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Project Summary

Retrofit Cost Relationships for Hazardous Waste Incineration

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This study reports a methodology that can be used to estimate the costs of major capital additions or subsystem modifications for retrofitting/upgrading existing hazardous waste incineration facilities to comply with RCRA performance requirements. The results of the study are expressed in a series of empirical relationships between the costs for various capital modifications/additions and factors that significantly impact these costs, e.g., capacity, materials of construction, etc. Costs are developed for (1) aspects of combustion system retrofit to improve destruction of toxic waste constituents, (2) scrubbing system component addition, replacement, or upgrading to improve particulate and/or HCl removal, and (3) addition or replacement of ancillary equipment mandated by combustion or scrubbing system retrofit. The costs are based on a combination of in-house engineering and vendor-supplied budgetary cost estimates.

This Project Summary was developed by EPA's Industrial Environmental 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

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 the RIA is the development of representative cost data for hazardous waste incineration, including:

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

The first two types of costs are addressed in a larger, more in-depth companion report entitled, "Capital and O&M Cost Relationships for Hazardous Waste Incineration."

The objective of the study summarized herein was to develop a methodology and an accompanying set of cost relationships that could be used to estimate the costs of retrofitting or upgrading components of existing hazardous waste incineration facilities to comply with RCRA performance requirements. Both the methodology and the retrofit cost relationships were intended to focus on major capital additions or subsystem modifications that *could be* required for existing facilities to: (1) increase destruction and removal efficiency (DRE) of the principal organic hazardous constituents (POHC's) in the waste feed, (2) reduce particulate loading in the stack gas to ≤0.08 gr/dscf, and/or (3) increase HCl removal to ≥99 percent in facilities burning a waste mix containing ≥0.5 percent organic chlorine.

This study provides engineering-cost relationships and cost data that can be used in an RIA to estimate the costs of those regulatory alternatives which require that existing incinerators be retrofitted. However, because there was insufficient design information available on existing incinerators, no attempt was made in this study to predict what the total costs would be for the incinerator industry to comply with a particular regulatory alternative. Instead, sufficient cost information was developed so that those performing the RIA could address the question: "If one or more capital additions/modifications are required for

Facility XYZ to achieve RCRA compliance, and Facility XYZ has specified design/operational characteristics, what will it cost to make the necessary modifications?"

It was recognized that major capital additions or modifications were not the only types of retrofit costs that may be encountered by facilities upgrading performance. Other potential costs associated with upgrading include minor finetuning adjustments, downtown-related costs, and increased O&M costs. However, these costs could not be quantified within the framework of this study.

Methodology

The results of this study are expressed in a series of graphical relationships between the costs for various capital modifications or additions and factors that significantly impact these costs, e.g., capacity and materials of construction. Costs are developed for:

- Combustion system retrofit
  - Burner replacement
  - Refractory replacement
  - Combustion chamber replacement
- Quench and/or waste heat boiler addition
- Scrubber system addition, replacement, or modification
- Flue gas handling system modification
  - Fans, stack, etc.

In addition to the cost curves themselves, guidelines are presented to aid the user in determining when particular retrofit activities need to be considered, what types of input data are needed to use the various cost curves, and how installation and indirect construction costs can be factored in.

The cost relationships and associated information are designed to cover as broad a range of incinerator facilities as possible. A wide range of waste compositions is also considered, including hydrocarbon-based mixtures with variable heating values, moisture contents, ash contents and compositions (including alkalis), and chlorine concentrations. Liquid injection, rotary kiln, and hearth-type incinerators are all addressed in capacities ranging from 1-1000 M Btu/hr. Quenches and steam-generating waste heat boilers are considered for gas temperature reduction; venturi scrubbers are assumed for particulate control; and packed bed absorbers are assumed for HCl removal.

Combustion

The primary driving force considered in this study for combustion system retrofit was to increase destruction efficiencies (DE's) for POHC's contained in the waste. At present, insufficient data are available to relate DE's directly to incinerator design and operational requirements. Therefore, this study focused on major capital additions or modifications that might be needed to raise incinerator temperature above original design specifications and/or to increase effective residence time, mixing efficiency, etc.

First, the costs of burner system replacement for improved combustion efficiency or increased fuel co-firing capability to elevate temperature were estimated. The major problem in estimating these costs was that high-efficiency burners capable of handling multiple liquid waste streams plus support fuel are almost always custom designed and fabricated, and the costs are therefore quite case-specific. As an alternative, a baseline costing approach was adopted wherein a purchased cost vs. capacity curve was developed for burner systems capable of firing waste oils. Burner auxiliaries such as blowers, dampers, flame safe-guards, and combustion controls were included in the cost estimates, as were installation costs. It was assumed that the burner system is physically compatible with the combustion chamber configuration. If this is not the case, more extensive retrofitting is required.

If incinerator temperature is increased substantially above the original design specifications, it may be necessary to replace the existing refractory lining with a higher grade material. In this study, approximate refractory replacement costs are estimated by first calculating the material requirements, then judging the type of refractory required and its cost, and finally, factoring in labor costs for removal of the old lining and installation of the higher quality material.

The volume of refractory required for a given application is estimated, in brick equivalents (9 in. x 4.5 in. x 3 in.), from the thermal capacity of the system, typical state-of-the-art heat release rates and residence times for the three generic incinerator designs considered, typical dimensions for these generic designs (length: diameter, surface: volume), and simplified thickness vs. temperature guidelines. Refractory "type" (brick vs. castable, alumina content) and unit cost are estimated based on temperature application guidelines, plus the qualitative presence or absence of alkalis and/or chlorine in the combustion environment.

Total material costs are then determined by combining the estimated volume requirements in brick equivalents and the dollar per brick equivalent cost for an appropriate refractory. A range of installed vs. material cost multipliers is provided to estimate the final installed cost, which is affected by local labor costs, ease of access to the combustion chamber interior, and other site specific factors.

In many cases, it may not be feasible to replace only the burner system or only the existing refractory. Complete combustion system replacement may be required to significantly improve performance. For example, a substantial increase in operating temperature may require a thicker refractory lining to limit skin temperature. This increased refractory thickness reduces internal volume and residence time. If the residence time reduction is significant enough to impact DE, a larger shell and, thus, a new combustion chamber is required.

Equipment cost vs. capacity curves are presented for liquid injection, rotary kiln/afterburner, and fixed hearth/afterburner combustion systems. The costs include burner systems, as previously described, refractory lined shell, auxiliaries, and controls. A range of retrofit installation costs is also provided.

Quench

If air pollution control devices (APCD's) such as venturi scrubbers or acid gas absorbers need to be added to existing incineration systems to comply with RCRA emission standards, some means of cooling the combustion gases prior to APCD entry must also be provided. Two alternatives are considered in the study: (1) direct water-spray quenching to 200°F, and (2) waste heat boiler and post-boiler quench application to achieve the same temperature reduction.

Separate capital cost vs. gas flow rate curves are provided for fullscale quenches and for smaller, post-boiler quenches. Costs for fullscale quench towers are based on the assumption of 2000°-2300°F inlet gas temperature and, thus, interior refractory lining. Acid-resistant design is also assumed. Inlet gas temperatures of 400°F-600°F and acid-resistant alloy construction are assumed for the smaller quenches. Installation cost multipliers are given for both generic designs.

Equipment costs vs. gas flow rate curves are also provided for waste heat boilers. These costs are for packaged firetube and watertube boilers with standard trim and controls. Installation cost ranges are presented as a function of retrofit difficulty.

Scrubber

In order to meet RCRA standards for particulate and HCl removal, existing hazardous waste incineration facility retrofit requirements may range from virtually nil to complete particulate and acid gas scrubbing system addition. In terms of *major* capital additions or modifications, however, the following four retrofit possibilities were selected for this study: (1) venturi scrubber addition/replacement for improved particulate collection, (2) conversion from once-through water absorption of acid gases to a caustic recycle system, (3) acid gas absorption column addition/replacement, and (4) total scrubbing system addition—venturi scrubber and caustic recycle acid gas absorption system, plus fan and stack.

Purchased costs for complete scrubbing systems, including flue gas handling equipment, are presented in Figure 1. These costs are for typical 30"WC back pressure systems and represent "baseline" costs for this study. Adjustment multipliers are provided to estimate the costs for (1) higher pressure drop systems, (2) addition of only a venturi scrubber and auxiliaries, (3) addition of a complete acid gas absorption system without particulate scrubbing capability, and (4) addition of a caustic recycle system for conversion from once-through water absorption of HCl. Installation cost multipliers are also provided.

Flue Gas Handling

In certain situations, particulate collection efficiency in the venturi scrubber may be limited because the fan capacity is insufficient to handle the combustion gas flow at the pressure drop necessary for good venturi performance. If this is the case, then particulate emissions can be reduced (without reducing waste throughput) by simply replacing the fan. Therefore, FOB and installation cost estimates are provided for carbon steel and corrosion-resistant fans as a function of total system back pressure and gas flowrate.

Cost versus height relationships are also provided for FRP-lined stacks. Although stack replacement will not reduce emissions in itself, this retrofit possibility was included at the request of the Office of Solid Waste for use in their dispersion model-based risk assessments. Since increased stack height reduces the maximum ground level concentration of emitted species, the costs for adding taller stacks are needed to perform cost/benefit analyses.

Indirect Costs

In addition to the direct costs for equipment and installation, the indirect costs associated with engineering, construction, and startup must be considered.

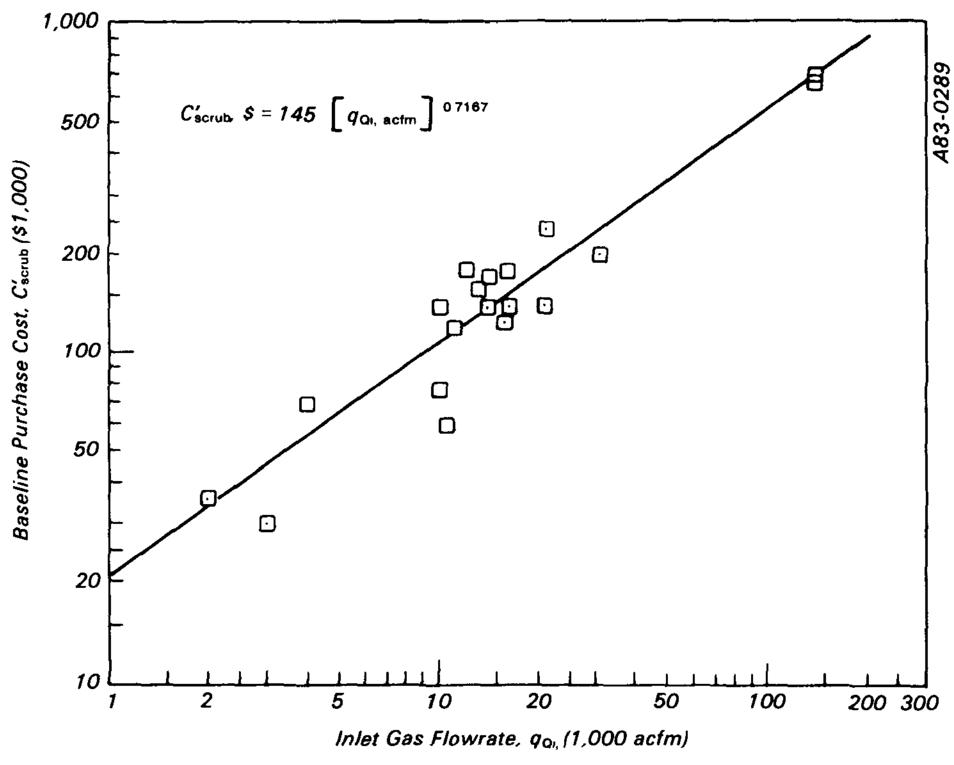

Figure 1. *Purchase costs for typical hazardous waste incinerator scrubbing system receiving 1,800° to 2,200°F gas (July 1982).*

For this study, indirect costs are estimated as percentages of the total direct cost as follows:

Engineering	10%
Construction overhead	10%
Construction fee	8%
Startup	2%

Thus, the indirect costs are estimated to total approximately 30% of the direct cost for a given retrofit. This figure does not include permitting and trial burn costs, which are difficult to predict for a retrofit operation. Permitting costs for new facilities are estimated in "Capital and O&M Cost Relationships for Hazardous Waste Incineration."

Example

In order to illustrate how the information presented above can be used to estimate costs for major retrofit activities, the following example is provided.

Basis

A small multiple chamber hearth incinerator is being used to dispose of liquid process wastes and plant trash. The toxic components of the liquid waste are not difficult to destroy, so the unit is achieving 99.99% destruction efficiency. However, because the system was installed prior to implementation of air emission standards, no pollution controls are provided. Combustion gas is vented directly to a refractory-lined stack. As a result, the unit exceeds RCRA emission standards both for particulates and HCl.

Retrofit Requirements

In order to achieve compliance, the existing stack must be bypassed, and a complete scrubbing system—venturi scrubber, HCl absorber, fan, and stack—must be added. The mean particle diameter in the gas is approximately 2 μm, so a 30" WC back pressure system is adequate. In addition, quenching can be accomplished in the venturi outlet. Because space is available for the scrubbing system, no special retrofit difficulties are encountered.

Costs

The combustion gas flow from the secondary chamber is 10,000 acfm at 1600°F. Therefore, from Figure 1, the purchased cost for the scrubbing system is approximately \$100,000. Since installation runs about 50% of equipment cost, the total direct cost is \$150,000. Adding 30% for indirect costs, the total capital expenditure is \$195,000.

Limitations

The study described in this summary is a basic, first-cut effort to estimate potential costs for hazardous waste incineration facility retrofit. Because of the many site specific factors that impact retrofit costs, the accuracy of the estimates may be no better than -50% to +100% for some facilities. Large discrepancies between projected costs and actual costs are most likely in situations where space is limited, service relocations are required, interferences are encountered, or structural relocation is required. Where these problems are not encountered, the estimating methods described in the report may achieve conceptual design accuracies of ±30-40%.

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The complete report, entitled "Retrofit Cost Relationships for Hazardous Waste Incineration," (Order No. PB 84-139 435; Cost: $10.00, subject to change) will be available only from:

National Technical Information Service
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