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Project Summary

Capital and O&M Cost Relationships for Hazardous Waste Incineration

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The objective of this study was to develop relationships between capital and operation/maintenance (O&M) costs for hazardous waste incineration and the various waste-specific, design-specific, and operational factors that affect these costs. These cost relationships have been designed so that total capital investment, annual O&M cost, and unit (dollars per lb, etc.) disposal cost estimates can be calculated for a variety of waste compositions, different incineration system designs and configurations, and a wide range of system operating conditions and performance requirements. Sequential elements of the estimation procedure are: (1) input data specifications, (2) design assumptions and engineering calculations, (3) capital cost estimation, (4) annual O&M cost estimation, and (5) unit disposal cost calculation.

The input data specifications include physical/chemical waste characteristics and throughput rates, generic incinerator design type, capacity, and operating temperature, particulate and acid gas removal requirements, energy recovery utilization, and operating schedule. When these data are specified by the user, conceptual design, material balance, energy balance, capital cost, and O&M cost calculations are performed in sequential fashion. The projected accuracy of this cost estimation procedure is ±30 to 40 percent.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The U.S. Environmental Protection Agency (EPA) is currently performing a Regulatory Impact Analysis (RIA) of the RCRA performance standards for hazardous waste incineration facilities. One of the key elements of this RIA effort is the development of representative cost data for hazardous waste incineration, including:

- Capital costs for new facilities designed in accordance with the Resource Conservation and Recovery Act (RCRA) requirements.
- Operation and maintenance (O&M) costs for these facilities.
- Retrofit costs for existing facilities to comply with RCRA standards.

This cost information is also needed by the Incineration Research Branch (IRB) of the Industrial Environmental Research Laboratory, U.S. EPA, to complement technical/environmental evaluations of hazardous waste incineration technologies, and to aid in identifying future research priorities.

The report summarized herein focuses on capital and O&M costs of incineration. Retrofit costs are addressed in a companion report entitled, "Retrofit Cost Relationships for Hazardous Waste Incineration."

The objective of the study was to develop relationships between capital and O&M costs for hazardous waste incineration and the various waste-specific, design-specific, and operational factors that affect these costs. These costs relationships were to be designed so that total capital investment, annual O&M cost, and unit ($/lb., etc.) disposal cost estimates could be calculated for a variety of waste compositions, different incineration system designs, and configurations, and a wide range of system operating conditions and performance requirements. This degree of parametric cost estimating capability was considered essential for the RIA effort and for future IRB utilization.

Based on these objectives, a capital and O&M cost estimation model has been developed in computer-ready format. Sequential elements of the model are: (1) input data specifications, (2) design assumptions and engineering calculations, (3) capital cost estimation, (4) annual O&M cost estimation, and (5) unit disposal cost calculation.

Input requirements for the model include basic physical/chemical properties of the wastes in question, plus a limited number of facility design and operating specifications. Based on these input data and numerous technical assumptions in line with current industry practice, a wide array of engineering calculations are performed to specify and design the required hardware for the facility and to estimate the rates at which fuel, power, and other chemicals/utilities are consumed.

Based on the preliminary design specifications, equipment costs are estimated using a series of empirical relationships between cost and capacity, materials of construction, or other relevant design features. Estimated costs for equipment installation and contingencies are then combined with the equipment costs to determine total capital investment.

Variable costs for fuel, power, etc. are estimated from the consumption rate calculations previously mentioned and a series of regionalized unit cost data. Semi-variable costs such as labor and maintenance, fixed charges to capital, and energy recovery credits (optional) are also estimated to determine the net annual O&M cost. This cost is then divided by the annual waste throughput to arrive at the final unit disposal cost estimate.

More details of the input requirements, intermediary calculations, and outputs are described below. Limitations of the model are also discussed.

Methodology

For input data specification purposes, wastes are divided into five categories: combustible organic liquids, non-combustible liquids (without support fuel), pumpable slurries or sludges, non-pumpable sludges or bulk solids, and containerized solids. The following data are required for each waste stream or mixture of wastes included in each of these categories: (1) normal or average feed rate, (2) gross heating value, (3) fractional content of carbon, hydrogen, oxygen, nitrogen, moisture, ash, and chlorine, and (4) presence of toxic, heavy metals or alkali metals in the ash. Certain facility design and operating conditions must also be specified to use the model, including (1) owner/operator designation, (2) generic incinerator design (liquid injection, rotary kiln, or multiple chamber/ hearth type), (3) nominal primary and secondary chamber incineration temperatures, (4) minimum excess air requirements, (5) frequency and duration of incinerator startups, (6) waste heat boiler utilization and generic design (firetube or watertube), (7) particulate size distribution and control requirements, (8) acid gas (HCl) control requirements, (9) regular operating schedule and annual facility utilization, and (10) regional location and climatical considerations.

These input data are self-explanatory with the exception of "owner/operator designation." Three distinct owner/operator scenarios are provided so that the economic impacts of regulation can be evaluated across different segments of the hazardous waste incineration user industry. These three scenarios are: (A) commercial, institutional, or small industrial firms operating ≤10 million Btu/hr incinerators, (B) large industrial firms operating 10 to 50 million Btu/hr facilities for captive waste disposal, and (C) commercial waste disposal, semi-private or corporate central facilities in the 50 to 100 million Btu/hr range.

Certain waste characteristics and design alternatives that can impact costs are not addressed in the study. First of all, wastes containing significant concentrations of sulfur, phosphorus, or halogens other than chlorine are not provided for. This limitation is imposed because few of these types of wastes are "listed" for RCRA purposes, and because assessment of air pollution control costs would be beyond the scope of the study if such wastes were considered. Similarly, air pollution control device (APCD) selection is limited to venturi scrubbers for particulate contol and packed bed absorbers for acid gas (HCl) removal. These limitations are realistic because venture and packed bed scrubbers are the choice of most designers.*

Before the input data can be used to estimate capital and O&M costs, a number of design assumptions and engineering calculations are needed for conceptual design purposes and to estimate raw material and utility consumption rates. The design assumptions incorporated in the model are too numerous to address in their entirety in this summary; however, the major underlying assumptions are as follows:

1. Either liquid injection, rotary kiln, or multiple chamber hearth incinerators are used. Unique, exotic, or hybrid designs are not considered.
2. Bottom ash from kiln and hearth incinerators is disposed off-site at sanitary or secure landfills, depending on ash toxicity.
3. Incinerators are equipped with sufficient fuel firing capacity to reach the designated operating temperature prior to waste injection.
4. Firetube and watertube waste heat boilers are the only energy recovery devices considered. Where utilized, waste heat boilers are located immediately downstream from the incinerator, recovering enough heat to reduce combustion gas temperatures to 550°F.
5. Waste heat boilers are followed by small in-line quenches to reduce gas temperatures to adiabatic saturation upstream from the APCDs. If waste heat boilers are not employed, larger quenches are used to achieve the same temperature reduction.
6. Three air pollution control system configurations are considered: (a) venturi scrubber for particulate control, (b) packed bed absorber for HCl removal, and (c) venturi scrubber followed by HCl absorber. It is assumed that at least one air pollution control device is needed. A flow diagram for a complete scrubbing and flue gas handling system is presented in Figure 1.
7. All scrubbing systems have a common sump that receives the quench, venturi scrubber, and absorber ef-

*An appendix to the report covering ionizing wet scrubbers is currently being written and will be published separately fluents. At least 5 percent of the combined effluent is discharged to limit solids buildup, and the remainder is recycled.

8. Caustic soda solution is used in stoichiometric quantities for HCl scrubbing and neutralization.
9. All systems are assumed to be balanced draft, with combustion air blowers for the incinerators and ID fans downstream from the APCDs.
10. Reasonable on-site storage capacities and/or housing structures are provided for liquid and solid wastes.
11. The overall system is adequately designed in terms of safety interlocks and materials of construction to prevent catastrophic failure.

These design assumptions are typical of good industry practice. Therefore, they provide a reasonable basis for cost estimation for the industry as a whole, which is the goal of the RIA. However, these assumptions do not reflect current practice for all facilities, so cost estimates derived from the model may not be representative for specific facilities.

Based on these design assumptions and the input data previously described, engineering calculations are performed for conceptual design and raw material/utility consumption rate estimations. These calculations include: (1) land and associated site development requirements; (2) storage tank capacities, agitation, nitrogen blanketing, and heating requirements; (3) pump capacities and power requirements; (4) piping requirements; (5) bulk solid waste handling equipment sizing and operational requirements (carts, transport vehicles, conveyors, and feeders); (6) atomizing air compressor capacity and power requirements; (7) square footage for buildings and structures; (8) incinerator operating requirements in terms of low-fire, supplemental heating, and startup fuel; combustion air blower capacity and power; ash handling water and power; and exit gas characteristics; (9) waste heat boiler steam generation, fuel savings, and exit gas temperature; (10) quench water requirements, booster pump capacity and power requirements, and saturated exit gas composition; (11) scrubbing system water requirements, chemical requirements, pump power requirements, and blowdown rate; and (12) induction draft fan capacity and power requirements.

Freight-on-board costs for front-end storage and handling equipment, incinerator subsystems and auxiliary equipment, packaged waste heat boilers and necessary trim, and scrubbing/flue gas handling equipment are based on vendor estimates. Cost versus capacity curves are presented for each equipment item or subsystem, based on the design and material-of-construction specifications previously determined. These cost versus capacity curves are used in conjunction with the actual conceptual design calculations to estimate purchased equipment costs for the facility in question

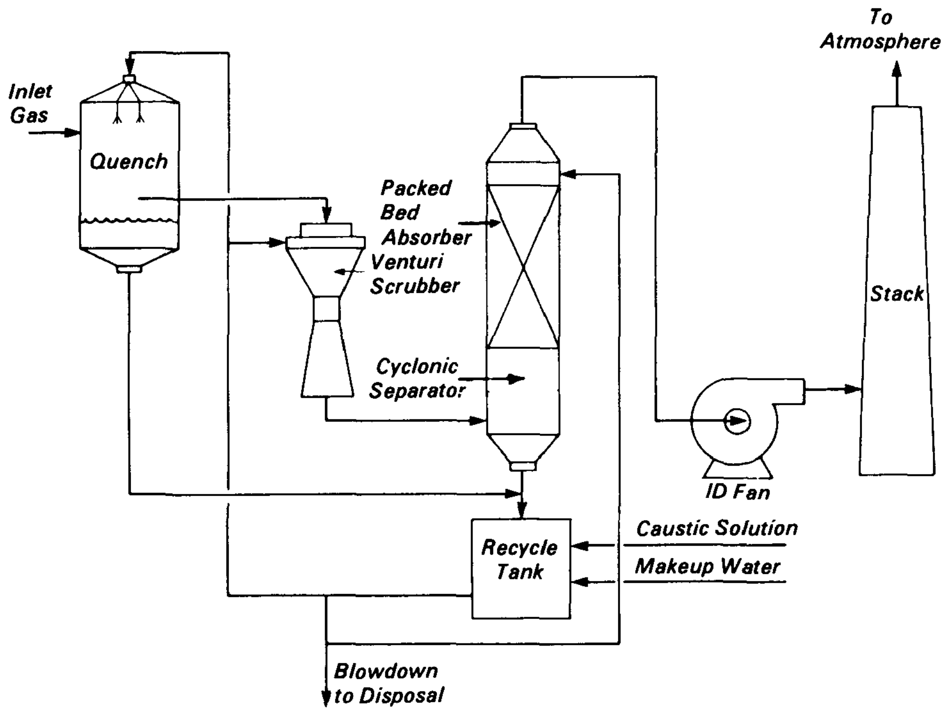

Figure 1. Generalized flow diagram for quench/scrubber system.

Costs for equipment delivery, installation materials and labor, engineering design, permitting, construction expenses and fee, and contingency are then estimated as percentages of the purchased equipment cost. These factored costs, combined with the purchased equipment costs, constitute the depreciable fixed capital cost estimate for the facility.

Total capital investment estimates include the depreciable fixed capital investment, plus allowances for land purchase, startup, trial burns, and working capital. Costs for land, trial burns, and working capital are estimated directly, based on facility design and operating characteristics. Startup costs are estimated as a percentage of the direct costs for equipment purchase and installation, plus indirect and contingency costs.

Annual O&M costs and credits are divided into four categories for calculation purposes: (1) variable costs, such as fuel, power, water, caustic soda solution for HCl scrubbing, liquid nitrogen for tank blanketing and residue disposal (ash and scrubber blowdown); (2) semi-variable costs, such as labor, maintenance, and waste analyses; (3) fixed costs, such as depreciation, insurance, and taxes; and (4) energy recovery credits for waste heat boiler utilization (optional). Annual variable cost estimates are based on the raw material-utility consumption rate calculations previously described, the assumed annual utilization percentage for the facility, and regionalized unit cost data. In this study, unit cost data are given for the Chicago, Houston, Los Angeles, and northern New Jersey metropolitan areas.

Operating labor cost estimates are based on assumed staffing requirements for the various categories and capacities of hazardous waste incineration facilities, and regionalized wage/salary rates. Six separate staffing scenarios are provided, with differentiation based on owner/operator designation (A, B, or C) and waste mix (liquids only or liquid and solids). Maintenance costs are estimated as a percentage of the depreciable fixed capital investment, as are the costs for depreciation, insurance, and taxes. Energy recovery credit estimates are based on the calculated fuel conservation rate, annual utilization percentage, and regionalized costs for fuel.

The net annual O&M costs is determined by summing the variable, semivariable, and fixed operating costs and subtracting any energy recovery credit. Dividing this net quantity by the estimated annual waste throughput yields the unit disposal cost estimate, which is the desired output.

Applicability and Limitations

The accuracy requirements stated at the outset of this study were ± 70 percent. For most facilities, the budgetary pricing procedures used in this study should provide better accuracy, i.e., ± 30 to 40 percent. This degree of accuracy is considered acceptable for purposes of the RIA and for first-cut comparisons of the costs for incineration versus other waste disposal alternatives. However, caution should be exercised if the model is utilized for site-specific cost estimating purposes.

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The complete report, entitled "Capital and O&M Cost Relationships for Hazardous Waste Incineration," (Order No. PB 85-121 119; Cost: $19.00, subject to change) will be available only from:
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