General Overall Approach to Industrial Incineration

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Abstract
A detailed outline has been prepared to guide and advise industry in planning a safe and economical facility for waste disposal. Among the factors to consider are types and quantities of gaseous, liquid and solid waste, methods of collection, transportation, storage and disposal. As a method of disposal, incineration is discussed in detail.

Introduction
In an effort to help those interested in industrial incineration, a review of the major factors has been prepared. We have outlined a general approach to incineration plant design which is, of course, subject to many variations.

Over the past few years, there has been a significant change in the living habits of most Americans as well as a complete revolution in the industrial world. Today a great many products are available that were unknown prior to World War II. The above, combined with the "population explosion" and the movement to the suburbs, have created problems as to the disposal of our waste materials. Dumping wastes into streams, open-pit burning, etc. are frowned upon by our neighbors and usually forbidden by law. In the interest of "public relations" or "public image" as well as a desire to avoid litigation, most industrial activities are seeking economical ways and means of waste disposal.

In addition, a continual problem that must be faced is the fact that regulation becomes more and more stringent. As an example, the State of New Jersey has recently prepared new air pollution standards under existing legislation. This points out the necessity for industry to be "on top" of the problem.

General Types of Waste Materials
Waste materials can be divided into three general classes as follows with examples
1) Gases – The sulfur-base gases, such as hydrogen sulfide, in petroleum refineries.
2) Liquids – Wastewater from domestic and business operations, tar residues from organic chemicals and petroleum industries, and pesticide solutions from agricultural activities.
3) Solids – Such as plastics, packaging materials, sludges, and bark from pulp and paper plants.

Of course, any combination of the above types can and frequently does occur.

Disposal Methods
The first thing to do when a waste results from an industrial activity is to find out where it came from and try to eliminate it, or at least, reduce the quantity. After this step, the next one is an investigation to determine if the material can be economically salvaged or used as, or in a by-product. Upon determining that a disposal problem does exist, then the disposal methods must be considered.
The major disposal methods are described as follows:

1) If the refuse will all sink, dumping at sea can be utilized. This method is applicable when the waste quantity is large and the source is on the ocean or a major estuary with barging and tug facilities.

2) Landfill is a most satisfactory method when adequate space is available and the neighbors do not object too strenuously. This is particularly advantageous to industries and municipalities owning sub-marginal lands which may be reclaimed for the future.

3) Spray irrigation is a method for disposing of liquid wastes particularly applicable to farming and grazing areas. Many food processing plants use this method.

4) Composting is an old method that every so often gains new adherents. When the waste is essentially organic, composting can be utilized economically if sufficient space is available and odors are controlled. However, any heavy timber, metal, glass, etc., must be removed.

5) Deep well injection is a method of disposal that ties in well with deep drilling operations such as in the petroleum field or in the brine well areas. The injected materials must be compatible with the receiving strata and ground-water pollution must not occur. Legal restrictions must be investigated.

6) Mechanical, chemical and biological wastewater treatment are exemplified in the municipal sanitary waste treatment plant. Biological treatment should be considered for organic wastes of relatively low concentrations. Where high concentrations of organics exist, the fuel values may be significantly high.

7) Incineration or burning has been used over the ages. As living space is reduced, this may become a necessity for most municipalities if not also for industry.

**Reasons for Incineration**

Incineration as the method of waste disposal may be selected for several reasons:

1) It may be the most economical process available. This could be especially true if heat recovery is possible, or if the fuel value of the waste material is sufficient to sustain combustion.

2) Toxic materials which cannot be treated in any other fashion can be oxidized or altered to a less toxic state during combustion.

3) Reduction in volume of the waste materials may be required because of limited available land area.

**Cooperative Efforts**

As in most processes, the largest plant operating on a continuous basis will be the most economical to build and operate. In view of this, local industries and/or municipalities should look into the possibilities of joint ownership and/or operation. This, of course, poses other problems, but the resulting savings can be significant.

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**Site Selection**

Site selection for industrial incineration facilities is usually quite limited in that most facilities are usually built within the confines of the manufacturing plant. However, there may be increasing emphasis in the future to choose a site which may be more advantageous from an air pollution control standpoint. The additional hauling costs may, perhaps, be offset by reduced capital and operating costs associated with gas-cleaning equipment which may not be required at a more remote location. If it is possible to have some choice in selecting a site, several factors should be kept in mind:

1) Isolation with respect to residential development.
2) Distance, in the direction of the prevailing winds, of the populated areas from the site.
3) Provision for wastewater treatment before discharge to a stream.
4) Availability of water supply.
5) Availability of power supply.
6) Accessibility by transportation equipment.
7) On-site ash disposal, if possible.
8) Minimize refuse and residue hauling distances.
9) Proximity to user of waste heat.
10) Cost of property.

**Sources, Quantity and Characteristics**

The initial task is to define the sources, quantity and nature of the materials requiring disposal. This may involve a lengthy study if many different waste sources and materials are involved.

All sources of waste material should be identified. These can include:

1) Production facilities,
2) Office operations,
3) Service areas, including cafeterias, paint shops, carpenter shop, wastewater treatment, etc.,
4) Laboratory facilities, including pilot-plant operations,
5) Salvage operations such as oil recovery.

The quantity of waste material produced must be related to time in order to be useful for design purposes. Of primary interest are the quantities produced per:

1) Shift,
2) Day,
3) Week,
4) Year.

The minimum and maximum waste production rates should be known as well as the average.

If the waste generating facility is existing, a survey can be made to determine what quantities of waste are produced. This may involve:

1) Contacting all production units with questionnaires regarding their waste materials,
2) Periodic weighing or measurement of volume,
3) Checking with the service group or private contractor that presently moves the waste materials for disposal,
4) Checking process efficiencies and process material balances.

For a new production facility, quantities of wastes can often be estimated from similar operating facilities, or from expected process efficiencies and contemplated packaging of purchased materials.

During a waste survey, the amount of in-plant storage for each source should be noted. These data, together with anticipated quantities of waste materials and current or expected pick up and transporting schedules, will be important factors in determining the most economical size and operating schedule for the incineration facilities. It may prove economical to increase in-plant temporary storage or change existing hauling schedules.

An essential element in the data-gathering stage is to determine the nature of the waste materials being considered for incineration. In some cases, the required data on physical and chemical characteristics will be known. Often a great deal of information must be obtained by laboratory tests and engineering estimates. Some of the key data required, depending on the type of waste material, are

1) Density,
2) Btu Value,
3) Moisture content,
4) Ash content,
5) Ultimate analysis,
6) Chemical reactivity,
7) Vapor pressure,
8) Corrosiveness,
9) Viscosity,
10) Physical description of solid waste materials, i.e., powder, pellets, sticky filter cake, long stringy film, etc.,
11) Toxicity,
12) Solids concentration in liquids (and approximate size of largest particles),
13) Presence of metals (element and amount),
14) Presence of halogens (element and amount),
15) Presence of other elements that would produce products of combustion which are air pollutants or damaging to refractory materials.

**Transportation Considerations**

The most economical method of transporting waste materials will depend on several factors, including length of haul, number of sources from which waste materials must be picked up, quantities and volume of waste materials, and the nature of the waste itself. However, from a general standpoint, rail, barge, pipeline or highway transportation systems could be considered. The important consideration in the evaluation of transportation possibilities are:

1) The ease of coordination with existing plant operations,
2) The amount of rehandling of waste materials at the production area and the incineration facility,
3) Flexibility in scheduling,
4) The expense of handling wastes requiring corrosive resistant material and/or heated storage,
5) The ease of maintaining vapor control,
6) The practicability of handling reactive liquid residues which will require segregation,
7) The speed of delivery of materials which will deteriorate and produce offensive odors if stored for lengthy periods,
8) Consideration of fire and toxicity hazards if waste materials are allowed to accumulate before shipment,
9) Economical loading and unloading conditions,
10) The capital investment and operating costs.

The optimum economical operating schedule for any transportation system is a 7-day-per-week schedule, which makes continuous use of the available transportation equipment.

To insure safe, dependable, flexible and economic handling, containerization systems frequently appear to be the optimum method for moving waste materials. Containerization of refuse in packer boxes can accomplish a four-fold reduction in volume to be hauled. Liquid residues can be shipped in 500 to 5,000 gallon portable tanks; and bulk materials, such as activated sludge, filter cake and large-size lumber, can be moved in portable boxes of various capacities up to 40 cubic yards.

Often, the container can be brought directly to the production unit for filling, thereby eliminating duplicate handling and, in turn, storage. In some cases, a centralized transfer loading area of modest size will minimize storage and transportation costs by the use of ramps or pits. In most cases, containers can be gravity loaded and unloaded.

The cost of providing protection against corrosion and providing heated storage can be limited to the specific problem materials.

The time required to move a filled container from the producing plant to the incinerator site and have it returned is a major factor in determining the number of containers which must be purchased. The time that a container is tied up in transit to and from the incinerator facility must be matched with additional containers at the plant.

Reactive residues can be kept segregated in shipment and the same container reused for the same service. This minimizes the necessity for cleaning the tanks and reduces the possibility of undesirable chemical reactions. Cleaning of and repairs to individual containers can be made without disrupting or significantly reducing the capacity of the transportation system. Additional con-
tainers of specialized design, if necessary, can be added as future needs change. The containerization concept can be used with any of the major modes of transportation, exclusive of pipeline movement. It is generally accepted that, barring unusual circumstances, highway movement is the most economical transportation system.

**Meteorological Conditions and Air Pollution Control Requirements**

The significance of the air pollution problem is closely related to geographical location and terrain. Air movement in the geographical area which surrounds a particular industrial plant or plants can usually be obtained from U.S. Weather Bureau data. Of particular interest are data on wind speed, direction and duration. Inversion conditions which prevail a significant percentage of the time may create the most stringent requirements for emissions resulting from incineration. Most industrial states now have some regulations regarding air pollution. The Federal Government has shown increasing awareness of this problem, with increasing activity by Federal regulatory agencies in this area. It is to be expected that this trend will continue in the future. Therefore, it is essential that a site be located, if possible, in the most advantageous point from a dispersion standpoint, and the design of the burning facilities be flexible enough to accommodate efficient gas-cleaning devices if not initially installed.

**Incineration Systems**

The criteria for selection of incineration systems are

1) Suitability of incineration design for the type of waste materials to be handled,
2) Emission quality and quantity from stacks,
3) Residue quality,
4) Labor requirements,
5) Maintenance requirements,
6) Utility requirements,
7) Construction costs.

When operating flexibility is required, all burning systems should be as versatile as possible in the type of materials that can be handled.

**Refuse Incineration**

There are basically three forms of modern continuous-flow-through refuse incinerators. The flow-through incinerator is the most economical and most satisfactory from a combustion standpoint, if the quantity of material is large enough to be burned to justify this type of equipment. Incineration furnaces utilizing metal grates of various types are the most widely used for municipal refuse. Several types of grate furnaces are in use, including traveling grates, rocker grates and drum-type grates.

The rotary hearth furnace is the second major type of incinerator system. This type of furnace is built with a rotating hearth and fixed rabble arms, or fixed hearth and rotating rabble arms. The rabble arms are of air-cooled metal construction. The furnace is often built with several hearths, one over the other.

The third type of incinerator is a rotary kiln furnace. Burning in this type of furnace is accomplished on the refractory hearth which rotates around an inclined axis.

Some waste materials require special consideration with regard to selecting incineration equipment. This would include plastics, solid tars, filter cake, drummed materials, etc. Plastics can be troublesome on a grate unit as they have a tendency to melt and run through the grate before being burned. Filter cakes can do the same thing. It is difficult to charge drummed materials to any incinerator. Often, it is desired to burn organic residues in the same facility as the refuse. There have been several installations built to accomplish dual fuel burning. Organic residues can act as auxiliary fuel for "wet" refuse. However, organic residue burning adds a complication to the design of refuse incineration facilities.

**Liquid Residue Incineration**

Several types of waste liquid burners are in use, which can be divided into four basic types. These are

1) Box furnace,
2) Tube furnace,
3) Special reactor-type furnace,
4) Submerged combustion or submerged exhaust burners.

The first three types are usually refractory lined, but can be constructed, at least partially, with water-cooled metal walls. They are suitable for liquid residues with

1) Reasonably high heat value,
2) No components which would destroy refractory materials,
3) No components which represent an emission problem.

Most liquid residues can be successfully burned in any of the four types of furnaces when proper design and operation is accomplished.

Liquid residues which contain materials such as sodium, which cause slagging and fluxing of ceramic refractories, require special consideration. Some liquid residues contain materials which will create a hazard to the environment if emitted in the combustion gas. Special incineration equipment, usually coupled with gas-cleaning equipment, is required for such residues.

**Storage Considerations**

Waste storage is required at the incinerator to

1) Allow equalization of the rate of heat release in the burning facilities as much as possible, to minimize or eliminate the need for auxiliary fuel,
2) Provide temporary hold-up during period of burner shutdown,
3) Allow the burning facilities to be sized to burn
average daily quantities of waste instead of the maximum quantities received per day.

Storage of refuse is usually accomplished in a pit adjacent to the incinerator furnaces. This pit can be divided for fire protection and to provide segregated storage of materials, when required.

Liquid residues are usually stored in a tank farm. A tank farm might consist of a single tank or many tanks, depending on the material and quantities of residues to be burned. Residue storage may require heating and agitation.

Bulky materials, such as large construction timber, may have to be stored separately on a slab and processed in a wood hog before they can be burned. Furnaces to burn bulky refuse without preparation are a recent development.

Drummed materials can be stored on a drum dock with facilities to drain the drums, if possible, to storage tanks.

The storage areas should be equipped with means of fire protection. This might include a CO₂ or foam system in addition to water.

**Delivery Systems**

Mixed solid refuse is generally fed to an incinerator by means of a bridge crane. Segregated materials such as activated sludge, filter-cake or pyrophoric filter cake may be fed by means of a screw conveyor.

Liquid residues are generally delivered to the residue burning facilities by pump. Consideration is often given to transferring residues from one storage tank to another, and if many residues of varying characteristics are to be burned, a blend tank immediately preceding the burning facilities may be an efficient way of providing mixing and eliminating rapidly varying combustion characteristics. Residue pipelines may require steam tracing, and overhead placement enhances inspection and maintenance. Residue streams can be pumped through homogenizers, which insure that suspended solids or sludge particles are reduced in size adequately to prevent blocking of nozzles.

**Ash Handling Systems**

Ash from refuse and residue incineration is usually in the range of 1 to 10 percent by weight of the materials incinerated, but can run as high as 50 percent. On-site ash disposal is usually the most economical solution if it is available. Modern incinerator practices result in an ash of very low organic content and suitable for high quality landfill. Continuous-type incinerators generally remove ash continuously via a water quench and chain conveyor. The ash may be discharged to a dump truck, portable box or directly to a fill area. The quantity of ash resulting from residue incineration is relatively low and can frequently be handled in a settling pond.

**Atmosphere Emission Control**

This topic is a complete subject in itself. There will not be an opportunity to cover this subject in detail. However, a minimum of spray chambers will be required for fly ash control on a refuse incinerator. The best means of air pollution control is to provide complete combustion and particulate separation in the incinerator. This means the 3 “T’s” must be provided for, i.e., temperature, turbulence and time. Significant improvements have been made in recent years in design of gas-cleaning equipment. However, efficient gas cleaning is still costly in terms of energy expended and first cost and will probably continue to be so in the future.

Stack design should take into consideration local topography and climatic conditions as well as draft requirements to minimize the effect of infrequent increases in emissions due to poor combustion or failure of control equipment.

**Energy Recovery**

Depending on the nature of the materials to be incinerated, a positive heat balance will normally exist. Sense of economy would suggest that heat recovery should be considered. The logical approach is to produce steam. Steam has a value only if a user is reasonably close by. In recent years, heat recovery has been practiced with increasing success. The economic benefit can represent a significant percentage of the total operating cost of the incineration facilities. Where steam recovery and sale is not practicable, due to distance to a consumer, it may be economically feasible to use steam to generate electric power for use and sale. It must be recognized, however, that a waste disposal facility must be designed primarily to accomplish that purpose and not as a steam or power generating facility.

Energy recovery, in general, warrants a careful examination.

**Utility Requirements**

**Water**

Usually two basic water systems must be provided, i.e., process water system and a potable water system. Potable water supply, depending on the plant site selection, usually is not critical.

Process water on the other hand, may be more difficult to obtain due to the much larger quantities. Process water is required for

1) Gas-scrubbing equipment,
2) Sluicing ash,
3) Cooling,
4) Lubrication,
5) Fire fighting,
6) Miscellaneous housekeeping.

The aggregate total requirements for process water
can be appreciable. Facilities have been planned where water usage has been as high as 2½ mgd.

In general, the quality of the process water is not critical, and perhaps wastewater from other production activities might be utilized for this service.

Steam

Steam may be required for space heating, heating of residues and residue atomization. Many of the liquid residues now wasted from industry require heat so that they may be handled and pumped. In addition, steam is useful for general equipment cleaning. Usage might vary from a few hundred pounds per hour up to 10,000 pounds per hour or more for a large incineration facility.

Electricity

The connected electrical load for an incineration facility can be appreciable, especially if forced-draft fans and additional processing equipment such as a wood hog are required.

Auxiliary Fuel

Provision is generally made for use of auxiliary fuel when the Btu balance requires it. The study of materials to be burned will indicate the degree to which auxiliary fuel will be required to maintain combustion, usually in the 1500–1600 °F range. In addition, auxiliary fuel may be required to start incineration units.

Sewers and Wastewater Disposal

Process wastewater which originates in the various burning units will probably contain mostly ash and dissolved solids. On an equalized basis, pH of the wastewater might be acid or alkaline, depending on the materials burned. Adjustment of the pH of the waste stream may be required before discharge. One way of accomplishing this is to utilize an equalization basin followed by pH controlled addition of acid or alkali. Thermal pollution in some instances may be a problem and can be avoided by providing a spray pond or cascade discharge. Care must be taken in a residue storage area to insure that any residue loss does not reach a natural water course. Storage areas should be diked and drained to a sump which can be pumped. Surface run-off water should be diverted away from the residue storage area. Organic content of wastewaters should be minimal with good combustion and only under exceptional circumstances require biological treatment before discharge.

Sanitary wastes should be collected separately and disposed of according to sanitary practices.

Plant Air

Compressed air is usually required for various uses such as purging, cleaning, tool operation, instrumentation, and sometimes atomization.

Fire Protection

Due to the nature of the operation, adequate fire protection and fire-fighting facilities are of the utmost importance. The main operating areas and storage areas should be separated by reasonable distances to reduce the possibility of fire spreading through the facilities. The liquid residue storage area should be at a lower elevation, if possible, than the burning units, to reduce the chance of fire from ruptured storage tanks. An effort should be made to locate burning units upwind of the residue storage area, based on average prevailing winds. It is recommended that a built-in fire-fighting system be installed, or at least heat-sensitive instruments should be installed to warn of trouble.

Access Roads

If the incineration facility is built on a site within the confines of the production facilities, service roads are usually of no major consequence. However, if an offsite location is chosen, access roads may be of primary concern. An all-weather heavy-duty road is usually required.

Safety Requirements

In general, safety requirements for an incineration facility are similar to those of other manufacturing operations. In addition, precautions must be taken due to unusual hazards. Frequently, unknown materials must be disposed of, some of which are highly flammable and/or chemically reactive. This requires that additional attention be paid to material handling and every effort be made to foresee any possible combination of circumstances which would result in an accident. Laboratory tests should be made routinely on residue materials which are of unknown characteristics before they are mixed. Small amounts of reactive chemicals should be disposed of in small quantities and as soon after delivery as is practicable. Special attention must be paid to toxicological properties of waste materials and precautions taken to protect operating personnel.

An essential element in the proper operation of any incineration facility will be a continued safety education program with constant checking and vigilance on the part of management to foresee accidents before they occur.

Administration

Proper operation of the incineration facilities will require a reasonable amount of technical supervision and administration and cannot in general be left in unskilled hands. In some large manufacturing facilities, it becomes important to allocate the cost of operation to the facilities where waste materials originate. This may involve a rather complex cost-splitting formula which takes into consideration differences in Btu value, required mate-
rials of construction, transportation, heat requirements during storage and additional processing.

Back charging of disposal costs to the originating facility encourages reductions in waste and allows economic comparison for proposed process improvement which reduce waste loads.

**Economic Feasibility**

Construction costs for industrial incineration tend, as a rule, to be somewhat higher than for municipal facilities of comparable capacity, as most industries try to minimize manpower requirements, and their waste materials often require a more sophisticated approach. In addition, industry tends to be more concerned with maintenance costs than municipalities and therefore tends to buy systems with lower operating cost, but often of high initial cost.

It is difficult to give average cost figures which are meaningful. There is no such thing as typical costs in that each industry’s problems, materials, and size make each installation unique so that cost factors are not readily comparable.

For a particular situation, construction costs could be estimated for the required incineration facilities. To this construction cost should be added project costs. These may include costs such as engineering, purchasing costs, labor, hiring and training, start-up, etc.

**Operating Costs**

The comments concerning construction costs with regard to typical costs are applicable here also. The main factors in determining operating costs are the same as for any other production facility, principal differences being that utility and maintenance requirements tend to be somewhat higher per unit weight of material handled than do most production processes. Generally speaking, the biggest annual costs are those associated with labor and capital recovery.

**Financing**

If a facility is built by a single industry for its own use, financing would be accomplished in the same fashion as an expansion or replacement of capital production equipment. If, however, there is a joint effort by several companies, or by companies and municipalities, there are other routes open to obtaining the required capital. One popular method which we have considered is to utilize recently enacted legislation which enables public ownership of industrial operations. This can result in low-cost financing and elimination of some local taxes.

**Basis for Unit Charges**

The unit cost for disposal for a particular waste material should represent as much as is practicable the actual costs involved in its handling and disposal. Unit charges could be made up of

1) Basic unit charges, which cover
   a) indirect costs such as capital charges for engineering, financing, land, etc., and administrative costs,
   b) direct costs including capital, labor, maintenance, chemicals and utilities associated with the disposal of waste materials, and

2) Supplemental unit charges which cover
   a) special handling,
   b) preparation, processing before incineration,
   c) special materials of construction,
   d) combustion gas scrubbing and associated, energy and water treatment costs,
   e) adjustment of Btu value to cover auxiliary, fuel costs or heat recovery, if any.

Unit charges should be adjusted periodically, as necessary, to reflect variations in load, if any.

**References**
