of air at the right temperature. In furnace zone 172 which may be considered to comprise the region above the air jet from the primary air nozzle 144 and the region within the air jet from the air jet nozzles 144 the products of incomplete combustion (as well as the products of complete combustion that may occur) are reacted to complete combustion products while escaping therethrough. The gaseous products generated within the gas producer zone 170, must, of course, escape by passing through the continuous air stream provided by the primary air nozzles 144 and, by an analysis on a statistical basis of the average constituents of representative trash samples it can be determined what the commonality of fuel-to-air ratio is necessary in the furnace zone in order that the gases produced within the producer zone 170 are burned to products of complete combustion.

Table VIII, above, shows the various constituents of solid waste and refuse from which are generated, ultimately, the products of complete combustion and solid incombustible products in applicant's improved incineration arrangement 10. It will be appreciated, of course, that this representative statistical analysis of waste and refuse products need not be constant but, according to applicant's invention herein, since the elements comprising the combustibles therein are substantially constant applicant's thermodynamic control will automatically account for variations in the percentage constituencies of calorific value and moisture content.

From Table 1 it can be seen that if 2000 pounds of the solid waste had been burned and complete combustion thereof was obtained, that is, all combustible materials were burned to gaseous products of complete combustion and solid incombustibles, the solid incombustibles from the organic material would be 27.4 pounds of ash, the solid incombustibles would be 361.5 pounds from the inorganics or a grand total of 389.45 pounds of solid incombustibles. It will be appreciated, according to applicant's invention herein, that these solid incombustibles are inorganic, non-gasifying and may be readily used for fill material or processed for reclaiming of any material constituents contained therein.

The function of the primary air is to supply to the products of incomplete combustion generated within the

gas producer zone sufficient oxygen so that they may be burned to products of complete combustion. However, it will be appreciated that gas generated from the solid waste and refuse in the gas producing zone may evolve in various and continuously varying combinations. However, since the elements comprising the solid combustibles waste products are in general known, a commonality of fuel and air may be readily attained according to applicant's invention herein. That is, a common fuel-to-air ratio may be maintained so that the proper amount of oxygen for the gases produced within the gas producer zone is supplied to burn them to products of complete combustion. With the typical analysis of solid waste and refuse as shown on Table VIII, applicant has determined that the primary gases generated in the gas producer zone which must be burned to products of complete combustion are carbon monoxide, hydrogen, methane, and hydrogen sulfide. Since these will be burned by air which is comprised generally of oxygen and nitrogen, Table XI presents the characteristics and properties of all the gases concerned in the combustion process of applicant's improved invention. For these gases, applicant has found that a commonality of fuel and air can be obtained by maintaining a flame temperature in the range of 2000° F. to 2500° F. Thus, each of the primary air nozzles 144 is controlled by its corresponding thermocouple 140 to provide sufficient air such that the flame temperature of the flame 174 is maintained substantially with this range of 2000° F. to 2500° F.

Within this temperature range applicant has found that any fuel air ratio can be maintained as is required to reduce any of the products of incomplete combustion generated within the gas producer zone to products of complete combustion. It will be appreciated, of course, that different amounts of air may be flowing at any one instant of time from different primary air nozzles 144 as they are controlled by their individual thermocouples 140 to maintain immediately adjacent flame temperature of the flame 174 at the range within 2000° F. and 2500° F. It will be appreciated that maintaining the flame temperature within this range provides a fire bed surface temperature on the order of 2000° F. The above temperature range ensures that temperatures are low enough so that disassociation of the gases will not occur to any substantial degree but that the temperatures are sufficiently high to ensure their combustion.

TABLE XI.—PROPERTIES OF THE GASES CONCERNED IN THE COMBUSTION OF FUELS
[Mass per unit volume (calc.), calorific value lb./ft.³ at 30 in. Hg and 60° F. B.t.u./ft.³]

Gas	Molecular weight	Calculated specific gravity (air=1)	Coefficient of solubility in water at 32° F. and 760 mm. Hg	G/M ³ at 32° F. and 760 mm. Hg (dry)	Dry	Sat'd (including the water)	Sat'd but excluding the water	32° F. and 760 mm. Hg dry (gross)
Oxygen, O ₂	32.00	1.1044	.0489	1,428	.08457	.08393	.08310	
Nitrogen	28.17	.9723	.6239	1,257	.07446	.07317		
Air	28.97	1.000	.0294	1,293	.07657	.07524		
Carbon dioxide, CO ₂	44.011	1.5189	1.713	1,964	.11631	.11512	.11429	
Carbon monoxide, CO	28.011	.9667	.0354	1,250	.07403	.07357	.07274	341.1
Hydrogen, H ₂	2.016	.06958	.0215	89.95	.00533	.00607	.00524	343.2
Methane, CH ₄	16.043	.5537	.0556	715.8	.04240	.04250	.04167	1,067.2
Water, H ₂ O	18.016	.6218		803.9		.04761		
Hydrogen sulphide, H ₂ S	34.082	1.1763	4.621	1,521	.09007	.07933	.08850	675.7
Combustion requirement, combustion products								
Volumes per unit volume=molecules per molecule								
Gas	30 in Hg and 60° F. Sat'd (gross)	30 in Hg and 60° F. Sat'd (net)	O ₂	Air	CO ₂	H ₂ O	N ₂	Total (dry)
Oxygen, O ₂								
Nitrogen								
Air								
Carbon dioxide, CO ₂					1.00			1.00
Carbon monoxide, CO	318	318	0.5	2.38	1.00		1.88	2.88
Hydrogen, H ₂	320	270	0.5	2.38		1.00	1.88	2.88
Methane, CH ₄	995	895	2.0	9.52	1.00	2.00	7.52	10.52
Water, H ₂ O								
Hydrogen sulphide, H ₂ S	630	580	1.5	7.14	1.00	1.00	5.64	6.64
					SO ₂			7.64

Basis of table: Oxygen content of air=21% by volume (i.e. 1 volume of oxygen in 4.76 volumes at 32° F. and 760 mm. Hg, 1 gram molecule of gas occupies 22.414 litres volume of one pound molecule, 359.00 ft.³ Round values for calorific value at 30" Hg and 60° F., saturated, representing most reliable data.

As indicated above, applicant also provides the water nozzle 150 for directing a jet of water into the interior of the incineration chamber 14. It will be appreciated that there are rare and exotic combustible materials with intensely high flame temperatures that can enter the incinerator with other solid waste and refuse. It has been noted above that magnesium is one of these materials and, in addition, some plastics also produce extremely high flame temperatures. If insufficient air to dilute these flame temperatures to the above-mentioned range is available to the corresponding primary air nozzle, then as an emergency control, water may be directed from the nozzles 150 to quench the flame temperature. Thus, there will generally be constantly varying air requirements throughout the length of the incineration chamber 14 from the front wall 98 to the rear wall 100 thereof. This is why applicant provides a plurality of individually controlled primary air nozzles 144. The constantly varying air requirements that are experienced in the different zones throughout the length of the incinerator chamber 14 for the front wall 98 to the rear wall 100 thereof vary directly with the heat content of the rubbish being gasified. This necessitates a constant variance of the air supply on a zonal basis in a moving bed of solid combustible waste and refuse products that is gasified since the heat content, moisture and constituency of the waste and refuse is not constant or homogeneous, such as experienced in traditional fuels, but constantly varies throughout each zone as it moves through the incinerator. Therefore, the various gases generated from the waste and refuse does not have common limits of inflammability that permit a common fuel air ratio that will allow burning of the various gases generated to a product of complete combustion throughout the entire length of the incineration chamber 14. That is, the fuel-to-air ratio will vary depending upon the gases produced in the particular zone thereof.

For example, waste and refuse being conveyed through one zone in the incinerator chamber 14 may have such a low calorific value that if a fixed quantity of air was introduced, the quantity of air might be so great that the flame temperature would be diluted so much that the resultant gas generator would not be amendable to be converted into a product of complete combustion with the same fuel-to-air ratio that is required to burn gases generated in another zone to a product of complete combustion.

The basis for reduction of air quantity supplied by the air nozzle 144 to increase and control the flame temperature in a gasifying bed 120 comprising low calorific content or high water content waste and refuse, is the relationship of the reversible carbon gas equilibrium, that is, the equilibrium between carbon monoxide and carbon dioxide and carbon, to the reversible methane-hydrogen equilibrium. If flame temperatures are made sufficiently high, though under the dissociated temperature, an identical common fuel-to-air ratio can be established that will permit the gases of both equilibria to be simultaneously burned to products of complete combustion. However, it will be appreciated, that at the same time, waste and refuse that has been moved into a preceding zone in the incineration chamber 14 may have such high calorific value, that a fixed quantity of air in this zone might be so insufficient and flame temperatures would be so great that the generated gases dissociate or revert to a state that does not permit the establishment of a fuel-to-air ratio that is compatible with all gases generated in the gas producer zone of this portion of the incineration chamber 14. Thus, a common fuel-to-air ratio is necessary for a simultaneous burning to a product of complete combustion.

Applicant has found that there is an approximate temperature range of 2000° F. to 2500° F., as noted above, within which the heterogeneous mass of generally hydrocarbon and carbohydrates comprising the bulk of the waste and refuse as shown on Table 1, can be gasified,

as indicated on Table 2, to the extent that a common fuel-to-air ratio can be established that will burn to a product of complete combustion all of the gases generated within the gas producer zone 170 of the incineration chamber 14. It will be appreciated, of course, that this is essentially a high temperature incineration process. However, only at the above stated temperature are completely burned gases achieved within the pressure range of 1 atmosphere. Therefore, it is necessary if a product of complete combustion is required in incineration, to completely control and vary the quantity and velocity of air introduced into the incinerator. The quantity of air supplied must be in conformity with the varying heat conditions existing in each zone of the incineration chamber 14 from the front wall 98 to the rear wall 100. Therefore, an incinerator zone as defined herein may be considered to comprise the area in which a relationship exists between a primary air nozzle 144, or a grouping thereof, and the adjacent heat sensing device for generating a signal proportional to the flame temperature of the flame 74 adjacent to the primary air nozzle or nozzles 144 and the control system for controlling the primary air flow rate therefrom in response to such measured temperature. The degree of combustion to products of complete combustion is, to a large extent, determined by the number of separate incinerator zones throughout the length of the incinerator chamber 14.

From the above, it can be seen that applicant has provided an improved incineration arrangement. In this incineration arrangement, waste and refuse are burned to provide gaseous products of complete combustion emitted therefrom together with solid incombustible products. No preclassifying is required and a purely heterogeneous refuse and waste may be rapidly combusted. By utilization of primary air to drive light weight materials such as papers and rags by an airborne state into and along the axis of the vortex generated by the primary air flow from the primary air flow nozzles 144 in the incineration chamber 14 these materials are burned at a much faster rate than the materials having a much lower surface-to-mass ratio. Thus, all materials are not limited by the combustion rate of the slowest material. According to applicant's invention, as described above, materials are constantly recirculated in the incineration chamber until they are completely gasified to gaseous products and incombustible products. Materials not amendable to rapid combustion to immediate products of complete combustion are contained within a gas producing zone wherein they are gasified into combustible gaseous products of incomplete combustion and the remaining solid ash. These products of incomplete combustion are then passed into the furnace zone where they are subjected to the primary air flow and converted into products of complete combustion which, in the bulk, comprise carbon dioxide and water. This is achieved by providing a plurality of spaced apart incinerator zones between the front wall 98 and rear wall 100 of the incineration chamber 14 wherein the primary air flow generating the vortex is adjusted so that the flame temperature emitted from the gas producing zone is in the range of 2000° F. to 2500° F.

I claim:

1. An open pit vortex incineration arrangement for burning waste and refuse comprising, in combination: an incineration chamber having a front wall, a rear wall, and a pair of spaced apart side walls, and a base means;
- input feed means adjacent said front wall of said incineration chamber for delivering waste and refuse into said incineration chamber through said front wall at a first predetermined feed rate;
- secondary air supply means for directing a first preselected amount of air at a predetermined pressure and predetermined flow rate through said delivery means and into said incineration chamber, for moving a first preselected portion of waste and refuse therein into said incineration chamber at a

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second predetermined feed rate greater than said first predetermined feed rate;
 said base means of said incineration chamber comprising:

- a first oscillating conveyor hearth for receiving second predetermined portions of the waste and refuse thereon adjacent the front end thereof from said delivery means to transport the waste and refuse in a first direction from said front wall to said rear wall adjacent to a first of said pair of side walls;
- a second oscillating conveyor hearth means for transporting material from said rear wall toward said front wall adjacent the second of said pair of side walls;
- means for transferring material from said first conveyor hearth means to said second conveyor hearth means adjacent said rear wall;
- means for transferring material from said second conveyor hearth means to said first conveyor hearth means adjacent said front wall;

primary air supply means comprising a plurality of spaced apart air nozzles adjacent said first of said pair of side walls and spaced a predetermined distance from said base means of said incineration chamber for discharging a controlled air flow into said incinerator chamber at a predetermined angle to said second side wall to generate a vortex extending substantially the length of said incineration chamber from said front wall to said rear wall and said vortex having an axis thereof substantially parallel to said base means;

- a plurality of temperature measuring means, one of each of said plurality of temperature measuring means adjacent at least one of said nozzle means for measuring the temperature of flame emitted from said base means toward said temperature measuring means and generating a control signal having a magnitude proportional to said measured flame temperature;
- control means for receiving said control signal and varying said primary air flow in each of said plurality of nozzles in response to the magnitude of said control signal to maintain said flame temperature in a predetermined temperature range;
- removal means for removing material from said incineration chamber.

2. The arrangement defined in claim 1 wherein said delivery means further comprises:

- an input oscillator conveyor for receiving the heterogeneous waste and refuse;
- a screw feed means adjacent said input oscillating conveyor means for receiving said heterogeneous waste and refuse therefrom and transmitting same to said incineration chamber.

3. The arrangement defined in claim 2 wherein said screw feed means comprises an Archimedean screw.

4. The arrangement defined in claim 1 and further comprising:

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said first and said second conveyor hearths being constructed to support a plurality of incandescent solids defining a fire bed having a predetermined thickness;

said primary air flow and the region immediately thereabove comprising a furnace zone;

said fire bed and said flame comprising a gas producing zone for combusting at least some of said combustible products in said waste and refuse to gaseous products of incomplete combustion;

said gaseous products of incomplete combustion passing through said furnace zone and reacting with said primary air to provide products of complete combustion.

5. The arrangement defined in claim 1 wherein said first oscillating hearth and said second oscillating hearth each have a portion thereof comprising a grate means, and said grate means comprising said removal means.

6. The arrangement defined in claim 5 wherein:

- each of said first and said second oscillating hearth means comprise edges defining an aperture there-through;
- each of said grate means movably mounted on one of said first and said second oscillating hearth means for reciprocal motion therewith and movable with respect thereto to selectively open and close said aperture; and motion producing means for moving each of said grate means.

7. The arrangement defined in claim 6 wherein:

- said motion producing means comprises:
- a motor mounted on said oscillating hearth;
- a screw drive means rotated by said motor and having a threaded portion;
- a nut means coupled to said grate means for threadingly engaging said threaded portion of said screw drive means;
- and guide means for guiding said grate means, whereby rotation of said screw drive means moves said grate means with respect to said oscillating hearth.

8. The arrangement defined in claim 7 wherein:

- said guide means comprises:
- a plurality of wheeled guide members mounted on said grate means;
- a support means mounted on said oscillating hearth and having a flange portion extending the length of said grate means;
- and said flange portion engaging said wheeled guide members.

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EDWARD G. FAVORS, Primary Examiner

UNITED STATES PATENT OFFICE

Certificate of Correction

Patent No. 3,465,696

September 9, 1969

Howard R. Amundsen

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below.

Columns 9 and 10, cancel Table VII and insert new Table VII.

TABLE VII—DATA DERIVED FROM IT ENTHALPY-TEMPERATURE DIAGRAM
Producer Zone—Gasification of Solid Waste Paper and Wood

Solid waste, B.t.u. per lb., 6,700 C gr. (gross) B.t.u., 6,000 C _a (Net) B.t.u.	Percent of excess air (solid fuel)	Air req'd., ft. ³ /lb. fuel	Vol. of Wet Combustion gas n, ft. ³ /lb.	B.t.u./ft. ³ of combustion gas	Temp., ° F., combustion temperature
	N	A	V	I C _a /V	
1 air factor:					
N=1.....		A 62.	V _o 73.5	I _o 81.5	3,210
N 1.2 Excess.....	14	74.5	86	70	2,970
N 1.4 Excess.....	25	87.	98.	61.	2,670
N 1.6 Excess.....	33	99.	110.	54.5	2,470
N 1.8 Excess.....	41	112.	123.	49.	2,215
N 2. Excess.....	46	125.	136.	45.	1,870

Furnace Zone—Production of Waste Gas from Air and Water Gas									
Solid waste, B.t.u. per lb., 6,700 C gr. (gross) B.t.u., 6,000 C _a (Net) B.t.u.	Caloric value of gas., B.t.u./ft. ³ On	Air req'd., ft. ³ /ft. ³ gas mix	Wet com- bustion gas volume n, ft. ³ /n, ft. ³ fuel	Ratio: air volume to gas volume	Enthalpy of com- bustion gas, B.t.u./ ft. ³	Temp., ° F., com- bustion temp. of mix	Percent of excess air to gas	Air for secon- dary combustion, ft. ³	Total air for pro- duct of complete combustion, ft. ³
		A	V	A/V	I CN/V		N		
1 air factor:									
N=1.....	81.5	A _a .567	V _o 1.460	.38	I _o 55.7	2,570	N 1=.....	44.5	106.5
N 1.2 Excess.....	70	.680	1.591	.43	50.1	2,370	N 1.2=7....	62.	136.5
N 1.4 Excess.....	61.1	.775	1.650	.47	45.3	2,155	N 1.4=12....	87.	174.
N 1.6 Excess.....	54.5	.883	1.782	.50	41.9	2,010	N 1.6=18....	110.	220.
N 1.8 Excess.....	49	1.083	2.007	.54	38	1,750	N 1.8=22....	123.	236.
N 2. Excess.....	45	1.243	2.182	.57	32	1,535	N 2=26.....	180.	305.

Signed and sealed this 8th day of December 1970.

[SEAL]

Attest:

EDWARD M. FLETCHER, JR.,
Attesting Officer.

WILLIAM E. SCHUYLER, JR.,
Commissioner of Patents.