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TECHNOLOGY EVALUATION REPORT

OGDEN CIRCULATING BED COMBUSTOR at the McCull Superfund Site

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NOTICE

The information in this document has been funded, wholly or in part, by the U.S. Environmental Protection Agency under Contract No. 68-03-3255 to Foster Wheeler Enviresponse, Incorporated and the Superfund Innovative Technology Evaluation (SITE) Program. It has been subjected to the Agency's peer and administrative review, and has been authorized for publication as an EPA document. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

FOREWORD

The Superfund Innovative Technology Evaluation (SITE) Program was authorized in the 1986 Superfund amendments. The Program is a joint effort between USEPA's Office of Research and Development and the Office of Solid Waste and Emergency Response. The purpose of the Program is to assist the research, development, and demonstration of hazardous waste treatment technologies necessary to implement new cleanup standards which require greater reliance on permanent remedies. This is accomplished through technology demonstrations which are designed to provide engineering and cost data on selected technologies. This treatability study will determine if a SITE Demonstration will occur.

This report provides documentation of a pilot-scale treatability study and demonstration of an innovative technology that took place in San Diego, California at the Ogden Environmental Services (OES) Research facility. Observation and sampling of a research-scale circulating bed combustor (CBC) took place during a preliminary test sponsored under an agreement between the SITE Program and OES. The treatability study was conducted on a minimal amount of representative McColl Site waste to determine if a full SITE Demonstration is feasible.

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ABSTRACT

An evaluation of the Ogden Environmental Services (OES) circulating bed combustor (CBC) technology was carried out under the Superfund Innovative Technology Evaluation (SITE) Program to determine its applicability as an on-site treatment method for waste site cleanups, and more specifically for use at the McColl Superfund Site in Fullerton, California, as a candidate technology to be tested in the SITE Program.

A treatability study and demonstration of the technology was performed at the OES research facility in San Diego, California in March 1989. Operational monitoring, process stream, and flue gas sampling and analysis data were collected and carefully evaluated to determine the technology's capability to destroy McColl Site contaminants and permit operation of a transportable, field-erectable unit at the McColl Site.

The report includes an Executive Summary presenting the program evaluation criteria, descriptions of the McColl Site and the CBC process, program results, and conclusions; a description of the SITE Program and the program performance criteria; the vendor's description of the CBC process; the test conditions from waste feed preparation through the sampling and analysis program; an evaluation of the treatability study results; a listing of the cost components of the study; and an encapsulation of the test results and conclusions.

The test results indicate that continued deliberations among the federal, state, and local agencies, and discussions with the technology developer are necessary to establish the conditions to conduct an on-site Demonstration test.

CONTENTS

	<u>Page</u>
Notice	ii
Foreword	iii
Abstract	iv
contents..	v
Abbreviations and Symbols -----	vii
Acknowledgment	x
Executive Summary -----	1
Introduction -----	1
Site Description -----	2
Vendor's System Description -----	2
Sampling and Analysis Program -----	4
Treatability Study Results -----	4
Conclusions -----	5
Introduction	7
The SITE Program -----	7
McColl Site Description -----	7
Program Objective -----	9
Performance Criteria -----	11
Key Contacts	12
Vendor's System Description -----	13
Introduction -----	13
System Description -----	13
Process Control -----	15
Process Monitoring and Data Acquisition -----	17
Test Program Procedures -----	19
Waste Feed Preparation -----	19
Operating Conditions and Operating Range -----	19
Sampling and Analysis Program -----	20
QA/QC Plan and Audits -----	27
Performance Data Evaluation -----	33
Introduction -----	33
Performance Criteria Results -----	34
Quality Assurance/Quality Control -----	45
Treatability Study Costs -----	51
Conclusions	53
Test Results	53
Recommendations -----	57
References	59

FIGURES

<u>Number</u>	<u>Page</u>
Figure 1. Schematic flow diagram of CBC for waste treatment.	3
Figure 2. McColl Site layout.	8
Figure 3. Schematic of the OES CBC system	14
Figure 4. Sampling and monitoring points of the CBC system.	24

TABLES

<u>Number</u>	<u>Page</u>
Table 1. Chemical Characterization of McColl Waste	10
Table 2. Baghouse Filter System	16
Table 3. Interlock Settings	17
Table 4. Test Durations	20
Table 5. Treatability Study Process/Permit Conditions	21
Table 6. Description of CBC Monitoring Parameters and Methods	22
Table 7. Process Stream Sampling and Analysis	23
Table 8. Flue Gas Sampling and Analysis	25
Table 9. Flue Gas Analyzers	27
Table 10. List of Volatile Organics	28
Table 11. HSL Semivolatile Organics	29
Table 12. TCLP List of Volatile Organics	30
Table 13. Number and Types of QC Samples	31
Table 14. Analytical QC Measures	32
Table 15. DREs for CCl ₄	34
Table 16. Combustion Emission Concentrations for Selected Compounds	35
Table 17. Flue Gas Results	36
Table 18. Chloride in the Flue Gas	37
Table 19. Continuous Emissions Monitoring Results	39
Table 20. Organics and Halide Results	40
Table 21. Total Metals Results	42
Table 22. TCLP Results	43
Table 23. Summary of Physical Parameters	44
Table 24. Percent Recoveries Results	46
Table 25. Treatability Study Costs	52
Table 26. Comparison of CBC Parameters to Other Tests	54

ABBREVIATIONS AND SYMBOLS

acfm	actual cubic feet per minute
AEERL	Air and Energy Engineering Research Laboratory
APCD	Air Pollution Control District
ATC	Alliance Technologies Corporation
Btu	British thermal unit
BTEX	benzene, toluene, ethylbenzene, xylene
Ca	calcium
CBC	circulating bed combustor
CCl ₄	carbon tetrachloride
CEM	continuous emissions monitor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	cubic feet per minute
C O	carbon monoxide
CO₂	carbon dioxide
CRT	cathode ray tube
cu	cubic
DAS	data acquisition system
DHS	Department of Health Services
DOT	Department of Transportation
DP	differential pressure
DRE	destruction and removal efficiency
dscfm	dry standard cubic ft/min
dsl	dry standard liter
EIR	environmental impact report
EPA	Environmental Protection Agency
FGC	flue gas cooler
ft	feet
FWEI	Foster Wheeler Enviresponse, Inc.
gal	gallon
GC/MS	gas chromatography/mass spectrometry
gpm	gallons per minute
gr	grain
HCl	hydrochloric acid
HEPA	high efficiency particulate air (filter)
hr	hour
HSL	hazardous substances list
IC	ion chromatography
ICAP	inductively coupled argon plasma
ID	induced draft
i.d.	inside diameter
in.	inch
ITL	Industrial Testing Laboratories
kg	kilogram
L	liter
lb	pound
LCS	laboratory control samples
mg	milligram
min	minute

ABBREVIATIONS AND SYMBOLS (continued)

ml	milliliter
M M	million
MM5	modified method 5
NBS	National Bureau of Standards
ng	nanogram
NIH	National Institutes of Health
NO _x	nitrogen oxides
NPL	National Priority List
O₂	oxygen
OES	Ogden Environmental Services, Inc.
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PCBs	polychlorinated biphenyls
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzo furan
PIC	product of incomplete combustion
PID	proportional integral derivative
PLC	programmable logic controller
POHC	principal organic hazardous constituents
ppm	parts per million
psig	pounds per square inch (gauge)
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RCRA	Resource Conservation and Recovery Act
RD&D	research, development, and demonstration
RI/FS	remedial investigation/feasibility study
RPD	relative percent difference
RREL	Risk Reduction Engineering Laboratory
RTI	Research Triangle Institute
sec	second
S	sulfur
S&A	sampling and analytical
SARA	Superfund Amendments and Reauthorization Act of 1986
SCAQMD	South Coast Air Quality Management District
Scfm	standard cubic feet per minute
SITE	Superfund Innovative Technology Evaluation
SO ₂	sulfur dioxide
SO _x	sulfur oxides
sq	square
SRO A	supplemental reevaluation of alternatives
s v	semivolatile
TCLP	toxicity characteristic leaching procedure
THC	total hydrocarbon
TIC	tentatively identified compound
TLI	Triangle Laboratories, Inc.
TOC	total organic carbon
ug	microgram
USEPA	United States Environmental Protection Agency

ABBREVIATIONS AND SYMBOLS (continued)

V	volume
VOHC	volatile organic hydrocarbon
VOST	volatile organics sampling train
wg	water gauge

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SECTION 1 EXECUTIVE SUMMARY

INTRODUCTION

The SITE Program treatability study and demonstration of the Ogden Environmental Services (OES) circulating bed combustor (CBC) was conducted during March 1989 at OES's research facility in San Diego, California. The main objective of the study was to evaluate the effectiveness of this technology in thermal destruction of hazardous wastes in feedstock from the National Priority List (NPL) McColl Superfund Site in Fullerton, California and, thus, to determine if the technology is a viable candidate for further on-site testing under the SITE Program. OES currently operates two transportable, field-erectable, 100-ton/day (10 MM Btu/hr) CBC units and has two additional units under fabrication.

EPA conducted the demonstration from March 27 to March 31, 1989, and processed approximately 8,600 lb of material, of which 5,500 lb were McColl waste and contaminated soil. The nominal 2 million Btu/hr pilot-scale CBC can process approximately 1,000 lb/hr of waste feed. It was limited during the treatability study, by permit, to less than 500 lb/hr of waste feed. During this period the EPA SITE staff, EPA Region IX, DHS, San Diego Air Pollution Control District (APCD), and EPA contractors observed the CBC operation, collected data, and documented the test proceedings.

To evaluate the CBC these principal performance criteria were applied:

- o DREs – the CBC's calculated destruction and removal efficiency for organic compounds.
- o Flue gas emissions -- the ability of the unit and its associated air pollution control system to control acid gas emissions, particulate matter, and criteria air pollutants.
- o Organics destruction -- the ability of the system to destroy hazardous organic constituents present in the feed, and the effectiveness of the CBC system in minimizing undesired combustion by-products and products of incomplete combustion (PICs).
- o Toxic metals distribution -- determining the partitioning of metals into the fly ash, bed ash, and flue gas Streams.
- o TCLP results -- evaluating whether or not toxic metal and organic contaminants in the waste feed could be rendered non-leachable in the ash residue thereby making the ash non-hazardous.
- o Physical parameters – evaluating the physical/chemical changes of the waste feed after processing.
- o System operating conditions -- effectiveness of current instrumentation and controls, including the ability to control critical process parameters and to respond to transient and upset conditions; and the effectiveness of sulfur dioxide (SO₂) capture and the calcium-to-sulfur (Ca/S) ratios needed to obtain this effectiveness.
- o QA/QC -- determining the quality of the collected data.

The demonstration was designed to collect as much data as possible to define the system operation. In addition to the information areas above, the following were to be collected: material balances based on the unit operations and material flows; mechanical operations history of the unit; operational requirements and system reliability; operating and maintenance data including labor, energy, and supply requirements, scheduled

maintenance requirements, equipment durability and reliability, and operational safety; pretreatment and posttreatment requirements to enable on-site operation within existing regulatory limits; unit costs to effectively develop a cost/economic analysis for the unit; and energy effectiveness.

SITE DESCRIPTION

The McColl Superfund Site was used from 1942-1946 for the disposal of acidic sludges resulting from the alkylation and product-treating processes used in the refining of aviation gasoline. The waste is characterized as having a low pH (approximately 2); a high sulfur content – making it quite malodorous; elevated concentrations of organic sulfur, aromatics, and aliphatic hydrocarbons; and low levels of some toxic metals such as chromium, arsenic, and cadmium.

In 1983 the California Department of Health Services (DHS) completed a remedial investigation/feasibility study (RI/FS) to determine the best course of action to be taken to remediate the site. In 1984, the EPA and DHS decided on an optimum course: excavation, removal, and transportation of the waste to an off-site facility for final disposal. Execution of the remedy was halted in 1985 by a state court injunction requiring the preparation of an environmental impact report (EIR) prior to removal of material from the site. In 1989, EPA completed a supplemental reevaluation of alternatives (SROA), which concluded that thermal destruction was a viable method for use in the site remediation. To take advantage of a full-scale on-site field demonstration, EPA began negotiations with the McColl residents and local authorities to gain their support for an EPA-sponsored on-site Demonstration of the transportable OES CBC system. The McColl residents and the McColl Interagency Committee asked EPA to conduct a treatability study and demonstration at the OES research facility to provide data showing the effectiveness of treating the McColl waste before bringing a full-scale unit onto the McColl Site.

VENDOR'S SYSTEM DESCRIPTION

The information in this section on the CBC system has been provided, reviewed, and approved by Ogden Environmental Services, Inc. The EPA makes no claims as to the accuracy of the statements.

The CBC is a thermal destruction system that uses high-velocity air to entrain circulating solids in a highly turbulent combustion zone (Figure 1). This design allows combustion along the entire length of the reaction zone. Solids, slurries, or liquids can be introduced into the combustor loop where they contact hot bed material recirculating through the cyclone. When introduced into the primary combustion zone, the waste heats rapidly and continues to be exposed to high temperatures (up to 1800°F) throughout its residence time (approximately 1.5 sec for gases) in the combustion loop. High velocity air entrains the circulating soil, which travels upward through the combustor and into the cyclone. The cyclone separates the combustion gases from the hot solids. The solids then are returned to the combustion chamber via a proprietary non-mechanical seal. As a consequence of the highly turbulent combustion zone, temperatures around the entire combustion loop are uniform to within $\pm 50^{\circ}\text{F}$. The hot flue gases and fly ash pass through a convective flue gas cooler into a baghouse filter which traps the ash. Filtered flue gas then exits to the atmosphere. Heavier particles of purified soil remaining in the combustor lower bed are removed slowly by a water-cooled bed ash conveyor system.

Acid gases and sulfur oxides formed during combustion are captured by limestone added directly into the combustor. The reaction of limestone and hydrochloric acid (HCl) forms calcium chloride; the reaction of limestone and SO_x forms calcium sulfates. The combustion and neutralization of the acid gases within the combustion chamber eliminate the need for afterburners and add-on scrubbers. Emissions of CO and NO_x are controlled to low levels by the turbulent mixing, low temperatures (1,425°F to 1,800°F), and staged combustion achieved by injecting secondary air at sequenced locations in the combustor. OES has found that because of the high heat of combustion and turbulent mixing, the CBC is capable of attaining required DREs for both hazardous wastes (99.99%) and toxic wastes (99.9999%) at temperatures below those used in other types of incinerators (typically > 2400° F) [2,3].

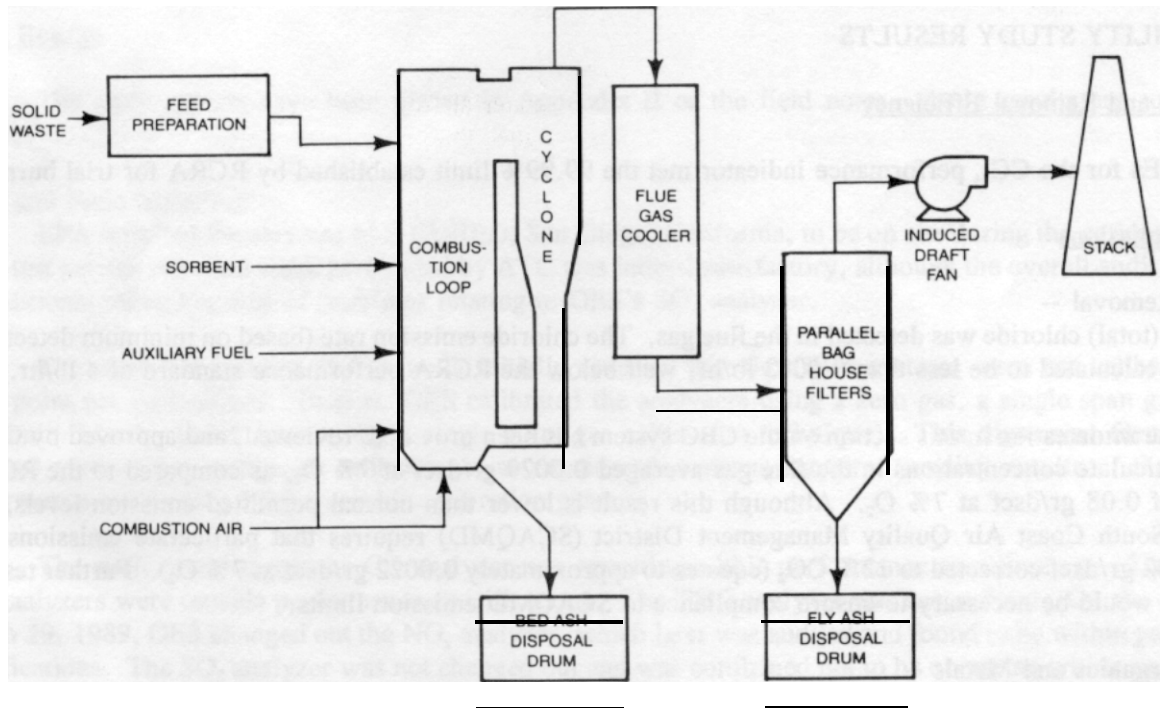


Figure 1. Schematic flow diagram of CBC for waste treatment.

The CBC technology accomplishes pollution control through a high efficiency fabric baghouse filter to control particulate releases; low operating temperatures, minimum excess air, and staged combustion to control NO_x emissions; gas/solids-mixing to control CO and volatile organic hydrocarbon (VOHC) emissions; and the addition of limestone to the combustor for in situ scrubbing of acid gases, with no liquid waste streams.

SAMPLING AND ANALYSIS PROGRAM

EPA contracted the services of the Alliance Technologies Corporation laboratories to sample and evaluate the physical and chemical characteristics of the waste feed, bed ash, and fly ash for volatile and semivolatile organics, metals, dioxins and furans, polychlorinated biphenyls (PCBs), and organic and inorganic halogens; the limestone feed for metals and calcium; and the stack gas stream for volatile and semivolatile organics, particulates and chlorides. OES collected operational data and conducted continuous emissions monitoring of the stack gas for SO₂, CO, NO, oxygen, CO₂, and THC.

TREATABILITY STUDY RESULTS

Destruction and Removal Efficiency

DREs for the CCl₄ performance indicator met the 99.99% limit established by RCRA for trial burns.

Flue Gas Emissions

Acid Gas Removal --

No (total) chloride was detected in the flue gas. The chloride emission rate (based on minimum detectable limits) was calculated to be less than 0.0083 lb/hr, well below the RCRA performance standard of 4 lb/hr.

Flue Gas Particulates --

Particulate concentrations in the flue gas averaged 0.0029 gr/dscf at 7% O₂, as compared to the RCRA limitation of 0.08 gr/dscf at 7% O₂. Although this result is lower than normal permitted emission levels, the California South Coast Air Quality Management District (SCAQMD) requires that particulate emissions not exceed 0.002 gr/dscf corrected to 12% CO₂ (equates to approximately 0.0022 gr/dscf at 7% O₂). Further testing of the CBC would be necessary to ensure compliance to SCAQMD emission limits.

Flue Gas Organics and Metals --

Only low concentrations of hazardous organics and metals were detected in the flue gas.

CEM Results --

CO, NO_x, and THC emissions were controlled below the OES facility permit limits of 250 ppm for CO and 100 ppm for THC. (NO_x emissions were not permit-specified.) SO₂ results were not quantifiable because, during the study, the SO₂ analyzer was not operating within performance specifications.

Organics Destruction

Organics originally present in the waste feed were not detected in the fly ash and bed ash streams, and were low in the flue gas. PCBs, PCDDs, and PCDFs were not detected in the waste feed, residual ash, or flue gas streams. PIC concentrations and concentrations of other undesired combustion by-products appear to have been minimized in this study, and will be further evaluated in the SITE test. Organic chloride detected in the Run 3 sample was attributed to the CCl₄ used to spike the sample.

Toxic Metals Distribution

Metals in the waste feed were partitioned into the ash and flue gas streams. Ash leachate tests defined the ash residue as non-hazardous. The effect of the metals concentrations in the flue gas will be evaluated in health risk assessment for the on-site Demonstration Test.

TCLP Results

Toxicity characteristic leaching procedure (TCLP) test results on the ash stream were below the established TCLP regulatory limits. However, the high pH of the ash matrix may have affected the results. No significant organic concentrations were found in the leachate.

Physical Characteristics

No anomalies were found in the physical/chemical results.

System Operating Conditions

Except for initial feed interruptions caused by the SO₂ and THC interlocks operating, the system performed reliably. However, the relatively high heating value and variable SO₂ content of the McColl feedstock will result in transient surges that will affect the operation of the CBC. The effectiveness of the CBC control system in reacting to intentionally-induced abnormal operating conditions -- intended to test its reaction to feed variations -- was not determined because of the facility permit conditions. The optimum Ca/S ratio required to limit SO₂ emissions also could not be evaluated because of the permit limitations.

Quality Assurance/Quality Control

The QA/QC analytical results indicated that reliable data was obtained from the study (except for the SO₂ analyzer data, as reported in the audit results).

Costs

OES's total costs for the demonstration were calculated to be \$193,505 based on permitting, labor, supplies, facility modifications, and decontamination. EPA costs were \$620,000 for waste preparation, transportation, sampling and analysis, waste disposal, and report preparation. More detailed costs will be developed during the SITE Demonstration Test at the McColl She.

CONCLUSIONS

It is concluded that the CBC technology can be evaluated further under the SITE Program. The SITE Demonstration Test should be designed to test the CBC at its full operating capacity. The viability of this option is dependent upon further deliberations among the regulatory agencies, discussions with the technology developer, and continued evaluation of the treatability study results and other available test data to verify that the CBC can meet the regulatory standards.

SECTION 2 INTRODUCTION

THE SITE PROGRAM

In 1986, the EPA's **Office** of Solid Waste and Emergency Response (OSWER) and **Office** of Research and Development (ORD) established **the Superfund** Innovative Technology Evaluation (SITE) Program to promote the development and use of innovative technologies to clean up Superfund sites across the country. Now in its **fifth** year, the SITE Program is helping to provide treatment technologies necessary to implement new federal and state cleanup standards aimed at permanent remedies, rather than quick **fixes**. **The** SITE Program is composed of three major elements: the Demonstration Program, the Emerging Technology Program, and the Monitoring and Measurement Technologies Program.

The major focus has been on the Demonstration Program, which is designed to provide engineering and cost data on selected technologies. To date, the demonstration projects have not involved funding for technology developers. EPA and developers participating in the program share the cost of the demonstration. The developers are responsible for demonstrating their innovative systems at chosen sites, usually Superfund sites, while EPA is responsible for sampling, analyzing, and evaluating all test results. The result is an assessment of the technology's performance, reliability, and cost. **This** information is used in conjunction with other data to select the most appropriate technologies for the cleanup of Superfund sites.

Developers of innovative technologies apply to participate in the Demonstration Program by responding to EPA's **annual** solicitations. EPA also will accept proposals at any time when a developer schedules a project to treat Superfund waste. To qualify for the program, a new technology must be at the pilot- or full-scale development stage and offer some advantage over existing technologies. Mobile technologies are of particular interest to EPA.

Once EPA has accepted a proposal, EPA and the developer work with the regional **offices** and state agencies to identify a site which contains wastes suitable for testing the capabilities of the technology. EPA prepares a detailed sampling and analysis plan designed to thoroughly evaluate the technology and to ensure that the resulting data are reliable. The duration of a demonstration varies from a few days to several months, depending on the length of time and quantity of waste needed to assess the technology.

Sometimes EPA conducts a series of tests to assess the performance of a specific technology on a specific waste. This is called a treatability study. **This** was the mechanism used to test the **McColl** waste at the **OES** research facility.

McCOLL SITE DESCRIPTION

The **McColl** Site in Fullerton, California, was used from 1942 to 1946 for the disposal of waste consisting of acidic sludges from the **alkylation** and product-treating processes used in the refining of aviation gasoline. The waste was deposited in twelve large pits (sumps). At that time, the property surrounding the site was relatively undeveloped except for an oil **field** to the north, a hog farm, and agricultural land to the south. From the mid-1950s to **1962** four of the six eastern sumps were covered with drilling mud from nearby **oil** fields. **The** other six sumps were covered in the late 1950s by the construction of the Los Coyotes golf course. **The** site currently consists of two distinct areas referred to as the Ramparts and Los Coyotes areas, **as** shown in Figure 2. In **1968**, homes were built in the area approaching the eastern border of the Ramparts section of the site. From 1978 to 1980, residential development was completed in the areas east, south, and north of the site. In the late **1970s**, local, state, and federal agencies investigated complaints from residents near the site about odors and health problems believed to be related to the **McColl** Site. As an interim measure, the Ramparts area of the site was covered in 1983, and odors from the site have since decreased. From 1980 to 1983, the California

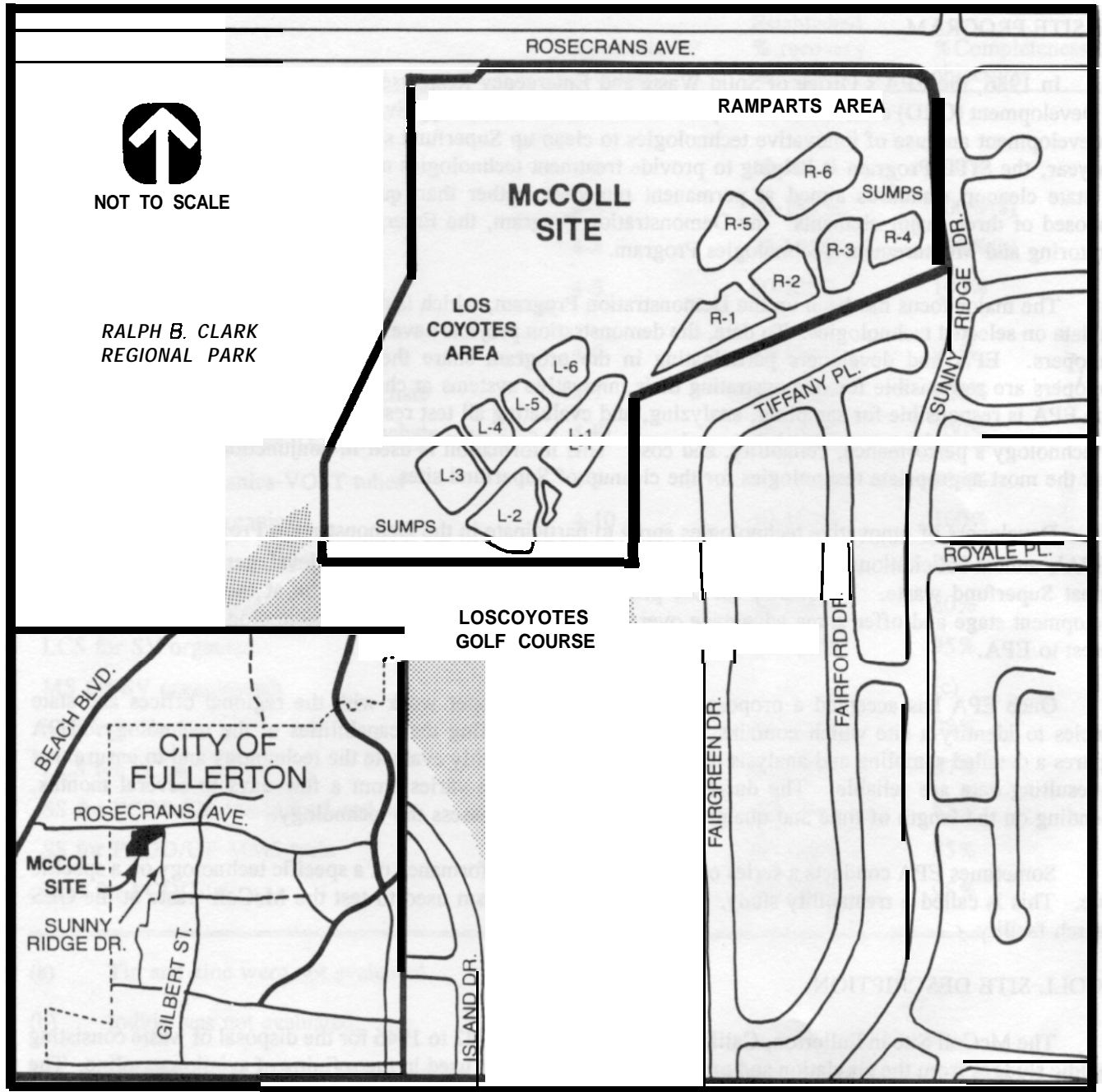


Figure 2. McColl Site layout.

Department of Health Services (DHS) conducted a remedial investigation/feasibility study (RI/FS) to determine the best course of action to be taken to remediate the site.

In 1984, the EPA and DHS decided that the appropriate action was excavation, removal, and transportation of the waste to an off-site facility for final disposal. Execution of the remedy was halted in 1985 by a State court injunction requiring the preparation of an environmental impact report (EIR) prior to removal of material from the site. In 1989, EPA completed an SROA which concluded that thermal destruction was a viable method for the site remediation.

The three major waste types encountered at the McColl Site are 1) viscous, black, tar-like wastes; 2) grey sludge-like material that may be drilling mud; and 3) hard, black, asphaltic wastes. The predominant type of waste is the hard black asphaltic type. It is characterized by having low pH(2), high sulfur content (8.1%), and elevated concentrations of organic sulfur, aromatics, and aliphatic hydrocarbons. The acid sludge has changed in physical and chemical character over the years: the acid component in the sludge has reacted with the oil component, producing a mixture of complex organic and sulfur-containing compounds. Some components of the sludge have hardened or polymerized, causing a physical change in the waste material.

Borings were conducted in 1987 to characterize the McColl waste. Each boring was sampled and analyzed for all of the organic and inorganic constituents on the hazardous substance list (HSL) excluding pesticides. (EPA had researched the waste disposed at the site and determined that pesticides never were present.) Table 1 lists the average and maximum concentrations of the organic and inorganic compounds identified in the site waste. Based on these results EPA selected drums of waste to be used in the treatability study. Further analyses of the candidate drums provided a final selection that was representative of the site waste and consistent with the OES research facility's permit conditions. The site waste material was screened, divided into two sets of feedstock (one blended with sand and the other left as raw waste), and transported to the OES facility for processing.

PROGRAM OBJECTIVE

The objective of the demonstration was to evaluate the effectiveness of the CBC technology in thermal destruction of the organic hazardous constituents from the McColl waste and thus to determine if the technology is a viable candidate for further on-site testing under the SITE Program. During the test, OES operated and maintained the CBC, and provided process monitoring and continuous emissions monitoring (CEM). EPA conducted process inlet and outlet stream sampling and analysis to determine the CBC's operating efficiency and contaminant destruction capabilities. Stack sampling and analysis were designed to provide the data necessary to evaluate the CBC and assess the environmental effects of a full-scale SITE Demonstration Test using the CBC technology. Ash analyses were designed to permit an evaluation of the disposal options for the ash product.

The treatability study's scope was limited by the OES facility permits. An extended project scope, development of more in-depth criteria, and collection of more extensive data will be required in any future SITE Demonstration Test.

EPA will be evaluating the results of the demonstration to determine if the emissions levels can meet SCAQMD requirements. If so, an on-site, full-scale test of the OES CBC technology would gather data about this type of thermal treatment and determine its applicability, not only to the McColl Site, but also to other Superfund site cleanups.

TABLE I. CHEMICAL CHARACTERIZATION OF MCCOLL WASTE

Constituent	Average(a) value (ppm)	Maximum(a) value (ppm)
<u>Organics</u>		
Methylene Chloride	3	17
Acetone	8	58
Chloroform	2	2
2-Butanone	0.4	3
Benzene	52	415
2-Hexanone	0.03	0.1
Toluene	71	728
Ethyl Benzene	27	208
Total Xylenes	74	744
2-Methyl Phenol	0.07	0.7
4-Methyl Phenol	0.6	1
Benzoic Acid	2	2
Naphthalene	55	120
2-Methyl Naphthalene	20	152
Diethyl Phthalate	2	9
Flourene	2	2
Phenanthrene	3	7
Di-n-Butyl Phthalate	0.03	0.05
Bis(2-ethylhexyl)Phthalate	0.4	5
Thiophene	89	678
Others (b)	553	10664
<u>Metals</u>		
Arsenic	17	203
Barium	71	517
Beryllium	1	1
Chromium	28	171
Cobalt	4	8
Lead	5	15
Manganese	104	242
Nickel	13	75
Tin	2	7
Zinc	28	43

(a) See Appendix V in Field Notes for details.

(b) Organic compounds not identified on the hazardous substances list.

PERFORMANCE CRITERIA

The criteria noted below were used to evaluate system performance and effectiveness, and to satisfy the program objective.

Destruction and Removal Efficiency(DRE)

DRE was the basis for evaluating the efficiency of the combustion process in destroying organic constituents while treating the McColl Site waste. The calculations for DRE were based on the destruction of a performance indicator (CCL₄) added to the feed material and analyzed in the residue streams. CCL₄ was selected because it is a difficult to destroy chlorinated compound that has been used as a performance indicator on previous RCRA trial burns.

Flue Gas Emissions

Flue gas analyses are among the most important criteria for a thermal destruction process because they evaluate the quality of the gas being emitted to the air. The treatability study was designed to evaluate acid gas emissions to indicate the chloride content of the flue gas and to determine the capability of the system to capture chlorides; particulate concentrations to show the amounts of solid material passing through the air pollution control devices; flue gas organic concentrations to determine the degree of organics destruction, the amounts of PICs and the in-process formation of new undesired hazardous organic components; metals concentrations to determine the disposition of volatile and particulate metals; and CEM results to quantify the criteria pollutants (CO, THC, SO₂, NO_x), oxygen (O₂), and carbon dioxide(CO₂) present in the gas being emitted to the atmosphere.

Organics Destruction

Organics (including those volatiles listed on the HSL), semivolatiles, dioxins, furans, and PCBs were analyzed in the feed, bed ash, and fly ash

streams, and in the stack gases. These analyses indicated the quantity of organic substances remaining in the residual streams, and thus, whether or not the process residuals had been rendered non-hazardous.

Toxic Metals Distribution

The feed, residue, and flue gas streams were evaluated for the presence of toxic metals to determine 1) the partitioning of the non-volatile metals into the resulting ash; 2) stabilization within the ash matrix to prevent the metals from leaching; and 3) capture of the volatile metals from the flue gas stream before their release into the air.

TCLP Results

TCLP tests measured metals and organics in the ash to determine if it could be designated as non-hazardous.

Physical Parameters

Several physical parameters of the waste feed and ash streams were evaluated to characterize the fly ash and bed ash residues.

System Operating Conditions

The process operating parameters were tracked and logged to allow 1) process calculations; 2) evaluation of system problems during operation; 3) determination of equipment maintenance requirements; 4) quantification of waste residuals; and 5) development of costs to process the material.

QA/QC

Laboratory quality control samples were collected to evaluate if the precision, accuracy, and completeness objectives of the QAPP had been achieved.

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SECTION 3 VENDOR'S SYSTEM DESCRIPTION

INTRODUCTION

The information in this section is a presentation provided, reviewed, and approved by Ogden Environmental Services, Inc. The EPA makes no claims **as to the** accuracy of the statements.

SYSTEM DESCRIPTION

The nominal 2 MM **Btu/hr** CBC used in the SITE treatability study is owned and operated by Ogden Environmental Services, Inc., San Diego, California.

The primary CBC components are the combustion chamber, hot cyclone collector and solids return system, flue gas cooler, baghouse, and stack. Auxiliary systems include feed material systems, auxiliary fuel system, forceddraft and induced-draft fans, bed ash removal conveyor, compressed air system, cooling tower, safety and process control equipment, off-gas analysis systems, and building ventilation. Figure 3 is a schematic presentation of the process.

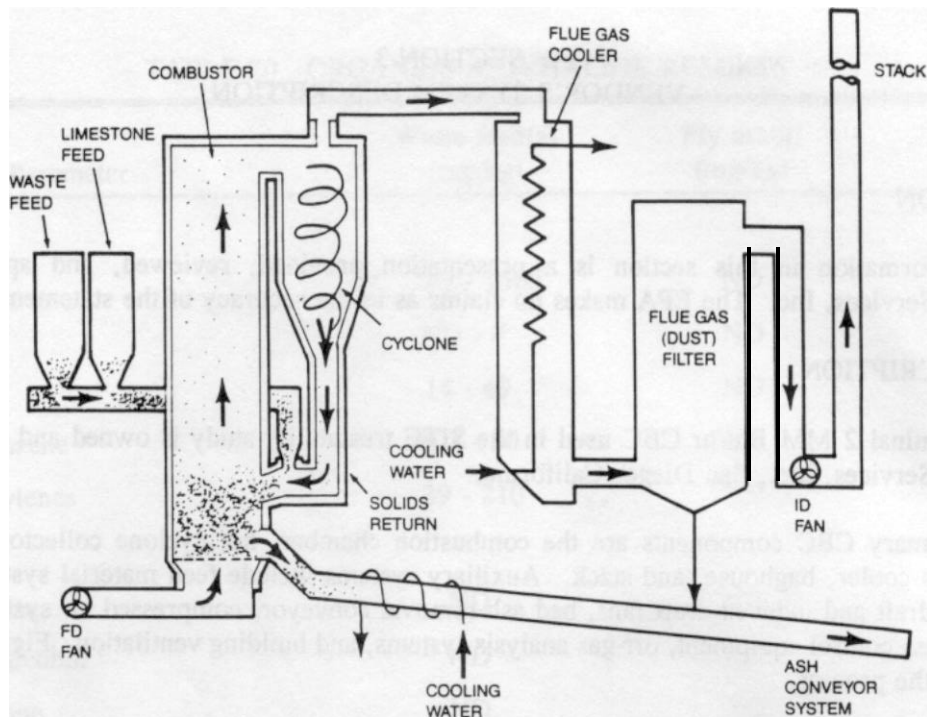
The OES pilot-scale combustor is 27 ft high with a **16-in.** inside diameter and 13-in. thick refractory liner. The CBC loop components (combustor, cyclone, and loop seal) are constructed of refractory-lined carbon steel which provides a thermal barrier as well as corrosion and erosion resistance.

System

A positive displacement blower pushes primary combustion air into the CBC below the air distributor and injects secondary combustion air through various ports along **the** combustor wall. The primary and secondary air flows are controlled independently. The primary air is pumped into the lower portion of the combustion chamber where **the** bed material is **fluidized** by turbulent mixing of **the** air and solids. Larger waste particles gravitate downward to form a more dense **fluidized** bed in the lower combustor zone. Smaller waste solids are carried up to the top of the combustor. The secondary air is supplied to various locations in the combustion chamber to ensure complete combustion of the waste and to minimize formation of nitrogen oxides (**NO_x**).

The high velocity of the combustion air and circulating waste create a uniform temperature (**± 50°F**) around the combustion loop, which is controlled at a **value** between **1,425°F** and **1,800°F**. This results in efficient combustion and eliminates the need for an afterburner. Residence times in the combustor range from approximately 1.5 **sec** for gases to 30 min for waste material. The combustion and neutralization of acid gases within the combustor chamber eliminate the need for high-alloy combustor components or post-burner treatment units -- such as wet scrubbers -- and effect the desired contaminant destruction and acid- gas capture. CO and NO_x emissions are controlled to low levels by 1) the mixing of **the** fuel, waste feed, and combustion air; 2) the combustor's relatively low operating temperatures; and 3) staged secondary air injection along the combustion chamber length at progressively higher locations, resulting in continued combustion and destruction of waste over the entire height of **the** combustion chamber.

The high turbulence of solids within **the** combustor makes the CBC combustion process relatively insensitive to feed properties. Wet waste feeds and slurries can be fed and incinerated as easily as dry solids. The high internal combustor heat transfer ensures that moisture in the feed evaporates **with** little depression in local combustor temperature. One effect of feed moisture on the incineration process is on **the** heat energy balance: energy that would otherwise go to processing contaminated soil is used to evaporate water. The CBC



(Courtesy of Ogden Environmental Services, Inc.)

Figure 3. Schematic of the OES CBC system

is insensitive to large amounts of fines in the feed streams - feed fines benefit the waste circulation that produces the isothermal combustor conditions. The combustor's design controls the behavior of fines automatically.

Fuel System

An auxiliary fuel system - capable of up to 2 MM Btu/hr thermal output - supplies natural gas in the ignitor during start-up and in the in-bed lances during steady-state operation. The natural gas provides process heat during waste treatment. An operator adjusts the natural gas flow rate to control the flue gas oxygen emissions at their target value. Retractable, water-cooled, bayonet heat exchangers are available, when needed, to remove heat from the combustor.

Solids System

A fully-enclosed solids feed station is used to prepare the waste feed. The station includes a ventilated alcove where drums are unsealed and waste is typically sampled before it is loaded into the feed bunker. The station is maintained at negative pressure to minimize fugitive emissions. Ventilation gases are pulled through activated carbon and HEPA filters before they are exhausted.

Waste is transported pneumatically from drums to a solids surge bunker and then is dropped into the feed bunker. A weigh cell continuously displays the inventory remaining in the feed bunker. (The San Diego APCD allowed a 200 lb/hr maximum feed rate for the treatability study.) An Acrison screw-auger meters the waste from the feed bunker in a rotary valve and into the CBC loop at the solids return leg where it contacts the hot waste stream recirculated by the cyclone. Key operating parameters are monitored continuously. If the permit-mandated limit is reached, the feed system stops automatically.

Auxiliary fuel and waste feed are introduced separately into the lower combustion chamber. Dry limestone sorbent is added to control gaseous emissions of sulfur and chloride. Sorbent feed is loaded manually into a bunker from which it is metered by a screw-auger to a rotary valve and into the CBC. A level sensor measures the inventory of sorbent in the bunker. The sorbent feed rate is adjusted manually to control acid-gas emissions below the permit-mandated limit. Elutriated solids are separated from the flue gas by a hot cyclone and reinjected into the lower combustor by means of a proprietary non-mechanical seal. The continuous ignition, burning, and reaction of the fuel, waste feed, sorbent, and ash components effectively destroy the waste's contaminants. Acid gases and sulfur oxides formed during incineration are captured by the limestone sorbent, which combines with hydrochloric acid to form calcium chloride, and with SO_x to form calcium sulfates.

During operation, bed ash is removed periodically from the CBC by means of a water-cooled ash removal system consisting of a screw conveyor and bucket elevator. The bed ash is cooled to below 350°F to allow safe discharge into drums. Negative pressure ventilation prevents the release of fugitive bed ash dust.

Flue Gas System

The temperature of the hot gas leaving the cyclone is lowered below 400°F in a watercooled flue gas cooler (FGC). The FGC heat transfer surfaces are cleaned on-line by soot blowers. A high-pressure blower, fixed position nozzles, and automatic sequencing controls and valves are provided for the soot-blowing system.

The fly ash that is carried through the FGC is collected continuously by baghouse filters. These filters reduce the particulate loading in the flue gas below the EPA RCRA particulate emission limit of 0.08 gr/scf. The system consists of two baghouse modules, each of which contains 25 fabric filters with 275 sq ft of filter surface area. The filters, cleaned on-line by pulse jets, are acid-resistant and can operate at temperatures up to 500°F. If necessary, either baghouse module can be removed from service without interrupting testing or compromising safety. The baghouse features are described more fully in Table 2.

An induced-draft (ID) fan is located directly upstream from the stack. The ID fan suction is adjusted automatically. It maintains the entire combustion loop, the flue gas cooling system, and the cleaning equipment slightly below atmospheric pressure to prevent fugitive emissions.

Exhaust Air System

The research facility is serviced by a dedicated ventilation system providing 7,500 cfm of air flow. All exhaust air is HEPA-filtered to control the release of fugitive dust.

PROCESS CONTROL

System control functions are exercised from a central control room. Microprocessor-based proportional integral derivative (PID) controllers govern process flows such as system pressures and combustion air, auxiliary fuel, and waste feeds. Thermocouples monitor combustor temperatures through thermowells penetrating the combustor shell and refractory. A control panel provides remote readout of the combustion temperatures.

Combustion air is injected below the air distributor and at various levels along the chamber wall. Primary air is maintained automatically at a specified flow rate. Secondary air is also controlled automatically – with a butterfly valve on the main secondary air supply header and by individual throttling valves in each secondary air injection pipe. Air flow rates are measured by annular flow meters. The ratio of secondary to primary air can be controlled manually, as indicated by the particular test requirements and by flue gas emissions. The ID fan is adjusted automatically to achieve the desired pressure balance at the waste feed inlet. The control panel gives remote readouts from a pressure sensor at the feed point and from differential pressure sensors at the gas distributor, the riser section of the combustor, the hot cyclone, and the non-mechanical seal.

TABLE 2. BAGHOUSE FILTER SYSTEM

Operating Conditions

Temperature	< 500°F maximum
Gas volume	800 acfm
Dust loading leaving filter	< 0.08 gr/dscf
Dust removal efficiency	99.6%
Maximum pressure drop	15" wc (baghouse cleaning will keep DP < 6" wc)

Design Criteria

Type of bag cleaning	Pulse jet/on-line (off-line as backup)
Gas flow pattern	Draw through/suction
Maximum air to cloth ratio	3.2 acfm/sq ft
Bag type	Outside collecting
Bag material	Gore-Tex membrane filter bags (total filtering surface 550 sq ft)
Cage material	Carbon steel
Number of modules	2

A speed-controlled metering screw conveys waste to the combustor feed point where the waste contacts hot circulating solids. This mixed waste is then injected into the combustion chamber. The natural gas fuel system used for start-up and for auxiliary heat is normally off during waste burning. If the waste feed is interrupted, the auxiliary fuel system will be reactivated. This feature allows combustion temperature control during brief, intermittent, and correctable fuel feed interruptions.

Safety Controls

The feed rate controllers are interlocked to key process parameters through the programmable logic controller (PLC). These key process parameters are identified in Table 3. If any of the measured variables exceed permit-mandated or acceptable limits, or in the event of a power failure, the feed stops automatically.

If the emergency stop button is pressed, all feeds and fluidizing air are shut off, while the ID fan is left on to maintain negative pressure on the system, thus minimizing fugitive emissions. Auxiliary fuel is controlled by a valve train that is interlocked to bed temperature, start-up burner flame-detection, flue gas oxygen, combustor pressure, cooling-water flow, and total air flow. If any of the measured parameters exceed acceptable limits, the valve train will shut off the auxiliary fuel. Valves with fail-safe positions are designed to enclose all solids and vapors within the combustor system.

The critical system equipment is monitored automatically, and conditions are displayed on the control panel, which is staffed by trained operators. Equipment failures, which could compromise system performance and safe operation, either initiate automatic control/corrective procedures, or alert the operator to the system problem through an alarm annunciator. This, coupled with frequent routine inspections, serves to adequately mitigate the effect of any equipment failure.

TABLE 3. INTERLOCK SETTINGS

Parameter	Set Point
CO concentration (5-minute average)	1,000 ppm (volume)
Combustion temperature (1-minute average)	<1,300°F
Combustion residence time (1-minute average)	< 1.0 sec
O ₂ concentration (5-minute average).....	1.0 volume %
THC concentration (5-minute average).....	400 ppm (volume)
SO ₂ concentration	504 ppm (volume)
Baghouse inlet temperature	>400°F

PROCESS MONITORING AND DATA ACQUISITION

All significant process data are monitored and logged either on manual logs, six 3-pen strip recorders, a 30-channel chart recorder, or the **256-channel** computerized data acquisition system @AS).

The computerized DAS displays key process variables on CRTs located in the control room. These variables include loop temperatures and flue gas composition. The system prints out selected data on a line printer at 15 min intervals. The data include combustion air flows; natural gas flow; concentrations of O₂, NO, (as NO), SO₂, CO, CO₂, and THC; **baghouse** and combustor differential pressures; and combustor loop and inlet **baghouse** temperatures. The DAS also can be used to analyze and plot data **after** a test's completion. Graphic and tabular summaries of the treatability study data collected in the DAS have been prepared by OES and are included as Appendix III in the field notes.

One chart recorder has 30 plotting channels. **These** process variables are described in Table 6 of Appendix III in the field notes. Additionally, **five** 3-pen strip chart recorders continuously retain 1) bed temperatures, O₂ probe readings, and THC analyzer outputs; 2) CO, **NO_x**, and **CO₂** analyzer outputs; 3) **SO₂** and **O₂** analyzer outputs; 4) primary air, secondary air, and reactor purge data; and 5) cyclone pressure and natural gas flows. Strip chart recordings are maintained in **OES's** files. Waste feed, limestone feed, fly ash, and bed ash logs are maintained manually to determine process rates.

SECTION 4 TEST PROGRAM PROCEDURES

WASTE FEED PREPARATION

In December 1988 selected drums of McColl waste were sampled to characterize the drum contents and to select candidate drums that were both representative of the McColl Site waste and within Ogden Environmental Services (OES) permit restrictions. Each drum was analyzed for total sulfur and total organic carbon (TOC); a composite sample was further analyzed for volatile and semivolatile organics, dioxins, furans, pesticides, PCBs, and metals. Results of the analyses are included in Appendix IV of the field notes.

After selection of the candidate drums, waste feed underwent preparation on-site in early March 1989 to allow processing with a minimum of handling at the OES facility. The waste feed was inspected visually to ensure that it was dry and free-flowing, then screened of debris, blended with sand if the sulfur content was in excess of 5% (to meet permit restrictions), placed into clean DOT 17-H 55-gallon drums, sealed, labeled, manifested, and shipped to the OES research facility on March 9, 1989.

OPERATING CONDITIONS AND OPERATING RANGE

The treatability study was conducted under processing conditions as close as possible to those expected in a full-scale CBC. Process conditions were adjusted to control stack emission concentrations of criteria air pollutants (CO, NO_x, SO₂, THC) and particulates while optimizing process rates for air and limestone. However, regulatory restrictions affected system optimization.

The CBC was heated to an operating temperature of 1,700^oF with an inert starting bed of sand and held at this temperature over 20 hours to establish thermal equilibrium within the combustor prior to introducing the waste feed. An 8-1/4 hr fine-tuning pretest to establish steady-state operating conditions was followed by Test 1, an 8-1/2 hr steady-state operation using blended, unspiked feed; Test 2, a 7-1/4 hr operation using unblended, unspiked feed; and Test 3, a 6-1/2 hr operation using unblended, spiked feed. The actual test durations are shown in Table 4; process conditions are listed in Table 5. An after-test operation using blended, unspiked waste was planned to gather additional CEM data but was not executed because the SO₂ analyzer was not operating within performance specifications.

Waste feed and limestone rates were controlled to ensure that emission concentrations of criteria pollutants were maintained within permitted levels. Several SO₂ spikes were experienced, activating the interlocks and stopping the feed. At least four SO₂ excursions occurred causing further feed interruptions. By late afternoon it became apparent that the waste feed properties required a larger auger to attain the desired feed rates. The auger was replaced during the night.

Test 1 began on March 29. Up to eleven SO₂ spikes occurred, causing waste feed interruptions. A hydrocarbon spike also caused a feed interruption, which delayed sampling for about one hour. Tests 2 and 3 were conducted on March 30. OES decided to saturate the bed with limestone to prevent any further SO₂ spikes. Test 3 was conducted in the afternoon using unblended McColl waste spiked with 6,000 ppm (by wt.) of CCl₄.

Each day's test began with limestone feed, followed by waste feed. Operation during the first test attempted to optimize the limestone-to-feed ratios, but SO₂ spikes resulted. In the interest of staying well within the permit limits, OES decided to use an excess of limestone. Combustion air and secondary air flows were adjusted to control CO, CO₂, and NO_x emissions. Process conditions were maintained constant throughout the sampling activity to ensure that adequate sample volumes were collected to obtain reliable analytical results. Except for several momentary feed cutoffs, the system remained operational throughout the sampling runs. At

TABLE 4. TEST DURATIONS

Day	Test	Duration (hrs)	Feed	Spiking	feedrate (lb/hr)	Waste rate (lb/hr)	Sampling
3/27/89	System heatup	21-1/2	Bed ash/sand	None		None	CEM only
3/28/89	Pretest fine tuning	8-1/4	Blended with sand	Unspiked	400	200	CEM only
3/29/89	#1	8-1/2	Blended with sand	Unspiked	325	163	4 hours full sampling
3/30/89	#2	7-1/4	Unblended	Unspiked	170	170	3 hours full sampling
3/30/89	#3	6-1/2	Unblended	Spiked (6000 ppm CCl ₄)	197	197	3 1/2 hours full sampling

the conclusion of each day's test, the waste feed was stopped and the system was idled at 1700°F until the next day's operations. Additional daily events logged by ATC and OES can be found in Appendices II and III of the field notes.

SAMPLING AND ANALYSIS PROGRAM

ATC was responsible for collection and analysis of all program samples including QA/QC samples. OES was responsible for ensuring uninterrupted operation of the CBC system, collection of all CEM data, monitoring of process parameters, and maintaining weight logs for waste feed, limestone feed, bed ash, and fly ash.

The CBC process stream monitoring locations are shown in Figure 4. Table 6 describes the OES monitoring parameters and methods, and Table 7 summarizes the ATC process stream sampling and analysis parameters and methods. Changes to the planned ATC program are summarized in Appendix II of the field notes.

Process stream sampling

Waste Feed –

Grab samples of the waste feed were taken during the flue gas sampling tests, composited, and riffled prior to aliquoting for the different analyses. Discrete grab samples were taken for volatile analysis on an hourly basis, yielding a total of eight discrete samples for the test. The samples were collected at a point after the feed hopper, just before the waste material entered the combustion chamber.

TABLE 5. TREATABILITY STUDY PROCESS/PERMIT CONDITIONS

Process conditions	Target test conditions	Federal/State Permit limits	APCD Permit limits	Test 1(a)	Test 2(a)	Test 3(a)
waste feed rate	400 lb/hr(b)	<500 lb/hr(c)	200	325(b)	171	197
Limestone feed rate	ns	ns	ns	197	349	182
30 meshes and	500 Lb/hr	ns	ns	162	0	0
FLY ash rate	ns	ns	ns	231	296	201
Bed ash rate	ns	ns	ns	201	53	21
Carbon tetrachloride	0.4 lb,hr	ns	ns	0	0	0.22
Mid combustortor temp.	1700°F +/-50 ⁰	>1425 ⁰ F	>1425 ⁰ F	1721	1726	1709
Residence time	1.5-1.7 sec	>1.4 sec	≥1.4	1.54	1.52	1.55
Superficial velocity	16-18 ft/sec	ns	ns	17.5	17.7	17.4
Combustion air	300-500 SCFM	ns	ns	331	331	331
Natural gas	10-20 SCFM	ns	ns	19.6	23.1	18.7
Flue gas oxygen dry	>5.5%	>5.3%	15.3	11	9.9	11.8
Flue gas oxygen wet	ns	ns	ns	9.1	7.9	9.7
CO emissions(d)	<100 ppm	1250 ppm	≤250	30	30	26
NOx emissions	100 ppm	ns	ns	49	58	48
SO ₂ emissions	<500 ppm	ns	≤504(e)	(f)	(f)	(f)
HCl emissions	0.2 kg/hr	≤1.8 kg/hr(g)	ns	~0.0040	<0.0035	<0.0037
THC emissions(d)	400 ppm	<100 ppm	≤100 ppm	5	1	2
Particulates(h)	<0.08 gr/dscf	<0.08 gr/dscf	ns	0.0029	0.0035	0.0023
Baghouse DP	<6 in wg	<12 in wg	<15 in wg	3.1	3.5	4.9
Baghouse inlet temp.	300 ⁰ -375° F	<400 ⁰ F	<400° F	377	368	357
Flue gas flow rate (dscfm)						
Metals	ns	ns	ns	979	957	984
Semi vol atiles	ns	ns	ns	868	850	905
VOST	ns	ns	ns	923	903	946

(a) Average values for comparison only. NOT TO BE USED FOR CALCULATIONS. See Appendix II and III in Field Notes for details.

(b) Includes 50% sand. Permit restriction of 200 lb/hr refers to waste only.

(c) Feed was restricted to 5% total sulfur content.

(d) Dry basis.

(e) APCD restricts flue gas SO₂ concentrations (corrected to 3% O₂ dry standard conditions) to less than the equivalent SO₂ concentration when the fuel composition is corrected to 0.5% sulfur by weight.

(f) Not quantifiable. SO₂ analyzer was not operating within performance specifications

(g) Or 99% removal efficiency.

(h) Corrected to 7% O₂.

ns not specified

TABLE 6. DESCRIPTION OF CBC MONITORING PARAMETERS AND METHODS

Process parameter	Location ^(a)	Instrument type	Recorder ^(b)	Recording frequency (per hr)
Combustion air flow rates	1A, 1B, 1c	Pilot tube plus DP cell	YEW, DAS, CR	
Natural gas flow rates	2	Mass flow meter	YEW, DAS, CR	
Limestone feed rate	3	Level detector	Vibrascrew log	1
Solid waste feed rate	4	Loss-of-weight-bunker	DAS, Acrison log	2
Bed ash drain rate	5	Barrel scale	Bed ash log	1
Fly ash drain rate	6	Barrel scale	Fly ash log	1
Combustion loop temperatures	7	Type K thermocouples	YEW, DAS, CR	
Combustion loop pressures	8	DP cells	YEW, DAS, CR	
Combustion loop DPs	8A	DP cells/DP Gauges	YEW, DAS, CR	
Flue gas outlet temperature	9	Type K thermocouples	YEW, DAS,	-
Flue gas oxygen	10	O ₂ probe	YEW, DAS, CR	--
baghouse DP	11	DP cell	YEW, DAS,	--
Extractive flue gas composition	12			
O ₂		Paramagnetic	YEW, DAS, CR	
CO		Infrared	YEW, DAS, CR	-
CO ₂		Infrared	YEW, DAS, CR	--
NO _x		Chemical luminescence	YEW, DAS, CR	--
SO ₂		Infrared	YEW, DAS, CR	--
HC		Flame ionization detector	YEW, DAS, CR	

(a) See Fig. 4

(b) Recording media: YEW= 30 channel recorder (every 8 s); DAS= data acquisition system (every 2 min); CR = chart recorder (continuous); logs = manual data.

TABLE 7. PROCESS STREAM SAMPLING AND ANALYSIS

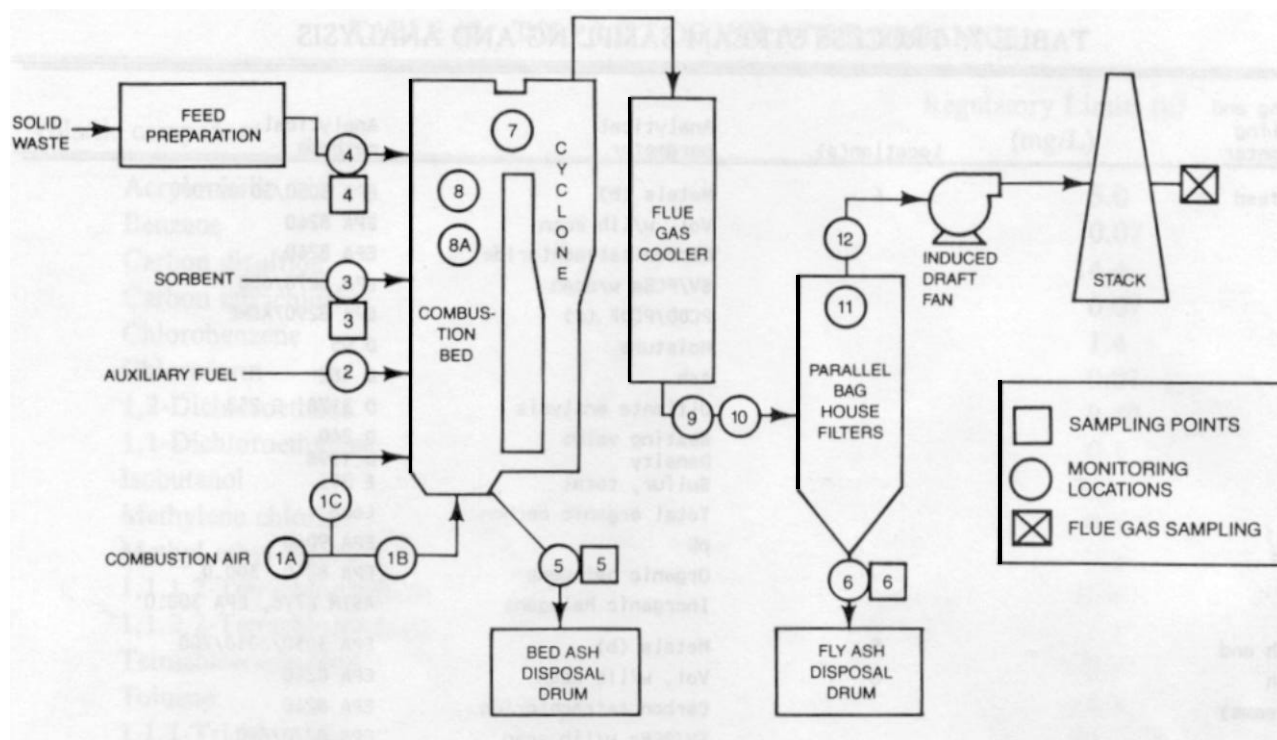
Locating and sampling parameter	Location(a)	Analytical parameter	Analytical methods
Waste feed	4	Metals (b)	EPA 3050/3010/7000
		Vol. w/libscan	EPA 8240
		Carbon tetrachloride	EPA 8240
		SV/PCBs w/scan	EPA 8270, 680
		PCDD/PCDF (c)	EPA 8290/ASME
		Moisture	D 95
		Ash	O 482
		Ultimate analysis	O 3178, E 258
		Heating value	O 240
		Density	O 1298
		Sulfur, total	E 395
		Total organic carbon	Leco
		pH	EPA 9040
		Organic halogens	EP. 4 8240, 300.0
Inorganic halogens	ASTM E776, EPA 300.0		
Bed ash and Fly ash (2 streams)	5	Metals (b)	EPA 3050/6010/700
	6	Vol. w/lib scan	EPA 8240
		Carbon tetrachloride	EPA 8240
		SV/PCBs w/lib scan	EPA 8270/680
		PCDD/PCDF (c)	EPA 8290/ASME
		Moisture	O 1744
		Ash	O 482
		Density	O 1298
		Sulfur, total	E 395
		pH	EPA 9040
		Organic halogens	EPA 8240, 300.0
		Inorganic halogens	ASTM E776, EPA 300.0
		TCLP volatiles	SW 846 8240
		TCLP metals, Cr(VI)(d)	SW 846 6010/7000/7196
Inorganic halogens	Extraction. EPA 9020		
Organic halogens	Leachate, EPA 9020		
Limestone feed	3	Metals (b) Calcium	EPA 3050/3010/7000

(a) See Figure 4.

(b) Total metal parameters include: Sb, As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, Se, Tl, Ag, Sn, and Zn.

(c) Dioxin/furan groups include tetra- through octa- groups and confirmation of 2, 3, 7, 8-TCDD and TCDF.

(d) TCLP metals include: As, Ba, Cd, Cr, Pb, Hg, Se, Ag.



(Courtesy of Ogden Environmental Services. San Diego, Calif.)
 Figure 4. Sampling and monitoring points of the CBC system.

Limestone Feed-

A grab sample from the limestone feed chamber was taken at the beginning and end of each test, designed to yield three discrete samples. However, due to a field oversight, limestone samples were not taken during Test 2.

Combustor Bed Ash --

Bed ash material was discharged from the bottom of the CBC and deposited into 55-gal drums; a time-integrated grab sample was taken from each drum, composited, and riffled. Volatile samples were collected as separate discrete samples and composited.

Fly Ash-

Fly ash was discharged from the baghouse into 55-gal drums. Core samples were taken from each drum, then composited, riffled, and aliquoted. Discrete samples were collected and composited for the volatile organics analyses.

Initial collection both of combustor ash and fly ash was attempted with a thief sampler. Because the sampler was unable to penetrate the drum depth without causing binding, the sampling procedure was revised for the first test by vacuuming the collection drum's contents into another drum and taking grab samples at equal depths throughout the drum. During Tests 2 and 3, 30-min grab samples were collected from the 55-gal drums.

TABLE 8. FLUE GAS SAMPLING AND ANALYSIS

Sampling parameter	Analytical parameter	Analytical parameter
Particulate	Particulate Metals(a)	EPA M5 Gravimetric EPA 3050/3010/7000
Semivolatile Organics	SV/PCB PCDD/PCDF (b)	EPA 8270/680 EPA 8290/ASME
Volatile Organics	Vol. w/library scan (c) Carbon tetrachloride	EPA 5040 EPA 5040
Chloride	Chloride	EPA 300.0
CO ₂ /O ₂ /CO/NO _x	CO ₂ /O ₂ /CO/NO _x	CEM System
SO ₂ /THC	SO ₂ /THC	CEM System

- (a) Metal parameters include: Sb, As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, Se, TI, Ag, Sn, and Zn.
- (b) Dioxin/furan groups include tetra- through octa- groups and confirmation of 2, 3,7, 8-TCDD and TCDF.
- (c) Four VOST pairs were collected per 4-hr run. Three pairs were analyzed and one pair held as backup. Analysis of VOST condensate is contingent upon flue gas moisture content.

Stack Sampling

The OES stack was modified to permit the use of several sampling trains to collect flue gas samples. A Modified Method 5 (MM5) train was used to collect particulates, metals, and semivolatile samples; a volatile organic sampling train (VOST) was used for organics; and a separate gaseous hydrogen chloride train was used for HCl. Gas rates were determined using a pitot tube. Table 8 summarizes the flue gas sampling and analytical parameters and methods.

ATC sampling and analysis activities determined the properties of the waste feed, limestone, bed ash, fly ash, and flue gas streams. The analytical workload was divided among three laboratories: Clean Harbors Analytical Services, Bedford, Mass. (formerly the Alliance Technologies Chemistry Division); Triangle Laboratories, Research Triangle Park, N.C.; and Industrial Testing Laboratories, St. Louis, Mo. Industrial Testing Laboratories was responsible for analysis of various physical parameters such as density, heating value, moisture, viscosity, ultimate analysis, pH, TOC, sulfur, and ash; Triangle Laboratories analyzed the flue gas samples for dioxins, furans, semivolatiles, and PCBs; and Clean Harbors Analytical Services was responsible for all other analyses, including volatiles, trace metals, total chlorides, HCl, organic and inorganic halogens, sulfur, TCLP results, calcium, particulates, and CCl₄.

The customized Method 5 train sampling was conducted isokinetically from 12 points in the stack for 15 min per Point. Sampling was conducted while traversing the train across a length equal to two stack diameters. Flue gas parameters were recorded every 10 minutes. The VOST was operated at a flow rate of one L/min for 20 min. Four 20-min samples constituted one VOST run. Three runs were completed to yield 12 sets of VOST

tubes, not including QA/QC sets.

The gaseous hydrogen chloride sampling train was operated for each sampling run, and semivolatile organic compounds including PCBs, PCDDs, and PCDFs were collected in an MM5 train. The train was operated for 20 min per point across a 12-point traverse.

Each train was leak-checked before and after each sampling run, and leakage rates were documented on the relevant field test data sheet. Recovery procedures for each train are documented in the Treatability Study Test Plan [6].

The Continuous Emissions Monitoring system (CEM) was maintained and operated by OES. The CEM sampling ports were located directly downstream of the baghouse filter modules. Particulates and moisture were removed from the flue gas sample before the sample was pumped into the continuous on-line analyzers. The flue gas analysis system provided an accurate near-real-time indication of flue gas composition. Provisions were made for on-line and off-line calibration of analyzers. The flue gas analysis system consisted of an extractive analysis system for monitoring O₂, CO₂, CO, NO_x, SO₂, and THC concentrations, and an in situ system for monitoring flue gas oxygen concentrations. The in situ oxygen probe was used to measure oxygen concentration at the exit of the flue gas cooler. The flue gas analyzers used to measure the flue gas composition are identified in Table 9.

EPA sampling methods were used to collect flue gas and particulate samples specific to each test and test feed material. Prior to planned operation of the research facility CBC, OES quality assurance performed a review and inspection of each of the CEM system transmitters and recorders system, as well as other essential control instruments to ensure that they were within designated accuracies. In addition, the EPA arranged for an independent audit of the CO, NO_x, and SO₂ analyzers as part of the test program. The operation of the analyzers is discussed in Section 5, and audit results are presented in Appendix II of the field notes.

Analytical procedures

Physical/Chemical Analysis --

Waste feed samples were analyzed at Industrial Testing Laboratories for moisture, ash, heating value, ultimate analysis, density, total sulfur, TOC, and pH.

Inorganic Analysis --

Metals-- Metals analyses were prepared using SW-846 methods 3010 or 3050. Occasionally certain wastes were not exactly amenable to these procedures, resulting in the need for such procedural modifications or alternative preparation procedures as 1) the use of a reduced sample size to provide elevated detection limits; 2) addition of small quantities of sulfuric acid in Method 3050 or hydrogen peroxide in Method 3010 to aid dissolution; or 3) elimination of hydrochloric acid from both Method 3010 or 3050. The need for these modifications was determined after sample preparation, and is documented in Appendix II of the field notes.

Analyses for all metals except mercury and hexavalent chromium were performed using inductively-coupled argon plasma emission spectroscopy (ICAP). Mercury analysis was performed using either Method 7470 or 7471, and hexavalent chromium in TCLP extracts was determined colorimetrically. Detection limits for these analyses are provided in the tables in Appendix II of the field notes.

Organic and inorganic halogen and hydrogen chloride -- Soil and ash samples were analyzed for chloride, bromide, and iodide by ion chromatography (IC). The preparation methods used various analytical techniques in a consolidation designed for this program. The procedures have not been tested relative to the precision, accuracy, detection limits, and anticipated method blank concentrations.

TABLE 9. FLUE GAS ANALYZERS

Parameter	Analyzer type	Range
O ₂	Beckman analyzer, Model 755	0-25%
CO ₂	Lira analyzer, Model 3000	0-25%
NO _x	Beckman analyzer, Model 951A	0-1,000 ppm
CO	Beckman analyzer, Model 865	0-1,000 ppm
SO ₂	Beckman analyzer, Model 865	0-1,000 ppm
THC	Beckman analyzer, Model 400A	0-1,000 ppm

TCLP metals -- Ash samples were prepared using the extraction procedure detailed in the Federal Register, Vol. 51, No. 216, November 7, 1986, pp. 40643-53. Analyses were performed for RCRA metals including arsenic, barium, cadmium, chromium, chromium (VI), lead, mercury, selenium, and silver.

Organic Analysis --

Volatile organics -- The waste feed, bed ash, fly ash, and flue gas samples were subjected to volatile organic analyses for CCI, and the compounds listed in Table 10. A library search was conducted to determine tentatively identified compounds (TICS) by comparing the unknown spectra to referenced spectra in the EPA/NBS/NIH library.

Semivolatiles/PCDD/PCDF/PCBs -- The semivolatile analytes included the HSL organics shown in Table 11. The PCDD/PCDF analyses provided concentrations of the tetra through octachlorinated homologues, and confirmation of the 2,3,7,8-isomers of TCDD/TCDF. The PCB analyses provided determinations of the mono through decachlorinated congeners.

In order to accommodate the analysis of SVs, PCBs, and PCDD/PCDFs from the same MM5 train, a two-stage extraction of the filter and XAD resin was used. This multiple analysis/extraction scheme was a combination of several approved EPA methods but the combination has not been validated. The data obtained using this method was flagged and evaluated in terms of the technique's questionability.

Organic halogens and sulfur -- Organic halogen and organic sulfur compounds were identified and quantified from the volatile and semivolatile GC/MS analysis of test samples.

TCLP volatile organics -- Ash samples were analyzed for TCLP volatile organics using the zero-headspace extraction procedure detailed in the Federal Register under TCLP metals. Analysis of the filtrates for volatile organics listed in Table 12 was also conducted.

QA/QC PLAN AND AUDITS

The QA/QC protocols followed for this program are outlined in the Treatability Study Test Plan [6]. Table 13 details the QC samples and blanks used to validate the data including method blanks, calibration check samples, matrix spikes, matrix spike duplicates, laboratory control samples, and surrogate spikes. Table 14 lists the frequency for each measure.

TABLE 10. LIST OF VOLATILE ORGANICS

Bromodichloromethane	trans-1,2-Dichloroethylene
Bemene	trans-1,3-Dichloropropane
Bromoform	1,2-Dichloropropane
Bromomethane	Ethylbenzene
Carbon tetrachloride*	Methylene chloride
Chlorobenzene	1,1,2,2-Tetrachloroethane
Chloroethane	Tetrachloroethylene
Chloroform	Toluene
Chloromethane	1,1,1-Trichloroethane
cis-1,3-Dichloropropene	1,1,2-Trichloroethane
Dibromochloromethane	Trichloroethylene
1,1-Dichloroethane	Trichlorotlouromethane
1,2-Dichloroethane	Vinyl chloride
1, I-Dichloroethylene	

* Performance indicator compound

The analytical data was validated by the individual laboratory's QC group using the criteria outlined in the Test Plan. In addition, ATC used results from field and laboratory method blanks, replicate samples, and internal QC samples to further validate the analytical results. **They** employed **field** blanks and replicate field samples to validate sample collection. The following criteria were used to evaluate **field** sampling data: implementation of approved test procedures; proper operation of the process being tested; maintenance of properly operating and calibrated equipment; performance of leak checks before and **after** tests; selection of reagents that conformed to QC specified criteria; use of NBS traceable CEM calibration gases; adherence to proper **chain-of-custody**; and verification of proper sample gas volume collection in VOST, **M5**, and MM5 trains.

Analytical data were evaluated using the following criteria: approved analytical procedures; properly operating and calibrated instrumentation; acceptable results from analyses of QC samples (i.e., the reported values had to fall within the 95% confidence interval for the samples); and achievement of precision and accuracy comparable to previous analytical programs and consistent with the Test Plan objective.

To evaluate the reliability of the data, precision, accuracy, and completeness objectives were established. Precision defines the degree of agreement among individual measurements made under prescribed conditions. Accuracy compares a measurement to an accepted reference or true value. Completeness determines the percent of samples judged to be valid.

The accuracy of this study was estimated through the analysis of laboratory control samples (**LCS**), matrix-spiked samples, and surrogate-spiked components. Completeness was determined by comparing the accuracy data to the recovery objectives in the Test Plan. Precision was verified through the analysis of duplicate matrix spikes for selected matrices.

Corrective actions were taken at several points during the program. They fell into two categories: immediate corrections that were implemented by the supervisor or analyst; and long term corrections that initiated a formal paper trail. Immediate corrections in the field most **often** result from equipment failure or operation oversight. They usually involve reevaluation, reanalysis, or repeating a sample run. Analytical corrections include recalibration of instruments, and reanalysis of QC samples or **field** samples.

TABLE 11. HSL SEMIVOLATILE ORGANICS

Phenol	3-Nitroaniline
bis(2-Chloroethyl)eter	Acenaphthene
2-Chlorophenol	2,4-Dinitrophenol
1,3-Dichlorobenzene	4-Nitrophenol
1,4-Dichlorobenzene	Dibenzofuran
Benzyl alcohol	2,4-Dinitrotoluene
1,2-Dichlorobenzene	Diethylphthalate
2-Methylphenol	4-Chlorophenyl-phenylether
bis(2-Chloroethoxy)methane	Flourene
4-Methylphenol	4-Nitroaniline
N-Nitrosodi-n-propylamine	4,6-Dinitro-2-methylphenol
Hexachloroethane	N-Nitrosodiphenylamine*
Nitrohenzene	4-Bromophenyl-phenylether
Isophorone	Hexachlorobenzene
2-Nitrophenol	Pentachlorophenol
2,4-Dimethylphenol	Phenanthrene
Benzoic acid	Anthracene
bis(2-Chloroethoxy)methane	Di-n-butylphthalate
2,4-Dichlorophenol	Flouranthene
1,2,4-Trichlorobenzene	Pyrene
Naphthalene	Butylbenzylphthalate
4-Chloroaniline	3,3'-Dichlorobenzidine
Hexachlorobutadiene	Benzo(a)anthracene
4-Chloro-3-methylphenol	Chrysene
2-Methylnaphthalene	bis(2-Ethylhexyl)phthalate
Hexachlorocyclopentadiene	Di-n-octylphthalate
2,4,6-Trichlorophenol	Benzo(b)flouranthene
2,4,5-Trichlorophenol	Benzo(k)flouranthene
2-Chloronaphthalene	Benzo(a)pyrene
2-Nitroaniline	Indeno(1,2,3-cd)pyrene
Dimethylphthalate	Dibenz(a,h)anthracene
Acenaphthylme	Benzo(g,h,i)perylene
2,6-Dinitrotoluene	

* Cannot be separated from diphenylamine.

TABLE 12. TCLP LIST OF VOLATILE ORGANICS

Volatile component	Regulatory Limits (u) (mg/L)
Acrylonitrile	5.0
Benzene	0.07
Carbon disulfide	14.4
Carbon tetrachloride	0.07
Chlorobenzene	1.4
Chloroform	0.07
1,2-Dichloroethane	0.40
1,1-Dichloroethylene	0.1
Isobutanol	36
Methylene chloride	8.6
Methyl ethyl ketone	7.2
1,1,1,2-Tetrachloroethane	10.0
1,1,2,2-Tetrachloroethane	1.3
Tetrachloroethylene	0.1
Toluene	14.4
1,1,1-Trichloroethane	30
1,1,2-Trichloroethane	1.2
Trichloroethylene	0.07
Vinyl chloride	0.05

- (a) Proposed toxicity characteristic contaminants and regulatory levels. FR Vol. 51, No. 114, June 13, 1986, p. 21652
- (b) Performance indicator for this program

TABLE 13. NUMBER AND TYPES OF QC SAMPLES

Location and sampling parameter	Analytical parameter	Program samples	MS*	FBI Audit	Method Blank	LCS	Total analyzed
Waste feed	Metals	3	2	—	1	—	6
	Vol w/lib scan	14	2	—	1	—	17
	Semivolatiles w/scan	3	—	—	1	1	5
	PCDDIPCDF	3	—	—	1	1	5
	PCBs	3	—	—	1	1	5
	Organic halogens	3	—	—	1	1	5
	Inorganic halogens	3	—	—	1	1	5
Furnace bed ash and filter fly ash (2 streams)	Metals	6	2	—	1	—	9
	Vol w/lib scan	12	2	—	1	—	15
	Semivolatiles w/scan	6	4	—	—	—	10
	PCBs	6	—	—	—	1	7
	PCDDIPCDF	6	—	—	—	1	7
	TCLP volatiles	12	2	—	—	—	14
	TCLP metals, Cr(VI)	6	2	—	—	—	8
	Organic halogens	6	—	—	—	1	7
	Inorganic halogens	6	—	—	—	1	7
Limestone feed	Metals	3	2	—	—	—	5
	Calcium	3	2	—	—	—	5
Flue gas	Particulates	3	—	—	1	—	4
	Metals	3	2	—	1	—	6
	Semivolatiles w/scan	3	—	—	1	1	5
	PCBs	3	—	—	1	1	5
	PCDD/PCDF	3	—	—	1	1	5
	Vol w/lib scan	(3x3)	—	7	2	5	23
	Chloride	6	2	1	1	—	10

* Matrix spikes for volatile organics contained carbon tetrachloride. TCLP matrix spiking was performed on the generated leachate.

MS Matrix spike

FB Field Blank

LCS Laboratory control sample

TABLE 14. ANALYTICAL QC MEASURES

QA measure	Minimum frequency
Method blank	Each sample set extracted, or daily for volatile organics.
Laboratory control sample	Each sample set extracted for VOST semivolatile organics, PCBs, PCDD/DFs, organic and inorganic halogens.
Calibration check sample	Daily for volatile organics, every 12 hours for PCB/PCDD/PCDF/SV.
Matrix spike/matrix spike duplicate	Each sample matrix for metals and volatile organics (except VOST). Standard additions are used for M5 train digestates, chloride impingers, and TCLP leachates.
Surrogate spike (GC/MS analysis)	Each sample.

Long-term corrections most often result in formalized changes to QA/QC procedures. Corrective actions taken during this program are shown in Section 5 of this report, and in Appendix II of the field notes.

Audits

At the request of EPA, five audits were conducted for this program. Each audit was performed under the guidance and supervision of EPA/RREL. Results of the audits are contained in Section 5 of this report.

The first audit consisted of a technical systems review of ATC's field sampling effort and OES's CEM system. Representatives of S-CUBED, the audit contractor selected by EPA, were at the CBC facility throughout the field sampling and process monitoring activities.

Three audits were conducted to observe and report on the laboratory operations. One audit was performed by S-CUBED at the Clean Harbors Analytical Services Laboratory and focused on the analytical procedures for volatile organics by Methods 5040 and 8240. Two audits were conducted by Research Triangle Institute at Triangle Laboratories, Inc., which observed the analysis for semivolatile organic compounds by Method 8270, and PCDD/PCDF analyses by Method 8290.

The final audit was an on-site VOST audit by S-CUBED, evaluated by Research Triangle Institute

SECTION 5 PERFORMANCE DATA EVALUATION

INTRODUCTION

As noted in the introduction to this report, the criteria used in this program to evaluate the efficiency of the CBC in destroying hazardous constituents were the following:

- o Destruction and removal efficiencies (DREs)
- o Flue gas emissions (including acid gas removal, particulates, organics, metals, and CEM evaluations)
- o Organics destruction
- o Toxic metals distribution
- o TCLP results
- o Physical parameters
- o System operating conditions

The primary objective of the demonstration was to gather data needed to evaluate the CBC technology and to determine the feasibility of conducting a SITE Program Demonstration Teat at the McColl Superfund Site in Fullerton, California. The treatability study was limited by the permit conditions of OES's research facility. The most significant permit restrictions were as follows:

- o Federal and State RCRA RD&D permits – limited the concentration of sulfur in the waste feed to 5%. This did not allow for the evaluation of the CBC system using McColl waste with a higher sulfur content.
- o OES and San Diego APCD -- restricted the McCall waste feedrate to 200 lb/hr, (which equates to a total throughput of waste and sand of 400 lb/hr) This prevented observation of the system operation at or near its full processing capacity.

APCD permit -- restricted the SO₂ emissions to a not-to-exceed value rather than a time-weighted average. This resulted in the use of large quantities of limestone to minimize the SO₂ emissions.

The permit restrictions prevented optimization of the Ca/S ratios and evaluation of the CBC control system's ability to react to intentionally induced abnormal operating conditions. The relatively high heating value and variable sulfur content of the McColl feedstock could result in transient surges which the treatability study had wanted to simulate. The SITE program was not involved in these permit decisions but nevertheless was required to modify the teat program in keeping with their limitations. In the event that a SITE Demonstration Teat is approved at the McColl Site, the test will be designed to elicit more detailed data than was required in the treatability study.

The tables presented in the balance of this section are summaries of the more detailed ATC tables included in Appendix II of the field notes. Details of any table can be found in the Appendix II tables in the field notes, as footnoted. Conversions of sample concentrations to emission rates, and concentrations of contaminant per weight of feed are presented in the Appendix II Tables 3-14 through 3-20 in the field notes. The raw analytical and QC data are provided in ATC's Volume II [1], not appended to this report.

The numerals and symbols used in the tables are as follows:

- o Numerical values -- Concentrations are reported when the concentration of the analyte was greater than the quantitation limit (the minimum concentration of the analyte that can be quantified using the specific procedure). Quantitation limits (i.e., minimum detectable limits) are tabulated in Appendix II of the field notes (ATC's Appendix A).
- o Not detected (ND) – This designation indicates that the component was not identified in the sample.
- o Less than (<) – This symbol is used to show that the analyte was positively identified in the sample, but that the quantity detected was less than the accepted limit for accurate quantitation.

PERFORMANCE CRITERIA RESULTS

Destruction and Removal Efficiency

The Test 3 unblended waste feed was spiked with sufficient quantities of CCl₄ to determine the destruction and removal efficiency of the system while the waste was being processed. The DRE results for CCl₄ are shown in Table 15. These results indicate a quite satisfactory DRE, indicating that the CBC performance in destroying CCl₄ met the existing regulatory requirements of 99.99%.

Table 16 presents combustion emission concentrations and CBC efficiencies that were calculated for benzene, toluene, ethylbenzene, and xylene (BTEX). The calculated emission rates for BTEX compounds ranged from less than 2.1 mg/hr to 76 mg/hr. (See Appendix II, Table 3-14 of the field notes). These rates are consistent with the expected formation of small quantities of PICs in combustion processes.

Flue Gas Emissions

Flue gas emission results are consolidated and summarized in Table 17. The table shows ranges (derived from the laboratory report in Appendix II of the field notes) for volatile and semivolatile organics, PCBs, PCDDs/PCDFs, metals, chlorides, and particulates.

TABLE 15. DREs FOR CCl₄

Parameters	CCl ₄ (a)
Waste feed concentration (ppm)	1168
Waste feed rate (lb/hr)	200
Compound feed rate (lb/hr)	0.224
Stack Flow (dscfm)	946
VOST volume (dsl)	19.633
VOST concentration (ng)	77.5
Emission rate (lb/hr)	1.42 E-05
DRE (%) (b)	99.9936

(a) Average values. See Appendix II Table 3-9 in Field Notes for details

$$(b) \quad DRE = \frac{\text{Compound feed rate} - \text{Emission rate}}{\text{Compound feed rate}} \times 100$$

TABLE 16. COMBUSTION EMISSION CONCENTRATIONS FOR SELECTED COMPOUNDS

Parameter	Benzene(a)	Toluene(a)	Ethyl Benzene(a,c)	Xylene(a,d)
Waste feed concentration (ppm)	4.1	28	16.8	113
Waste feed rate (lb/hr)	232	232	232	232
Compound feed rate (lb/hr)	9.63 E-04	6.50 E-03	3.90 E-03	2.62 E-02
Stack Flow (dscfm)	924	924	924	924
VOST Volume (DSL)	18.4	18.4	18.4	18.4
Vost Concentration (ng)	54	114	37	127
Emission Rate (lb/hr)	1.02 E-05	2.20 E-05	7.03 E-06	2.52 E-05
CBC efficiencies (%) (b)	98.94	99.66	99.82	99.90

(a) Average values for comparison purposes only. NOT TO BE USED FOR CALCULATION. See Appendix II Table 3-10 in Field Notes for details.

(b)
$$\text{CBC efficiency} = \frac{\text{Compound feed rate} - \text{Emission rate}}{\text{Compound feed rate}} \times 100$$

(c) No ethyl benzene was detected in 8 of 9 samples. The quantitation limit was used as the basis for these calculations.

(d) No xylene was detected in 3 of 9 sample. The quantitation limit was used as the basis for these calculations.

Acid Gas Removal --

Chloride samples were collected for each test; the results are shown in Table 18. No detectable amounts of chloride were found in the flue gas even though detectable amounts were analyzed in the waste feed. Emissions rates were based on minimum detection limit concentrations and were calculated to average less than 0.0083 lb/hr, well below the RCRA performance standard of 4 lb/hr. This indicates very good chloride control in the CBC.

Flue Gas Particulates --

The RCRA particulate emissions standard for incinerator operations is 0.08 grains/dscf (corrected to 7% O₂). The test results for the McColl waste showed particulate loadings to be 0.0039 gr/dscf corrected to 7% O₂ for Run 1, 0.0035 (Run 2), and 0.0023 (run 3). As a comparison, emissions from state of the art equipment typically range from 0.01 to 0.02 gr/dscf. The test results indicate that the baghouse collectors very adequately captured stack gas particulates. However, the SCAQMD regulations require particulate emissions to be less than 0.002 gr/dscf corrected to 12% CO₂ (approximately 0.0022 gr/dscf at 7% O₂).

TABLE 17. FLUE GAS RESULTS

Parameter		Quantities (a)	
Volatiles (ng)	Carbon Tetrachloride	ND 140	
	Benzene	29 120	
	Toluene	ND - 660	
	Ethylbenzene	ND 130	
	Total xylenes	ND 840	
	Semivolatiles (ug)	Phenol	30 79
		Benzyl alcohol	(b)
		Isophorone	(b)
		Benzoic acid	(b)
		Naphthalene	<10 16
2-Methylnaphthalene		(b)	
Phenanthrene		ND	
Dimethylphthalate		(b)	
Di-n-butylphthalate	(b)		
Bis (2-ethylhexyl) phthalate	(b)		
PCBs (ug)	(c)		
PCDDs/PCDFs (ng)	(b)		
Metals (ug)	Barium	15 - 26	
	Cadmium	5.3 11	
	Chromium	18 - 71	
	Cobalt	3.2 13	
	Copper	37 - 50	
	Lead	ND 13	
	Manganese	8.5 33	
	Nickel	20 84	
	Tin	68 - 647	
	Zinc	406 - 2970	
Chlorides	Chloride (mg/l)	NO	
	Emission Rate (lb/hr)	<0.0083	
Particulates	Grain Loading (gr/dscf)	0.0029	
	Emission Rate (lb/hr)	0.0242	

(a) Ranges are for comparison purposes only. NOT TO BE USED FOR CALCULATION. See Appendix II Tables 3-6, 3-11, and 3-13 in Field Notes for details.

(b) Trace amounts. Laboratory contaminants.

(c) Trace Amounts. Incorrect Identification.

ND Not detected. See Appendix II in Field Notes for quantitation limit.

< Detected at levels Less than the quantitation limit.

• Priority pollutant metals.

TABLE 18. CHLORIDE IN THE FLUE GAS

	Run number*		
	1	2	3
Sample concentration, mg/L	< 1.5	< 1.5	< 1.5
Sample volume, ml	86.7	72.5	82.5
Chloride collected, mg	< 0.13	< 0.10	< 0.12
Emission rate, lb/hr	< 0.0090	< 0.0077	< 0.0082

* Average values for comparison purposed only. See Appendix II Table 3-13 in Field Notes for details.

< Detected at levels less than the quantitation limit.

Flue Gas Organic and Metals Concentrations –

Volatile organics --Organics were sampled and analyzed not only to determine the degree of destruction of organics initially present in the waste feed, but also to identify and quantify any new hazardous components, not present in the waste feed, that were formed in the combustion process.

The volatile organic concentrations of benzene, toluene, xylenes, and ethylbenzene found in the flue gas (Table 17) should be considered in light of PIC formations and VOST tube contamination. Benzene, toluene, and xylenes, although present in low concentrations in the waste feed (Table 16), are also common PICs of combustor processes, (i.e., can be created as a result of the combustion conditions). These aromatic compounds also can be contaminants in the VOST train components. It was not determined whether the reported flue gas organics concentrations (Table 17) are the result of incomplete thermal destruction, PIC formation, or sampling train contamination. A combustion blank (feed sample prior to burning) was collected, and the organic concentrations adjusted for background combustion products. Nevertheless, the flue gas volatile organics concentrations are low.

Semivolatile organics -- Except for phenols, eight of the semivolatile compounds detected in the flue gas (Table 17) have been discounted as sample medium contamination prior to or after sampling. The phenol concentrations were low.

Inspection of the PCB analytical data shows trace concentrations of PCBs that were slightly above the established limits of detection. Since PCBs and chlorinated hydrocarbons are not known to be contaminants at the McColl Site and were not identified in the pretest feedstock sampling performed by ATC (Appendix II of the field notes), it is questioned as to why PCBs were identified. The methodology used to analyze PCBs can produce results that identify the spectra as PCBs when they could be something else. It is the conclusion of this report that these reported materials are not PCBs.

The presence of trace amounts of PCDDs and PCDFs in the flue gas -- while neither they nor chlorinated hydrocarbons are suspected as site contaminants nor were detected in the waste feed, bed ash, fly ash, and pretest feedstock samples -- indicates that the presence of these congeners can be attributed to sources other than the McColl waste. The ATC report concludes that the compounds probably originated as laboratory contaminants.

It is the conclusion of this report that the indicated PCDD/DFs are laboratory contaminants.

PICS – In general, PICs and other undesired combustion by-products appear to have been controlled in the process.

Metals– Only low quantities of metals were found in the flue gas. The analytical methodology used to detect metals in the flue gas cannot differentiate between those metals that are vaporized and later condense, and those that are carried through the gas stream as discrete particles. The reported quantities are the combined amounts of metal particles from both mechanisms.

Continuous Emissions Monitoring (CEM) Results –

The CEM results in Table 19 show that CO, NO_x, and THC emissions were controlled within the OES permit limitations. A momentary spike of THC resulted in an interlock shutdown of the system, interrupting sampling for about an hour. During the test, the system operated at higher than usual excess air levels. The effect of lower excess air on CO and THC emissions will be re-examined during the Demonstration Test.

An independent audit (Appendix II of the field notes) of the CO, NO_x, and SO₂ analyzers revealed that the CO and NO_x analyzers operated within performance specifications, but that the SO₂ analyzer did not. The SO₂ emission results therefore were not quantifiable. It is likely that the SO₂ emissions in the latter part of the program were controlled to low levels as a result of the large amounts of limestone used to control the spikes (6: 1 to 14: 1 Ca/S ratio). It is expected that further testing under the SITE program will establish the optimum Ca/S ratios needed to control SO₂ emissions within environmentally acceptable limits. The audits also revealed that the analyzers -- although calibrated to manufacturer's specifications -- were not calibrated in accordance with EPA standard reference methods for multipoint calibrations. Consequently, calibration procedures were not in strict conformance with prescribed EPA QA/QC protocol.

The OES CEM output data are displayed in three ways: 1) direct reading from the analyzer meters; 2) tables, graphs, and a video display of major operating parameters printed by DAS software; or 3) strip chart recordings. The DAS provides information at two-minute intervals for internal system records and video displays, and at 15-min intervals for printed graphs and charts. Observations during the test of the three output sources revealed that the analyzer readings, DAS outputs, and strip chart readings differed slightly. The average DAS values were used throughout this report. The CO, NO_x, and SO₂ tabulations in the OES test results (Appendix III of the field notes) contain many "zero" readings. At low input concentrations analyzers often record these concentrations and those less than the detection limits of the instrument as zero. Some degree of error is inherent in the data; the amount of error for each parameter can be estimated to be about 7% for CO and 13% for NO_x. (See audit report in Appendix II of the field notes). The SO₂ data cannot be evaluated because the SO₂ analyzer did not operate within performance specifications.

Organics Destruction

Organics results are shown in Table 20. The test runs were performed with three different feed materials: Run 1 with McColl waste blended with an equal weight of sand; Run 2, unblended McColl waste; and Run 3, unblended McColl waste spiked with 6,000 ppm of CCl₄ as a performance indicator for DREs. Note that the tables present ranges of concentrations for comparison purposes only. The baseline data for these tables can be found in the footnoted references.

Volatile Organics --

Although the Run 3 feed was spiked to 6,000 ppm CCl₄, none of the feed sample concentrations exceeded 1,500 ppm. This can be attributed to several possibilities such as: high volatilization of the CCl₄ during transfer into the feed bunker, or in the feed bunker itself (CCl₄ concentrations in the carbon filters were not evaluated); nonhomogeneous mixing of the CCl₄ in the feed material (not likely since visual feed observation and precise

TABLE 19. CONTINUOUS EMISSIONS MONITORING RESULTS

Test Period	CO(a) (ppm)	NO _x (a) (ppm)	THC(a) (ppm)	SO ₂ (ppm)	CO ₂ (a) (%)	O ₂ (a) (%)	In situ Probe O ₂ (a)(b) (%)
3/28/89 10:55-19:12 Pretest Fine Tuning	0-45	0-20	0-7.4	(C)	4.7-9.9	9.5-14.1	9.1-12.8
3/29/89 9:45-11:14 Test No. 1	22.4-39.9	22.5-55	4.9-12.4	(C)	9.1-11.6	9.5-12.6	7.5-10.3
11:14-16:33 Run No. 1	0-37.4	0-62.5	0-32.4	(C)	2.3-11.8	8.5-19.6	7.5-18.8
16:33-18:18 End Test No. 1	32.4-62.4	0-67.5	2.4-89.9	(C)	9.1-13.7	8.9-12.5	6.9-11.7
3/30/89 7:45-11:28 Test No. 2	0-47.4(d)	0-50(d)	0-4.9(d)	(C)	6-13.8	8.3-13.6	6.5-13.1
11:28-14:52 Run No. 2	22.4-34.9	0-67.5	0-2.4	(C)	9.8-13.1	8.8-11.3	6.7-9.6
1:52-17:25 Test No. 3	9.9-32.4	7.5-65	0-2.4	(C)	5.1-11.7	9.8-13.8	7.8-12.2
17:25-21:23 Run No. 3	14.9-42.4	0-57.5	0-7.4	(C)	6.0-10.3	10.5-13.8	8.6-11.7
Permit Limits	<250	ns	≤100	≤504	ns	>5.3	ns

(a) Ranges for comparison only. NOT TO BE USED FOR CALCULATIONS. See Appendix III tables in Field Notes for details.

(b) Wet probe. Readings are not correct for moisture.

(c) Not quantifiable. Sulfur dioxide analyzer was not operating within performance specifications.

(d) Zero values are calibration results.

TABLE 20. ORGANICS AND HALIDE RESULTS

Parameter	Waste feed(a) (mg/kg)	Fly ash(a) (mg/kg)	Bed ash(a) (mg/kg)
Volatiles			
CCl ₄	N D - 1500	ND	ND
Benzene	N D - 7	ND	ND
Toluene	14 - 49	ND	ND
Ethylbenzene	ND - 30	ND	ND
Total Xylenes	39 - 210	ND	ND
Semivolatiles			
Phenols	ND	ND	ND
Benzyl alcohol	ND	ND	ND
Isophorone	ND	ND	ND
Benzoic Acid	ND	ND	ND
Naphthalene	25 - 33	ND	ND
2-Methylnaphthalene	22 - 46	ND	ND
Phenanthrene	< 10	ND	ND
Dimethylphthalate	ND	(b)	(b)
Di-n-hutylphthalate	ND	(b)	(b)
Bis(2-ethylhexyl)phthalate	ND	(b)	(b)
PCBs	ND	ND	ND
PCDDs/PCDFs	ND	ND	(b)
Halides			
Organic chloride	ND- 540	ND	ND
Inorganic chloride	ND- 240	83 - 530	ND

(a) Ranges are only for comparisons of concentrations in solid streams. NOT TO BE USED FOR MATERIAL BALANCES. See Appendix II Tables 3-1, 3-2, and 3-4 in Field Notes for details.

(b) Trace amounts. Laboratory contamination.

ND Not Detected. See Appendix II in Field Notes for quantitation limits.

< Detected at levels less than the quantitation limits.

analytical results indicate good mixing); nonrepresentative samples; or errors in preparing the spiking quantities. It is not clear where the loss of CCl₄ occurred.

Table 20 indicates that no organics present in the waste feed were found in quantifiable concentrations in the ash. This indicates that the CBC successfully destroyed the organic contaminants.

Semivolatile Organics –

Analyses of the bed ash and fly ash samples indicated that trace amounts of three semivolatile plasticizers were present. Insofar as these components were found in equivalent concentrations in the laboratory blanks, their presence is attributed to laboratory contamination.

No PCBs were found in the waste feed or ash streams. One trace PCDD/DF congener in one bed ash sample has been attributed to laboratory contamination. PCB, PCDD, and PCDF compounds have not been detected as contaminants at the McColl Site.

Tentatively identified compounds (TICS) are those compounds whose spectra closely – but not exactly -- fit the spectra of known compounds, and whose identity is assumed but cannot be verified. These compounds are listed in Appendix II Table 3-8 of the field notes.

At the request of DHS, EPA added to the program the analysis of polynuclear aromatic hydrocarbons (PAHs), specifically in the fly ash and bed ash streams, to determine further if the ash had been detoxified. The results of the matrix spike analyses are presented in Appendix II Table 4-14 of the field notes and will be evaluated further by DHS.

Halides --

Organic chloride was detected only in the Run 3 sample, and is attributed to the CCl₄ material used to spike the Run 3 waste feed.

Toxic Metals Distribution

Total metals results are shown in Table 21. The limestone stream is included in the table since limestone interacts in the process in several ways: as a source of metals; as a matrix in which metals can be complexed or organics absorbed; and as a pH adjuster which affects the chemistry of some of the contaminants.

Limestone was used in large amounts to control the SO₂ emissions and, as a result, the ash material had a high concentration of lime. It can be seen from the ranges in the table that metals were distributed mostly in the fly ash and bed ash. Metal concentrations in the fly ash were consistently higher than in the bed ash – probably due to fly ash particles being finer, which provide more surface area for metals adherence. The metals concentrations found in the solid streams were low.

TCLP Results

TCLP Metals –

Although the total metals results give little indication as to the mobility of the metals in the ash, the TCLP leachate results (Table 22) allow a much narrower interpretation of the data. The leachate amounts of the detected metals were all well below the regulatory limits.

TCLP results are used as a criterion to determine if a waste is hazardous. However, once a waste is defined as hazardous, it continues to be hazardous until it is delisted. The delisting criteria are established on a case by case basis. Various dispersion/leaching models are used to determine whether or not ash resulting from a thermal process will release toxics into the environment. In the past, the delisting criteria for other processes

TABLE 21. TOTAL METALS RESULTS

Parameter	waste feed(a) (mg/kg)	Limestone(a) (mg/kg)	Fly ash(a) (mg/kg)	Bed ash(a) (mg/kg)
Antimony	ND	ND	ND	ND 5.0
Arsenic*	ND	ND	ND	ND
Barium*	65 136	13 14	44 49	11 - 16
Beryllium	ND 0.7	ND	ND	ND
Cadmium*	ND	0.25	ND 0.20	ND - 0.45
Calcium	NA	351,000-382,000(b)	NA	NA
Chromium*	45 - 65	0.9 - 1	17 - 26	4.4 7.4
Cobalt	3.6 - 6.8	ND	1.4 1.7	ND 0.75
Copper	14 - 95	0.6 1.1	5.1 -9.1	1.5 2.5
Lead*	ND	ND	ND	ND
Manganese	95 - 211	44 - 58	114 - 148	35 - 41
Mercury'	ND	ND	ND	ND
Nickel	15 - 19	ND - 1.0	5.1 9.2	ND - 4.1
Selenium*	ND	ND	ND	ND - 3.3
Silver'	ND 1.1	ND 1.0	ND	ND - 0.99
Thallium	ND	ND	ND	ND
Tin	ND 6.3	ND	ND	ND
Zinc	33 49	1.2 4.4	6.8 23	6.1 - 9.4

(a) Ranges are only for comparison of metals concentrations in solid streams. NOT TO BE USED FOR MATERIAL BALANCES. See Appendix II Tables 3-1, 3-3, and 3-1 in Field Notes for details.

(b) Calcium content of the limestone was measured to range from 35 to 38%

NA Not analyzed

ND Not detected. See Appendix II in Field Notes for quantitation limits

* Priority pollutant metals

TABLE 22. TCLP RESULTS

Parameter	Fly ash(a) (mg/l)	Bed ash(a) (mg/l)	Regulatory limit(b) (mg/l)
Volatiles			
Toluene (c)	N D <0.025	ND	14.4
Metals			
Arsenic	ND	ND	5.0
Barium	0.10 - 0.30	0.10 - 0.20	100
Cadmium	ND	ND	1.0
Chromium	0.07 - 0.08	0.04 - 0.05	5.0
Chromium VI	0.04 - 0.05	0.02 - 0.04	NL
Lead	ND	ND	5.0
Mercury	ND	ND	0.2
Selenium	ND - 0.07	ND	1.0
Silver	ND	ND	5.0

(a) See Appendix II Table 3-5 in Field Notes for details.

(b) Regulatory limits proposed in Federal Register Vol. 51, No. 114, June 13, 1986.

(c) No other volatile compounds were detected.

ND Not detected. See Appendix II in Field Notes for quantitation limits.

NL Not listed in proposed regulatory reference.

< Detected at levels less than the quantitation limit.

have established levels more stringent than the criteria that defined the waste as hazardous. The leachate levels from this test were very much lower than the TCLP regulatory limits. It is likely, therefore, that the ash from the CBC could be delisted successfully. In addition, if the McColl fly ash and bed ash can pass the TCLP test based on the leachate performance of the ash versus the regulatory standards, the ash can be defined to be nonhazardous. Since the treatability study results prove that the ash meets this criterion, the on-site Demonstration is expected to produce ash that is nonhazardous. However, since the TCLP test is sensitive to the pH of the matrix, the on-site program must determine whether or not the TCLP results can be replicated when the Ca/S ratios are optimized, the limestone use is reduced, and the pH of the material changes.

TCLP Organics --

Toluene (at a concentration of <0.025 mg/L) was the only organic compound detected in the TCLP leachate, indicating that essentially no leachable organic contaminants remained in the fly ash and bed ash.

Physical Parameters

Physical parameters are listed in Table 23. Note the expected increase in ash percentages, pH, and bulk density as compared to the waste feed stream. No out-of-the-ordinary physical results were found in the residue Streams.

System Operating Conditions

The following is a summary of the operational events that caused process interruptions.

Feed of waste material began on March 28, 1989 at approximately 11:00 a.m. with the SO₂ analyzer interlocks set at 200 ppm to alarm, 250 ppm to interlock. After several hours, several SO₂ spikes occurred. As

TABLE 23. SUMMARY OF PHYSICAL PARAMETERS

Parameter	Waste feed(a)	Fly ash(a)	Bed ash(a)
Moisture (%)	8.34	< 0.001	< 0.001
Ash (%)	72.6	98.2	99.2
pH	2.3	12.6	12.1
Bulk density (lb/cu ft)	57.9	76.8	88.3
Heating value (Btu/lb)	1253		
Sulfur (%)	4.4	3.6	1.0
Carbon (%)	7.6		
Hydrogen (%)	1.6		
Nitrogen (%)	0.1		
TOC (%)	7.2		

(a) Average of three runs. See Appendix II Table 3-7 in Field Notes for details

the waste feed rate increased, the limestone feed also was increased to enhance SO₂ capture. The installed limestone feed auger was found to be undersized.

Feed was interrupted for about an hour to install a larger auger. (Several limestone augers had been calibrated prior to the test.) By 19:30, after several hours of system progression to full operating conditions, the waste feed auger proved unable to deliver feed at the target feed rate. The feed auger was removed and replaced during the night with a larger auger. System operation continued early on the morning of March 29. Waste feed recommenced at approximately 08:00. Waste feed and limestone feed were quickly increased to the established test conditions. Several SO₂ spikes occurred with momentary feed interruptions, proving that the SO₂ interlocks were operating. Sampling for Run No. 1 began, but was interrupted due to a THC spike that interrupted sampling for about one hour (also proving that the THC interlocks were operating). Feed and sampling recommenced; additional SO₂ spikes caused additional momentary shutdowns.

By early evening it was decided to lower the SO₂ interlock settings to 75 ppm alarm/100 ppm interlock. OES chose the addition of excess limestone to prevent feed interruptions caused by SO₂ spikes. This precluded the study of optimum Ca/S ratios. Runs Nos. 2 and 3 were performed on March 30 with only a few interruptions caused by SO₂ spikes. The CCl₄ spiked material initially was difficult to feed, but this was resolved by a change in the feed procedure.

In general, the system components operated without major interruptions, allowing the sampling and analysis effort to proceed without problems. Except for the SO₂ analyzer, process instrumentation performed reliably.

The facility permit limitations prevented the observation of system response to variations in the feedstock and the evaluation of SO₂ emissions, as the Ca/S ratios were varied. These parameters would be evaluated fully in any on-site Demonstration.

QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance/quality control protocols for this program were detailed in the Test Plan. Changes to the Test Plan QAPP are discussed in this section and in Appendix II of the field notes.

Data Quality Objectives

Precision, accuracy, and completeness objectives were established in the QAPP to evaluate the quality of the collected data.

Precision is the measurement of agreement of replicate results without consideration of the true results, and is expressed as the relative percent difference (RPD). Therefore, the closer the RPD value is to zero, the more reliable are the data. Accuracy is defined as the nearness of a result to an accepted reference or true value, and is expressed as percent recovery. The closer a percent recovery value is to 100%, the more reliable the data. Completeness is an estimate of the percentage of measurements made whose values are judged to be valid as compared to the amount of expected data. Completeness values close to 100% indicate reliable data. Note that completeness percents are subjective evaluations of ATC, based on experience and laboratory knowledge.

Percent recovery ranges were established for each of the analyses, thus quantitatively determining the reliability of the data. Table 24 lists the percent recovery objectives for each analytical parameter, and the results of the QC analysis. A discussion of the reliability of the data based on accuracy, precision, and completeness objectives follows.

TABLE 24. PERCENT RECOVERIES RESULTS

Parameter	Appendix II* table	Established % recovery objectives	% Completeness of objectives
MS for metals-waste feed limestone and ash	4-2	10-120%	100%
MS for metals -flue gas	4-3	50-150%	100%(a)
MS and LCS samples for halides	4-4	75-125%	100%(b)
MS for metals-TCLP leachates	4-5	50-120%	100%
SS for volatile organics-waste feed and ash	4-6	50-150%	97%
SS for volatile organics-TCLP leachate	4-7	50-150%	100%
MS for volatile organics-TCLP leachate	4-8	50-150%	100%
SS for volatile organics-VOST tubes	4-9	50-150%	100%
LCS for volatile organics	4-10	50-150%	100%
SS for SV organics-waste feed and ash	4-11	10-120%	80%
SS for SV organics-MM5 train	4-12	10-120%	80%
LCS for SV organics	4-13	10-135%	95%
MS for SV organics-ash	4-14	--	(c)
SS for PCBs	4-15	40-120%	98%
LCS for PCBs	4-16	50-140%	97%
SS for PCDD/DF-waste feed and ash	4-17	40-120%	85%
SS for PCDD/DF-MM5 train	4-18	40-120%	85%
LCS for PCDD/DF	4-19	50-120%	98%

(a) Tin and zinc were not evaluated.

(b) Iodide was not evaluated

(c) QA objectives for this analysis were not established for this program.

LCS Laboratory control spike

MS Matrix spike

SS Surrogate spike

* Appendix II Tables in Field Notes

Flue Gas Samples

Acid Gas Removal –

Halide recoveries were all within the 75-125% range established for the program. This indicated good reliability of the data, except for iodide, which was not included in the analysis.

Organics and Metals --

VOST sample recoveries for volatile organic surrogate spikes ranged from 80 to 110% and, for the laboratory control samples, from 80 to 118% – all well within the 50-150% established range.

Recoveries for PCBs, PCDDs, and PCDFs were near mid-range for the MM5 samples, indicating valid data.

Percent recovery objectives for the flue gas metals were established at 50-150%, but the actual values were 80-115%. This indicated good recovery and reliability of the data. Tin and zinc results were not calculated because the spiking level was below the native concentration of the analyte. However, since the recoveries of these two metals showed relatively high concentrations, the data appeared to be reliable -- based on the accuracy and precision of the analytical method used to determine their concentrations.

Organics Samples

Volatile Organics –

The waste feed, bed ash, and fly ash recoveries for volatile organic surrogates ranged mostly between 80-130%. except for three results, which exceeded the 150% established objective. Since they exceeded the objectives, and all other values were well within the objectives, the volatile organics data are judged very reliable.

Semivolatile Organics –

Accuracy of the SV data was evaluated through analysis of surrogate compounds spiked into all samples. Also, ash matrix spike pairs and LCSs for the waste feed and MM5 train samples were analyzed along with the program samples.

A high outlier percentage recovery in the bed ash required re-extraction and re-analysis of the sample. Outlier percentages still remained high. The troublesome recoveries were in the phenol and 2-fluorophenol surrogates, indicating that phenolic data should be evaluated cautiously. It should be noted that ATC found the recovery of semivolatile surrogates typically troublesome, not only in the samples in this program, but in many other programs as well. The other semivolatile recoveries indicate that the balance of the semivolatile data are quite good.

Two pairs of ash matrix spikes were prepared by the addition of a solution containing 16 polynuclear aromatic hydrocarbons (PAHs). Although no QA objectives were established in the Test Plan, the resultant recoveries were well within typically reported ranges for reagent water.

Recoveries for PCBs in the waste feed and ash samples indicated that recoveries for the waste feed were about mid-range and, for the ash streams, very close to the lower objective (with one outlier in the bed ash). This suggests that the reliability of PCB data is somewhat weaker for the ash streams than for the waste feed stream, although all data can be judged valid and within the QC objectives.

Analysis of the samples for PCDDs and PCDFs resulted in recoveries well above mid-range for the waste feed and ash samples. Although completeness was estimated at only 85% -- less than the 90% objective of the Test Plan -- the data are considered very reliable, since all outliers were biased high.

Toxic Metals Results

Percent recovery objectives for the waste feed, limestone feed, fly ash, and bed ash metals were established at 10-120%, but the actual values lay between 60-110%. This indicates a good recovery and strong reliability of the metals data.

TCLP Results

TCLP Metals --

The recovery objectives for the TCLP metals were established at 50-120% but actually ranged between 80-105%, indicating very good reliability of the TCLP metals data.

TCLP Organics –

Organic TCLP leachate recoveries for volatile organic surrogate spikes ranged from 86 to 107% and, for TCLP leachate volatile organics, matrix spikes from 100 to 120% – also indicating very reliable data.

Deviations from the QAPP

Modifications to the QAPP resulting from field changes, program oversights, or sampling/analysis requirements are discussed in ATC's test report in Appendix II of the field notes, and are listed below for reference.

The initial sampling schedule shown in the Test Plan was changed from 3 days to 2 days because less feedstock was available than originally anticipated, thereby shortening the test period. Also, the CEM data to be taken after the spiked feed run were deleted from the program because the SO₂ analyzer was not operating within performance specifications.

Spiking concentrations of CCl₄ originally were established at 2,000 ppm, then increased to 3,000 ppm to ensure sufficient concentrations to achieve calculated results of at least 99.99%. but, due to a calculation error, ended up at 6,000 ppm. This error inadvertently aided the DRE calculations since CCl₄ concentrations in the waste feed samples were much lower than anticipated.

Two matrix spike duplicates of surrogate spiked PAHs were added to the chemical analysis program to determine PAH recoveries in the ash stream samples. Analysis of the ash for PAHs was added to the program to determine if the fly ash and bed ash material had been detoxified of residual PAHs.

One limestone feed sample was scheduled for each of the three runs, but was only taken for two runs – the result of a field oversight. This oversight did not negatively affect the program, since the results from the limestone samples for Run 1 and 3 were nearly identical.

Field bias blanks were programmed for metals and MM5 semivolatile train QC, but they were overlooked. Instead, reagent blanks were used. The laboratory audit report determined that this procedural change had not significantly affected the data quality.

Four pairs of VOST tubes were analyzed for the third (spiked) run, instead of the 3 in the QAPP. This was done to insure that adequate VOST samples were available for DRE calculations.

The QAPP ash sampling procedure was modified during the test because the originally planned method – to penetrate the drums with a thief sampler -- could not be executed as planned. Instead, for Run 1 the ash was vacuumed into another container, and grab samples taken. For Runs 2 and 3, grab samples were taken during the run. This modification provided a safer and more effective sampling procedure.

The number of feed samples taken for Run 3 was increased from 2 to 8, to provide more representative samples of the spiked waste. Both visual evaluation and waste feed sample analysis indicated that the spiked material was adequately mixed in the feedstock.

Waste feed samples were prepared for semivolatiles analyses in accordance with the sonication procedures of the Test Plan. However, due to the presence of elevated levels of hydrocarbons in the extract, an extra dilution was necessary prior to analysis by GC/MS. Since this dilution would have made the surrogate compounds undetectable, a re-extraction was performed using a 1-gram aliquot of the samples. This permitted quantitation of the surrogate-spiked compounds.

Because of a laboratory error, the ash samples were prepared by soxhlet extraction instead of the sonication specified in the Test Plan. No corrective action was taken because both methods are cited in SW846. This procedural change did not negatively affect the generated data.

Audit Results

The audit reports have been placed in Appendix II of the field notes. Audit results are summarized below.

CEM and Field Sampling --

EPA solicited the services of S-CUBED, San Diego, California, to be on site during the entire treatability study test period. All field work performed by ATC was judged satisfactory, although the overall audit was given a conditional rating because of problems relating to OES's SO₂ analyzer.

The technical systems review audit initially revealed that the CEM systems were not calibrated using multi-point gas calibrations. Instead, OES calibrated the analyzers using a zero gas, a single span gas, and an electronic linearity check (essentially a single point gas calibration technique). This digression from the EPA standard method for multipoint calibration was considered a minor concern, pending results of the analyzer performance audit using NBS-traceable calibration gases.

The audit revealed that the CO analyzer was operating within performance specifications. The NO_x and SO₂ analyzers were outside performance specifications. The THC analyzer was not audited. On the evening of March 29, 1989, OES changed out the NO_x analyzer, which later was audited and found to be within performance specifications. The SO₂ analyzer was not changed out and was confirmed not to be operating within performance specifications, a major concern. The audit report (attached to Appendix II of the field notes) concludes that "... the SO₂ measurements collected during the test burn are subject to an undefined degree of negative bias, which will limit the application of the data." This resulted in unquantifiable SO₂ emissions data.

No field bias blanks were collected for the M5 and MM5 sampling trains. This was not discovered until after the sampling effort had concluded. Instead, samples of all the field reagents were collected as a means to measure reagent contamination. It was the audit's conclusion that the data quality was retained within acceptable levels by use of this alternate technique.

Clean Harbors Analytical Services --

This review by both S-CUBED and EPA/RREL focused on the analysis of volatile organics. Method performance was given a satisfactory rating.

Triangle Laboratories, Inc. --

TLI was audited twice -- once for the analysis of semivolatile organic compounds, and once for analysis of PCDDs/PCDFs. Both reviews achieved a rating of satisfactory.

The first audit was conducted in April 1989 by Research Triangle Institute (RTI), and focused on the semivolatile and PCB analyses. The audit was conducted over a 3day period and reviewed project organization, sample custody, sample extraction procedures, standards preparation, sample analysis, and QC. The one major concern -- that the MM5 blanks had not arrived with the rest of the samples -- was corrected a week later when the field blanks were received.

The audit concluded that the semivolatile analysis was satisfactory, and that the minor concerns would not prevent achievement of the data quality objectives established in the QAPP.

In May 1989 a second audit was conducted by RTI that focused on the dioxin analysis. Only one minor concern was expressed, giving the audit a rating of satisfactory.

Industrial Testing Laboratories --

No audits were conducted at ITL.

VOST --

Research Triangle Institute was solicited to conduct a field/analytical audit of ATC's VOST methods. The audit conclusions are not yet available.

Summary

The QA/QC sample results indicated that reliable data had been collected during the test sampling and that the deviations from the QAPP had not negatively affected the data quality. The audit results showed that, except for the CEM analyzer calibrations and the deficiency in the SO₂ analyzer, the methods and procedures established in the QAPP for the test program had been followed, and the data quality could be expected to be satisfactory.

SECTION 6 TREATABILITY STUDY COSTS

The demonstration project costs were calculated by Ogden Environmental Services (OES) and EPA. OES presented the costs to prepare for and execute the treatability study at their pilot-scale facility. The EPA totalled the costs for waste preparation, transportation, sampling and analysis, waste disposal, and report preparation. These costs are not to be used to extrapolate to the potential on-site costs of a full-scale operation. Such on-site costs will be determined during the on-site Demonstration Test.

The principal categories used to evaluate a typical on-site Demonstration, and their relationship to this treatability study are:

- o Site preparation costs – not applicable, since the treatability study was conducted at an existing pilot-scale research facility.
- o Permitting and regulatory costs -- enabling OES to acquire test-specific permits for the facility.
- o Equipment costs -- not applicable, since the facility was an established, operating unit. Note that waste pretreatment and posttreatment costs also were not included.
- o Start-up and fixed costs -- not applicable. This category is directed at on-site operations. The costs for the facility modifications applicable to this study are included in the “facility modifications, repair, and replacement costs” category shown below.
- o Labor costs – providing the outside (contract) labor and in-house (OES) labor required to prepare the system for operation, and to conduct the test.
- o Supplies and consumables costs – included in this study.
- o Effluent treatment and disposal costs -- not applicable, as the CBC is a dry system and does not generate liquids that require treatment and disposal.
- o Residuals and waste shipping, handling, and transport costs – allowing the disposal of the residual ash.
- o Analytical costs – EPA-supplied sampling and analysis. OES internal analysis costs are not included.
- o Facility modification, repair, and replacement costs – OES-incurred in preparing the facility for the test.
- o Site demobilization costs -- providing only decontamination of the system.

The costs associated with each of the categories are shown in Table 25.

TABLE 25. TREATABILITY STUDY COSTS

Cost category	OES test preparation costs	OES Test execution costs	EPA costs
Site preparation	N/A	N/A	N/A
Permitting and regulatory			
APCD fees	\$40,345		N/A
OES labor	16,416		
Equipment	N/A	N/A	N/A
Start-up and fixed costs	N/A	N/A	N/A
Labor			
Contract labor	9,918	29,298	197,110
OES labor	6,000	36,416	
Supplies and consumables (a)		13,430	70,700
Effluent treatment and disposal	N/A	N/A	N/A
Residuals and waste shipping, handling, and transport	NI	NI	11,000
Analytical costs	NI	NI	324,190
Facility modification, feed and vent system modifications	12,538		17,000
Contract labor	4,150		
OES labor	2,000		
Site demobilization (decontamination)			
Supplies		2,594	N/A
Contract labor		8,400	
OES labor		12,000	
	\$91,367	\$102,138	\$620,000
TOTAL COSTS	\$ 813,505		

(a) Limestone costs were: \$166/ton Pfizer limestone; \$18,75/ton (1986 quoted price) Colton limestone.

N/A Not applicable

NI Not included

SECTION 7 CONCLUSIONS

The objective of the demonstration was to evaluate the OES CBC technology for possible further testing at the McColl Superfund Site under the SITE Program.

The treatability study results indicate that the CBC technology can be further evaluated under the SITE Program. This observation is based on the results of the treatability study conducted in March 1989 at the OES pilot-scale research facility in San Diego, California. The treatability study data indicate that the CBC technology can be used to destroy McColl Site organic contaminants while producing an ash residue that is nonhazardous. Emissions of criteria pollutants can be controlled to regulatory levels. The test data are discussed below. Where data is incomplete, extrapolations are based both on good engineering judgment and on comparisons to the fully-operational OES 36-inch diameter CBC. (See Table 26.)

The following were not evaluated in this program: material and energy balances; equipment reliability; labor, energy, supply, and maintenance requirements; economics; and pretreatment and posttreatment of waste feed and residue streams. Of these, pretreatment of the waste feed, and ash pretreatment and posttreatment requirements will most influence the final evaluation of an on-site operation. It is anticipated that some form of waste pretreatment may be desirable to allow the CBC system to reliably process the McColl waste. Based on TCLP results it is anticipated that no posttreatment at the McColl Site will be required. These considerations will be evaluated in a more detailed SITE Demonstration Test.

TEST RESULTS

Destruction and Removal Efficiency

The destruction and removal efficiencies (DREs) for the CCl_4 performance indicator met the 99.99% RCRA requirement. This indicates that the system is effective in destroying many organic contaminants.

Flue Gas Emissions

Acid Gas Removal --

Chloride was not detected in the flue gas. Using the quantitation limit (1.5 mg/l) for calculations, the average chloride emission rate was calculated at less than 0.0083 lb/hr, well below the RCRA performance standard of 4 lb/hr. Chloride emissions from an on-site demonstration are expected to fall well within existing regulatory limits.

Flue Gas Particulates --

Particulate concentrations in the stack gas averaged 0.0029 gr/dscf (at 7% O_2); the RCRA limit for trial burns is 0.08 gr/dscf (at 7% O_2). This indicates high efficiency capture of particulates in the CBC baghouse filter, resulting in particulate emissions much lower than normal permitted levels. These low results have been replicated in other tests [4,5]. However, SCAQMD regulations require that particulate emissions not exceed 0.002 gr/dscf, corrected to 12% CO_2 (approximately 0.0022 gr/dscf at 7% O_2). Further testing of the CBC is indicated to ensure compliance with SCAQMD emission limits.

Flue Gas Organics and Metals --

Low concentrations of some volatile organics were detected in the flue gas. Of those detected, almost all are either common PICs or ubiquitous sample contaminants. Reported quantities of PCBs, PCDDs, and PCDFs are attributed to laboratory contamination. PIC concentrations in the flue gas were insignificant.

TABLE 26. COMPARISON OF CBC PARAMETERS TO OTHER TESTS

Parameter	Swanson River, Alaska(a)(d)	Stockton California (b)(e)	Pilot facility, California(c)
CBC diameter (in.)	36	36	16
Feed rate (lb/hr)	9000	4000	200
CO (ppm)	8.7-17.5	23.6-28	0-5 l
O ₂ (%)	3.4-6.3	13.6	8.3-19.6
CO ₂ (%)	8.6-8.9	6.6-7.0	2.3-13.7
NO _x (ppm)	82-9.5	6.7-7.4	0-67
SO ₂ (ppm)	19	12-24.2	(g)
THC (ppm)	2	<2	0-84
Chlorides (lb/hr)	1.08-1 .57	Not measured(h)	<0.0077-0.0090(i)
Particulates (g/dscf @ 7% O ₂)	0.0065-0.0190	0.045-1.046	0.0029
DREs (%)	> 99.9999	99.9996	99.9936

(a) Soil amtaminated with PCBs.

(b) Soil contaminated with No. 6 fuel oil.

(c) Soil contaminated with residues from aviation gasoline manufacture.

(d) **Reference [4].**

(e) Reference [5].

(f) Results of treatability study.

(g) Not quantifiable. SO₂ analyzer was not operating within performance specifications.

(h) **No chloride in feed.**

(i) **Based on minimum detection level. No chlorides ware detected.**

Low concentrations of metals were also detected in the flue gas. Metals concentrations in the flue gas are a combination of vaporized/recondensed concentrations, and discrete particles carried through the system. Health risk assessments of an on-site demonstration would determine the importance of the flue gas metals concentrations.

CEM Results –

The CO, NO_x, and THC data indicated that the CBC can be operated and maintained within permit limitations. It is expected that CO, NO_x, and THC emissions of the on-site operation will change as the O₂ performance is optimized, but other test data [4,5] indicate that emissions of a full-scale system also are low. It is expected that the CO, NO_x, and THC emissions can be controlled within existing SCAQMD limitations.

SO₂ data cannot be evaluated since the SO₂ analyzer was not operating within performance specifications. The data indicate that sufficient quantities of limestone can be used to limit SO₂ emissions, and it is expected the SO₂ emissions from a full-scale operation could be controlled to permitted levels. The SITE Demonstration Program would determine the Ca/S ratios needed to achieve acceptable SO₂ emissions.

Organics Destruction

Volatile organics present in the feed were destroyed in the solids streams. PCBs, PCDDs, and PCDFs were not present in detectable concentrations in the waste feed, and were not found in the ash streams. The trace amounts reported by the laboratory have been attributed to laboratory contamination. Since there are no chlorinated hydrocarbons in the site waste, the Demonstration Test is not expected to produce any PCDDs or PCDFs.

PIC concentrations and concentrations of other undesired combustion by-products were examined in the treatability study. The CBC incineration of McColl waste can be expected to create only low concentrations of PICS.

Toxic Metals Distribution

Metals were distributed mostly into the fly ash and bed ash streams. Low concentrations were detected in the flue gas. Ash leachate tests showed the ash to be non-hazardous. The effect of the flue gas metals concentrations would be evaluated in health risk assessments of an on-site Demonstration.

TCLP Results

TCLP Metals --

The TCLP leachate tests performed on the ash streams indicated that the McColl Site ash residue would likely be classified as nonhazardous. However, since the TCLP test is sensitive to the pH of the tested matrix, it is possible that the leachate results will change if Ca/S ratios are optimized and the amounts of limestone reduced, thereby lowering the pH of the matrix. Further testing of the system and optimization of limestone use are indicated.

TCLP Organics –

Toluene was the only organic detected in the TCLP leachate; it was present at less than 0.025 mg/L in only one of three samples. This indicates that the ash leachate is essentially organic-free.

Physical Parameters

No out-of-the-ordinary physical characteristics were found in the ash and flue gas residues.

System Operating Conditions

Permit Limitation Effects --

The optimum Ca/S ratio required to limit SO₂ emissions could not be evaluated because of permit limitations. One important feature of the CBC technology is its capability to control SO₂ emissions using dry materials, rather than a wet scrubber. The necessity of using a wet scrubber to meet SO₂ emission levels would influence EPA's interest in conducting a Demonstration Test of the CBC at the McColl Site.

The permit limitations also affected the evaluation of the CBC control system's effectiveness in reacting to intentionally-induced abnormal operating conditions. It is important that any on-site, full-scale system control emissions with feedstock that varies widely in heating value and in SO₂ content.

Waste feed was restricted to 200 lb/hr feed rate and 5% sulfur content. This prevented evaluation of the system's response to higher feed rates at the typically higher sulfur content of the McColl waste.

Process Interruptions --

The installed limestone feed auger was undersized. This was resolved by an auger change.

A larger waste feed auger was installed during the overnight standby operation.

SO₂ system interlocks initially caused repeated feed interruptions. This was resolved by adding large amounts of limestone, which precluded the study of Ca/S ratio optimization.

Operational Concerns --

The CO and NO_x analyzers operated within performance specifications. The relative accuracy was within 7% and 13% respectively. The SO₂ analyzer had electronic malfunctions that affected the reliability of the SO₂ data. EPA determined that the SO₂ data were not quantifiable.

The analyzer output data, strip chart recordings, and DAS outputs differed slightly. The discrepancies were less than **±3%** of full scale.

The CCI, spiked material initially was difficult to feed. This problem was overcome by removing the feed mechanism and directly adding the spiked material.

QA/QC

The QC sample analyses indicated that reliable data were obtained from the study.

Costs

OES total costs for conducting the treatability study were \$193,505 -- based on permitting, labor, supplies, facility modifications, and decontamination. EPA costs were \$620,000 for waste preparation, transportation, sampling and analysis, waste disposal, and report preparation. These costs cannot be extrapolated to a full-scale system since they lack important cost elements of an on-site operation. It would be an objective of the SITE Demonstration Test to determine full-scale operating costs.

RECOMMENDATIONS

It is recommended that the CBC technology be evaluated further under the SITE Program. The SITE Demonstration Test should be designed to test the CBC at its full operating capacity. The viability of this opinion is dependent upon further deliberations among the regulatory agencies, discussions with the technology developer, and continued evaluation of the treatability study results and other available test data to verify that the CBC can meet the regulatory standards.

REFERENCES

1. Alliance Technologies Corporation. 1989. Sampling and Analytical Results for the Preliminary Test Burn Treatability Study of McColl Superfund Waste in Ogden's Circulating Bed Combustor Plant in San Diego, CA, Volume II - Appendices, Alliance Project No. 7-536-999, Bedford, Mass.
2. GA Technologies, Inc. 1985. Process Demonstration Test Report for Trial Burn of PCB-Contaminated Soils. GA-C18051. 10955 John Jay Hopkins Drive, San Diego, California
3. Journal of Air Pollution Control Association (JAPCA). 1987. Evaluation of a Pilot Scale Circulating Bed Combustor as a Potential Hazardous Waste Incinerator. JAPCA, March 1987. Vol. 37, No. 3.
4. Ogden Environmental Services, Inc. 1988. Process Demonstration Test Report for Demonstration Test of PCB-Contaminated Soils, Swanson River, Alaska. OES-910095. 10955 John Jay Hopkins Drive, San Diego, California
5. Ogden Environmental Services, Inc. 1989. Source Test Data Report for the OES Circulating Bed Combustor. ACUREX Project No. 9423. OES, Inc., P.O. Box 85178, San Diego, California
6. USEPA 1989. Preliminary Test Burn/Treatability Study of McColl Superfund Waste in Ogden's Circulating Bed Combustor Research Facility. Foster Wheeler Enviresponse, Inc. Contract No. 68-03-3255, Risk Reduction Engineering Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio.