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Municipal Incineration

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With End Notes by Robert L. Merle
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Municipal Incineration[1]

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Introduction and Summary

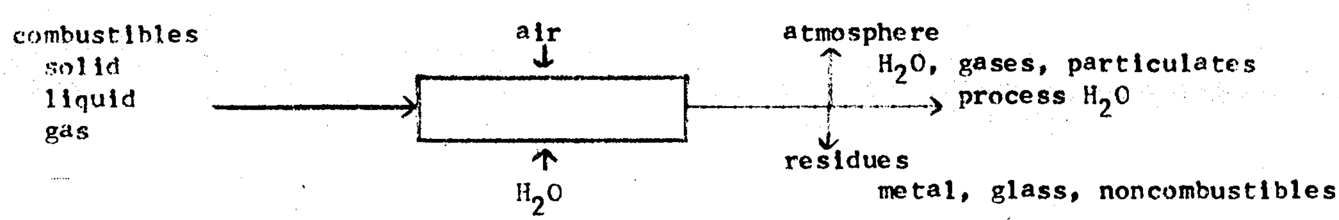
The topic of municipal incineration is of considerable interest at present; it is also much more involved than many realize. Since a single good source of information on this topic is available in "Incinerator Guidelines - 1969" (1) RCSI has considered it worthwhile to present it in a short, digest form. The areas included are: main principle of incineration, incineration in schematic form, preliminary data needed for planning, site selection and plant, common furnace types, furnace construction details, combustion process, heat recovery potential, incinerator costs, effluents, and advantages and disadvantages of incineration. A glossary of terms is provided at the end.

Main principle of incineration

The main principle of incineration is to achieve the maximum volume and weight reduction of solid waste, by means of combustion, without producing air and water pollution.

Incineration in schematic form

A diagram shows the main aspects of the process involved.



[1] This Bulletin was prepared by the Recycling Task Force under the chairmanship of Fred Ford. The task force disbanded with the initiation of the RESOURCE study of the Rochester Engineering Society, and its members joined the more comprehensive effort. R.C.S.I. will publish Bulletins based on the RESOURCE reports. These will be written in non-technical language as far as possible.

Preliminary data needed for planning

Preliminary data is needed for designing and planning the location of an incinerator. Knowledge of present and predicted future population density are important, as are such things as number, size, type and location of industries to be served. Air, land and water pollution regulations in the area must be noted. In considering zoning laws, one should expect them to be increasingly severe.

Information about quantity and character of available wastes is essential in determining the size of furnace, storage pit, grate area and feed mechanism. Trends to be noted are 1) increasing per capita production of waste, 2) higher combustible content, 3) lower water content and 4) higher heat value. Seasonal fluctuations and expected downtime should be noted.

Typical residential solid waste composition by percent of weight is as follows:

paper products	47.6
food	22.3
metals	8.3
glass, ceramics	6.8
garden products	4.4
rocks, dirt, ash, etc.	4.2
plastic, rubber, leather	2.8
textiles	2.2
wood	1.4

Heat release rates, combustion volume, excess air volume and grate areas are calculated. Heat value, the heat released per pound of solid waste, and oxygen bomb calorimetry are used. Two laboratory methods of analysis used are proximate analysis and ultimate analysis. Proximate analysis involves the weight percentage of moisture, noncombustibles, carbon, hydrogen, oxygen, nitrogen and sulphur.

The typical analysis of residential-commercial waste, excluding bulky items, is as follows:

Proximate: (general grouping of components)	moisture	15-35 weight percent
	volatiles	50-65
	fixed carbon(non-volatile)	3-9
	noncombustibles	15-25
Ultimate: (specific chemical character of most components)	moisture	15-35
	carbon	15-30
	oxygen	12-24
	hydrogen	12-24
	nitrogen	2-5
	sulphur	.02-.1
	noncombustibles ("minerals" or "ash")	15-25

higher heating value $\dfrac{3000\text{-}6000 \text{ BTU}}{\text{lb. solid waste}}$

Site selection and plant

The site selection and plant layout are considered. Public acceptance depends on satisfactory appearance and efficient operation. The economics of operation is a very important factor. Other important considerations are: 1) incineration is a heavy industry; 2) residential areas should be avoided; 3) noise and heavy traffic will be produced in order for materials to reach the incinerator; 4) accessibility is needed for rapid collection of refuse and disposal of the residue; 5) utilities must be readily available; and 6) the topography must be suited to dispersion, allowing for a proper stack height.

Common furnace types

There are four common furnace types: 1) vertical circular, 2) multicell rectangular, 3) rectangular, and 4) rotary kiln. A heat release of 18,000 BTU per cu. ft. furnace volume per hour is an average design figure used.

The vertical circular furnace is refractory lined, has a central rotating circular cone grate with rabble arms extending over a stationary circular outer grate and a secondary combustion chamber.

The multicell rectangular furnace is refractory lined or water-cooled, and has a common secondary chamber and residue disposal system.

The rectangular furnace is the most common and may be adapted to various grate systems.

The rotary kiln furnace has a slowly rotating inclined kiln with cascading action and is used in conjunction with the rectangular furnace in which drying and partial burning have occurred. The rotary kiln furnace has a secondary combustion chamber.

Furnace construction details

Important furnace construction details include: 1) grates and stoking and 2) receiving and handling procedure.

Grates and stoking are responsible for transport through the furnace and are needed to promote combustion by agitation, without causing excessive particle entrainment in the gas.

Typical receiving and handling procedure includes the weighing of refuse when delivered and dumping into the storage pit from the tipping area. This tipping area can be enclosed for dust, odor and noise control. The storage pit has waste mixed for uniformity of feed and the capacity is dependent upon peak loading times and the presence or absence of heat recovery. Charging is by a front-end loader, vibrating hopper and conveyor and/or cranes. This may be by batch or in a continuous fashion and by gravity or reciprocating and/or a vibrating mechanism.

Combustion process

Ideally all combustibles present will be burned in the combustion process. Factors involved are time, temperature and turbulence, and enough oxygen in the right place. The two types of combustion are primary and secondary.

Primary combustion involves drying, volatization and ignition, operates in the initial stages of furnace operation, and preheated air is often used to aid drying. Secondary combustion involves oxidation of gases and particles released by primary combustion, elimination of odors and oxidation of suspended carbon. Requirements for secondary combustion are sufficiently high temperatures, air and turbulence for mixing of gas with air.

Air introduction occurs at two stages. Underfire air, from beneath grates, provides oxygen and cooling of the grates, but may blow particles upward. Overfire air, introduced above the fuel bed, provides oxygen and air turbulence. The average overfire/underfire ratio is 50/50. The total quantity is the sum of the two. The typical quantities of air involved in the refractory-lined furnace are usually 150-200% in excess of the air necessary for complete combustion. The excess air is needed for proper temperature control. The typical quantities of air involved in the water-cooled furnace are 50-100% in excess of air necessary for complete combustion. Too much air is detrimental in that it lowers the furnace temperature.

Temperature control is extremely important. If the temperature is too high, there will be incomplete combustion and nitrogen oxides will form. If it is too high, there will be structural damage. Typical temperatures are:

2100 - 2500°F	over primary fuel bed
1400 - 1800°F	in secondary chamber
500 - 700°F	in pollution control equipment

Cooling is achieved by excess air, water evaporation, heat exchange and combinations of these factors. Water evaporation and heat exchange result in less gas volume to be handled by the pollution control equipment.

Heat recovery potential

Heat recovery potential is an uncommon consideration in the United States. It is encouraged by reduction in effluent gas volume, leading to smaller air pollution control equipment, gas handling devices and passageways; it is also encouraged by waste with increased heat content.

Basic designs are: 1) boiler systems with tubes behind the conventional refractory wall, 2) water-tube wall combustion chambers, 3) combination water-tube wall and refractory combustion chambers and 4) integrally constructed water-tube wall and boiler combination. Gas-to-air exchange is possible if a high-temperature exchange metal can be used.

Problems include soot-fouling of tubes, slagging, corrosion, additional cost, variable heat value waste and lack of dependability, and provisions for auxiliary power and dissipation of excess heat necessary.

In considering applications of heat recovery potential, there must be an economical balance between the sale of steam and power and the cost of heat recovery equipment and control. In-plant uses are for heating, hot water and desalinization. The power may also be sold to institutions or large power companies.

Incinerator costs

Financial considerations of incineration are the capital investment, operating costs, and ownership depreciation plus interest.

A capital investment, averaged on 170 installations and excluding land, is $6,150 per ton capacity. Items needed are scales, cranes, furnaces, air pollution control devices, process water treatment, recycling equipment, instrumentation, waste heat recovery equipment, residue removal equipment, flue and duct equipment, building ramps, tipping area, storage pit, hoppers, chimney, landscaping, site preparation and administrative facilities.

A typical cost breakdown is:

furnace and appurtenances	60-65%
building	20-30%
air pollution control equipment	8-10%
miscellaneous	7-13%

Operating costs average $5 to $15 per ton processed. The range is due to various factors: extent and type of pollution control equipment, labor, utilities, landfilling of residue and extent of automated control present.

Ownership depreciation plus interest ranges from $1 to $2 per ton.

Effluents

The effluents usually produced are shown in table form.

Origin	Description	Destination
dust control in tipping area; hosing of pit area	certain pesticides, cleaning solution, litter in water	surface waters, sanitary sewer
residue, all solids remaining after burning	ash, clinker, tin, rocks, unburned organics	leaching out of soluble organic and inorganic compounds into ground or surface water, unless properly landfilled
fly ash	ash, cinder, mineral dust, soot, charred paper, partially burned materials, oxides of silicon, aluminum, calcium and iron, water-soluble compounds	scattered by wind, renders process water of low pH, landfill
process water from residue quenching, cooling, flyash sluicing, air pollution	suspended solids, dissolved inorganics, organic material, BOD, COD, bacteria	in-plant treatment, sewer to municipal treatment, recycle

The quantity of particulate emission is affected by the amount of underfire air. The size distribution and specific gravity are affected by the nature of the waste and furnace conditions and determine the type of air pollution control to be used, e.g., inertial versus scrubbing, filtration, or electrostatic precipitation.

Resistivity is an important consideration for electrostatic precipitation. If resistivity is high, disturbances reduce collection rate and mean larger, costlier devices. If low, there is a loss of charge to the electrode and repulsion into gas again.

Established emission limits are quantitative (grams particles/volume or weight of gas) and visual (Ringleman number). There is a lack of correlation between the visual and quantitative.

Control methods include settling chambers, wetted baffle, spray systems, cyclones, wet scrubbers, fabric filters and precipitators.

In viewing the matter of gaseous emission, carbon dioxide, water, oxygen and nitrogen equal 99%, by weight. Trace gases, the least desirable odor-producing organics, are sulphur oxide and nitrous oxide, representing 1/100 to 1/10 of emission from fossil fuel.

Water vapor plumes cause poor visibility and corrosion. They can be avoided by cooling without vaporization and dry particulate collection.

Emission limits are contemplated or established on sulphur oxide, nitrogen oxides, carbon dioxide, hydrogen chloride and total hydrocarbons. Although the total of hydrocarbons is not of serious concern, the control of trace odor producers is very desirable.

There is no control of sulphur dioxide, which represents .16% compared to 1 to 3% for coals, and much sulphur is retained in ash. Neither is there control of nitrogen oxides, which represent 1/10 of emission from fossil fuels. Hydrogen chloride is the result of an increased amount of PVC (polyvinylchloride) containing plastics and can be controlled by water scrubbing.

Salvage operations, resulting in recycling, have large economic variability. The amount and type of salvaging alters design and burning performance. Salvaging results in the inherent conservation of natural resources.

Advantages and disadvantages

Incineration has advantages when landfill sites are not economically feasible, and when the incinerator can be centrally located. It can produce residue fill which will not attract insects or rodents. Large volume reduction of waste is possible (80-90% by volume or 75-80% by weight, including initial moisture). Volume reduction compared to landfilling is as follows:

	incinerator/fill
without bulky items included	11/1
with bulky items (20% by weight)[1]	2.1/1

Flexibility is possible if an incinerator is properly designed.

Disadvantages of incineration include: 1) large capital investment, 2) high operating costs, 3) need for skilled personnel, 4) need for special design or shredding and grinding equipment for large, bulky wastes, and 5) landfilling still required for residue and fly ash.

1. This is a critical fact which has been generally overlooked in recent discussions. An astonishing amount of large bulky items and material must be salvaged, shredded for burning, or buried. Editor's note.

Glossary

BOD	biological oxygen demand - a measure of organic matter in water based on bacterial respiration
clinker	rocks, dirt, etc.
COD	chemical oxygen demand - a measure of organic matter in water based on chemical oxidation
cyclone	cone-shaped device produces "cyclone", used to separate entrained particulates from a gas stream
downtime	time scheduled for maintenance or repair of equipment
entrainment	trapped in moving gas
oxygen bomb calorimetry	laboratory means of determining the heat content of a combustible material of interest; a hollow metal sphere is charged with the combustible and burned with oxygen and the rise in temperature is measured in the water bath in which the bomb is placed
particulates	tiny particles of matter
refractory	material designed to withstand stresses of high temperatures and to provide insulation
Ringleman number	applies to a white-gray-black opaqueness spectrum for judging stack gas; a number of 0 means gaseous emission is clear and a high number means there is a black emission
scrubbing	usually involves passing a gaseous stream through a chamber into which is introduced a finely divided liquid spray (or aerosol); the undesirable component of the gas stream is dissolved in the liquid and the liquid is then treated.
wetted baffle	a flat plate over which passes a film of water placed so that a gas stream impinges upon it and gas particles are trapped by the water

Reference

This Bulletin was abstracted from:

(1) Incinerator Guidelines, U.S. Department of Health, Education, and Welfare, Public Health Service, Environmental Control Administration, Bureau of Solid Waste Management, Cincinnati, 1969

End notes by Robert L. Merle

Trends in incineration - Higher temperatures do not result solely from the use of larger furnaces and more combustion air, but also from the inclusion of new types of materials such as plastics.

Common furnace types - The four most modern incinerators in North America (Chicago, Montreal, Norfolk, and Kodak-Rochester) are water-wall boilers. In Europe this type is common.

Furnace construction details -- The vibrating mechanism has not yet proven successful for refuse.

Heat recovery potential - The decision on use of heat to generate and sell steam is not necessarily dependent on simple economics. In the case of Chicago's new Northeast Plant, steam was not figured in at all. In this case air pollution control was required and cooling of the flue gas was needed.

Incinerator costs - The cost stated in the base reference ($6,150 per ton capacity) was based on earlier air pollution control devices which were ineffective by today's standards. A new plant in Delaware City, Pennsylvania cost $5,000,000 for a plant with capacity of 300 tons per day (almost $17,000 per ton).

Control methods - No knowledge is available that the method of fabric filters has ever been applied to incinerators.