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Technical Area Status Report for Second-Stage Destruction and Offgas Treatment

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ACRONYMS

A/E	architect/engineer
AC	activated carbon
acfm	actual cubic feet per minute
ALARA	as low as reasonably achievable
APC	air pollution control
APCD	air pollution control device
APCE	air pollution control equipment
ASTM	American Society for Testing and Materials
BACT	best available control technology
BIF	Boilers and Industrial Furnaces
CAA	Clean Air Act
CAI	controlled air incinerator
CDD/CDF	polychlorinated dibenzyl dioxin/furen
CDO	controlled decomposition and oxidation
CEM	continuous emission monitor
CHEAF	cleanable high-efficiency air filter
CIF	Consolidated Incineration Facility
DAC	derived air concentration
DFB	direct-fired burner
DOE	U.S. Department of Energy
DRE	destruction and removal efficiency
dscf	dry standard cubic foot
dscm	dry standard cubic feet
DSI	dry sorbent injection
EDE	effective dose equivalent
EDV	electrodynamic venturi
EER	Energy and Environmental Research Corporation
EM	Office of Environmental Restoration and Waste Management (DOE)
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERH	electrical resistance heater
ESP	electrostatic precipitator
FB	fluidized bed
FBI	fluidized bed incinerator
FBU	fluidized bed unit
FFCA	Federal Facilities Compliance Act of 1992
FGD	flue gas desulfurization
FPD	flame photometric detector
FWF	final waste form
GHSV	gross hourly space velocity
HAD	hot air dilution
HC	hydrocarbon
HEME	high-efficiency mist eliminator
HEMF	high-efficiency mist filter
HEPA	high-efficiency particulate air
INEL	Idaho National Engineering Laboratory

ACRONYMS (continued)

IWS	ionizing wet scrubber
LDR	land disposal restriction
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
MLLW	mixed low-level waste
MPC	maximum permissible concentration
MWIP	Mixed Waste Integrated Program
MWTP	Mixed Waste Treatment Project
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NMHC	nonmethane hydrocarbons
NMM	nonmetallic melter
NO_x	nitrogen oxides
OTD	Office of Technology Development (DOE)
PCB	polychlorinated biphenyl
PCE	polychloroethylene
PIC	product of incomplete combustion
POHC	principal organic hazardous constituent
PREPP	process experimental pilot plant
PSD	prevention of significant deterioration
PSD	prevention of significant deterioration
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RDT&E	research, development, testing, and evaluation
SAIC	Science Applications International Corporation
SCC	secondary combustion chamber
SCR	selective catalytic reduction
SD/FF	spary dryer/fabric filter
SDA	spray dryer absorber
SER	specific energy requirement
SHX	surface heat exchange
SNCR	selective noncatalytic reduction
SOAPP	State-of-the-Art Power Plant (software)
TAESH	terrain adjusted effective stack height
TASR	Technical Area Status Report
TCE	trichloroethylene
THC	total hydrocarbon
TSG	Technical Support Group
TTP	Technical Task Plan
VOC	volatile organic compound
VPPM	volumetric parts per million
WC	water column
WERF	Waste Experimental Research Facility
WESP	wet electrostatic precipitator
WSRC	Westinghouse Savannah River Corporation

EXECUTIVE SUMMARY

This report was sponsored by the Mixed Waste Integrated Program (MWIP), which was established by the Department of Energy (DOE), Office of Environmental Restoration and Waste Management (EM), Office of Technology Development (OTD). DOE/EM carries the charter to direct and coordinate waste management and site remediation throughout the DOE complex. Within EM, the OTD established the MWIP to identify and develop new technologies for treatment of DOE low-level mixed waste.

MWIP is organized into five technical areas, divided according to treatment technologies required to operate a fully integrated waste processing facility: (1) Front-End Handling; (2) Chemical/Physical Treatment; (3) Waste Destruction/Stabilization; (4) Offgas Treatment; and (5) Final Waste Forms Production and Assessment. The purpose of this structure is to coordinate related activities within each technical area, such as evaluation and guidance of technology development projects and development of Technical Area Status Reports (TASRs).

This report represents the second TASR for the Second-Stage Destruction and Offgas Treatment technical area. The first TASR[1] was published in September 1992. This (second) TASR updates technology information, a design methodology for air pollution control systems for mixed waste treatment, and technology development needs for DOE/EM. The TASRs form the basis of a technology development program that addresses the highest priority DOE environmental needs and is coordinated with other technology development efforts both inside and outside DOE.

The main functions of the second-stage destruction and offgas treatment system are to treat the gaseous effluent from the primary treatment process to acceptable levels for release to the atmosphere. Specific functions include (1) destruction of volatile organics; (2) capture of particulate matter; (3) capture of volatile metals; (4) capture and control of volatile, condensed-phase, and solid-phase radionuclides; (5) control of acid gases; (6) NO_x abatement; and (7) gas cooling and reheating as required to perform these functions.

APPROACH

A systems analysis is fundamental to the MWIP approach. The first step is to define the waste streams to be treated. DOE has just completed a report[2] documenting waste streams, treatment capacities, and technologies across the DOE complex. Once the waste streams are defined, treatment technologies can be selected. DOE's approach is to use existing technologies where possible. If modifications or new technologies are necessary, they will be demonstrated first on a component basis and then in an integrated pilot plant that includes all the elements of an operational mixed waste treatment facility.

Although ideally waste treatment parts of the system would be well defined before assessing offgas treatment needs, it is necessary to define systems and address needs simultaneously to meet tight schedules imposed by the Federal Facilities Compliance Agreement.

The Second-Stage Destruction and Offgas Treatment Technical Support Group (shortened to Offgas TSG) is a team of air pollution control (APC) experts from the DOE complex and industry. The TSG's charter is to identify existing APC technologies and define areas where additional research and development is needed. The TSG is also available to recommend APC systems for treatment technology demonstration tests.

The Offgas TSG took a systems-based approach to determine technology development needs. Eleven conceptual state-of-the-art APC designs were evaluated to treat effluent from nine waste treatment systems (two systems warranted two different APC designs). These systems were evaluated from both an operational and design viewpoint. Technology development needs and operational issues were extracted from these evaluations. This approach is described in Sect. 3.2. Moreover, we consider generic waste treatment systems and do not describe details such as individual waste streams, mass balance, etc.

An important by-product of this approach is documentation of the design process itself. The design process includes establishing design criteria, selecting APC components for each pollutant of concern, and optimizing the APC system as a whole. Chapter 4 contains a design guide to treat effluent from mixed waste treatment processes. We hope this design guide will aid in selecting APC equipment for mixed waste applications. The guide can also be used to identify data that are needed to design and optimize an APC system.

RECOMMENDATIONS AND CONCLUSIONS

The offgas TSG has identified the following technology development needs:

Technology Development Needs	Description
Develop continuous emissions monitors (CEMs) for volatile organic compounds (VOCs), metals, and radionuclides.	CEMs are needed for process control and to ease public opposition and permitting procedures for waste treatment systems. Real-time feedback will improve system performance by regulating emissions at the stack rather than at the waste feed. Unmonitored effluent is also a leading issue for public opposition to waste treatment plants. Real-time data will also be useful during technology development to characterize component and system performance.
Extend the life of high-efficiency particulate air (HEPA) filters.	Plugging HEPA filters create significant maintenance and handling problems and generate secondary waste that can be difficult and expensive to dispose of. Technologies are needed to (1) prevent plugging upstream of HEPA filters and/or (2) develop cleanable HEPA filters.
Characterize the performance of "new" technologies for initial removal of fine particulates (e.g., CHAEF filters, ceramic filters Froth columns).	Particulate removal is extremely important. The payback for reliable, high performance is substantial. Performance data are not available for some "new" commercial technologies.
Demonstrate the performance of APC systems and components for radioactive, metal, and particulate removal efficiencies.	Although experience, and to some degree data, allows APC system designers to predict the performance of equipment, most needs to be tested at a smaller scale prior to full-scale implementation. The performance of such tests is to optimize and protect the substantial investment required for full-scale equipment. Another purpose is to determine operational flexibility. For example, how tolerant is a mercury cleaning component to low levels of acid gas?

Technology Development Needs	Description
Investigate commercial and emerging technologies for high-temperature particulate removal (e.g., ultrafiltration, ceramic bags, ceramic candles, molten glass scrubbers).	Normally, particulate removal is performed at lower temperatures at downstream locations in the APC system. If particulate removal can be accomplished upstream, it will keep most of the radionuclide contamination upstream, resulting in a safer, easier-to-maintain system.
Evaluate state-of-the-art NO_x abatement technologies.	The TSG recommends that DOE not invest in new NO_x abatement technologies until a survey of industry R&D (especially the electric power industry) is performed. Industry is doing much work to improve catalysts, etc., that will likely be applicable to DOE mixed waste treatment systems. The payback for a major technology improvement in this area is large, but the probability of DOE initiating a new, major improvement technology appears small.
Evaluate state of the art in second-stage destruction technology.	Good mixing is imperative for organics destruction in a second-stage destruction unit. If this unit functions properly in a system, there is no need for further equipment (e.g., tertiary VOC capture such as catalytic devices) to assure VOC destruction. Combustion can be inherently improved by a plug-flow geometry and possibly other techniques combined with traditional burners. The need is to evaluate commercial activities, products, and technology development.
Evaluate "new" commercial technologies to minimize secondary waste streams without sacrificing pollutant removal efficiency.	Possible technologies include acid gas removal, using "amine" solutions that can be recycled, and new mercury capture technologies. Treating secondary waste generated in a mixed waste treatment system is not trivial, especially for liquid secondary waste streams. The benefits of implementing technologies that minimize secondary waste generation should be evaluated in a systems analysis that includes formal technology selection logic to account for factors such as cost, risk, and performance. The MWIP should at least be familiar with technology options and use site-specific analysis to consider their applicability to DOE systems.

Technology Development Needs	Description
Modeling of metals partitioning in waste treatment and air pollution control equipment.	This is especially important in later phases of treatment technology development. The models are primarily thermodynamic equilibrium models. Work should coordinate with work funded by EM at Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, and Rocky Flats Plant (through the U.S. Environmental Protection Agency at Energy and Environmental Research Corp., Irvine, California). It is extremely useful for designers of APC systems to know the physical (and sometimes chemical) form of the metals that must be captured and also to understand operational parameters that affect capture.
Hot testing.	Hot testing (using real radionuclides) is required to demonstrate the capture efficiency of radionuclides in an APC system prior to full-scale implementation. Some surrogate radionuclide testing can also be useful. Selection criteria for surrogates include molecular weight, volatility, and thermodynamic properties. Final surrogate selection depends on the feature being tested.
Provide technologies that address issues affecting public opposition/concern toward mixed waste treatment facilities.	This issue is partially addressed by stating the need for CEMs, but any other technical solutions to this important problem should be considered.

1. INTRODUCTION

1.1 BACKGROUND—MIXED WASTE INTEGRATED PROGRAM

The Mixed Waste Integrated Program (MWIP) was established by the Department of Energy (DOE), Office of Environmental Restoration and Waste Management (EM), Office of Technology Development (OTD). DOE/EM is chartered to direct and coordinate waste management and site remediation throughout the DOE complex. EM is divided into five organizations: the Office of Planning and Resource Management (EM-10); the Office of Environmental Quality Assurance and Resource Management (EM-20); the Office of Waste Operations (EM-30); the Office of Environmental Restoration (EM-40); and the OTD (EM-50).

The mission of the OTD is to develop treatment technologies for waste operations and restoration where current treatment technologies are inadequate or not available. The purpose of the MWIP is to identify and develop new technologies for treatment of DOE low-level mixed waste (LLMW). Currently, much of DOE's large inventory of LLMW is out of compliance with the land disposal restrictions (LDRs) promulgated by the Environmental Protection Agency (EPA), making treatment of these wastes an important issue.

The MWIP is developing a unified approach for the treatment of all DOE LLMW either currently in inventory or being generated. Although some of DOE's LLMW may be treated using existing technologies and facilities, the MWIP is developing more cost-effective, lower risk approaches. This is being accomplished through coordination with the Mixed Waste Treatment Project (MWTP), under direction of EM-30. The MWTP is designing a generic waste treatment facility to treat all DOE mixed waste streams. The purpose of this design is to serve as a prototype for facilities to be built at a (yet-to-be determined) number of sites. The MWTP design contains treatment technologies in six areas:

- Segregation.
- Opening and Removal.
- Sorting/Assignment.
- Feed Preparation/Size Reduction.
- Waste Treatment.
- Subsequent Support Operations (including Second-Stage Destruction, Offgas Treatment, and Final Waste Form Disposal).

MWIP has organized five technical areas divided according to the MWTP technical areas:

- Front-End Waste Handling.
- Chemical/Physical Treatment.
- Waste Destruction and Stabilization.
- Second-Stage Destruction and Offgas Treatment.
- Final Waste Form Disposal.

The purpose of the technical areas is to coordinate activities such as evaluation and guidance of technology development projects and development of a Technical Area Status Report (TASR) in each technical area.

The mission of the MWIP is to identify and develop technologies for treatment of DOE mixed low-level wastes (MLLW) into forms suitable for final disposal. These technologies

must have improved performance, reduced risk, and minimized life cycle costs over existing technologies or provide treatment for waste streams for which no current treatment technology exists. Some of the near-term (< 5 years) objectives of the MWIP are as follows:[2]

- To identify priority mixed waste treatment needs and pursue near-term technologies for development.
- To develop improved or alternative mixed waste treatment technologies to meet the following needs: complex-wide waste treatment needs; site-specific waste treatment needs; and small-volume, problematic mixed wastes.
- To assess the feasibility and applicability of enhanced waste forms.
- To initiate and participate in public outreach programs and activities, as appropriate.
- To facilitate information exchange and technical support to all customer organizations.

The MWIP's overall strategy for mixed waste treatment technology development can be summarized as developing innovative technologies that (1) minimize up-front waste characterization and handling; (2) simplify treatment system configurations by replacing multiple specialized technologies with fewer, more versatile technologies; (3) generate enhanced final waste forms; and (4) will be accepted by customers for implementation.

Under authority from DOE/EM, the MWIP writes solicitations for Technical Task Plans (TTPs). The TTPs are mechanisms that allow researchers to submit proposals and receive funding for the development and/or improvement of treatment technologies for eventual use by the Office of Waste Management (EM-30). The MWIP technical area leaders assist DOE Headquarters in the TTP evaluation process through the following responsibilities:

- determine treatment technology needs in conjunction with technology users;
- assess available treatment technologies against the identified needs;
- identify potential innovative treatment technologies;
- communicate with the MWIP; and
- develop a systematic approach that will provide a defensible rationale for the selection and funding of TTPs.

Once the TTPs are funded, the technical area leaders are responsible for ensuring that all developmental activities generate quality data. With quality data, MWIP can select technologies with the highest potential to successfully treat DOE MLLW. Pilot-scale demonstrations of these technologies will determine necessary design and operational parameters. Finally, MWIP will assist Waste Operations (EM-30) and Environmental Remediation (EM-40) in applying these technologies on a full-scale level and will provide technical support throughout the design, construction, start-up, and operation of the treatment systems. The end result of this work will be to develop and demonstrate technologies that are safe, cost-effective, and meet all applicable requirements.

1.2 MWIP OFFGAS TECHNICAL AREA

The purpose of the MWIP Second-Stage Destruction and Offgas Technical Area is to address technologies that treat or monitor offgas streams generated by waste destruction and chemical/physical treatment processes. These technologies include second-stage (thermal) destruction, air pollution control (APC), and effluent monitoring. The effluent to be treated contains both radioactive and hazardous components.

The main functions of the second-stage destruction and offgas treatment system are to treat the gaseous effluent from the primary treatment process to acceptable levels for release to the atmosphere. Specific functions include (1) complete destruction of volatile organics, (2) capture of particulate matter, (3) capture of volatile metals, (4) capture and control of volatile, condensed-phase, and solid-phase radionuclides, (5) control of acid gases, (6) NO_x abatement, and (7) gas cooling and reheating as required to perform the preceding functions.

The purpose of this TASR is to identify deficiencies and posture a development plan for APC technologies to support DOE mixed waste treatment. This document also provides guidance for design and operation of an APC system for mixed waste treatment.

This report represents the second TASR for the Second-Stage Destruction and Offgas Treatment Technical Support Group (TSG). The first TASR[1] was published in September 1992. This (second) TASR includes updated technology information, a design methodology for APC systems for mixed waste treatment, and technology development needs for DOE/EM. The TASRs form the basis of a technology development program that addresses the highest priority DOE environmental needs and is coordinated with other technology development efforts both inside and outside DOE.

1.3 OFFGAS TREATMENT TECHNOLOGIES DESCRIBED IN OTHER REPORTS

Two references provide important material on APC and second-stage destruction technologies. The first reference is the 1992 Offgas TASR, *An Assessment of Offgas Treatment Technologies for Application to Thermal Treatment of Department of Energy Wastes*.[3] This report begins with a discussion of the types of air pollutants and the factors that influence pollutant generation. It also summarizes regulations for waste treatment and pollution control. Issues involved in selecting and evaluating air pollution control equipment (APCE) are discussed. Forty-one types of APC devices are described. Each description includes the principle of operation, the advantages and disadvantages of the technology, and areas where improvements could be made in the technology. A partial list of vendors for APCE is also given and has been incorporated into Appendix A of this TASR.

The second reference contains similar information but is directed at selecting a pollution control system for the proposed Rocky Flats Fluidized Bed Incinerator.[4] This report includes a discussion of waste characteristics and the appropriate regulatory requirements. The report discusses offgas control technologies and includes a chapter on monitoring techniques. A discussion of offgas components selection is also presented. Both of these documents identify additional work that is needed in the area of pollution control for thermal treatment systems.

In addition to standard APC systems, DOE has investigated at least one unconventional system, consisting of a large holding tank that would capture offgas after it is processed through a standard APC system. Operators would then test the offgas for purity, releasing it if in compliance or further processing it if out of compliance. This system, dubbed "Hold, Test, and Release," was proposed for the Rocky Flats Fluidized Bed Incinerator for implementation during the next 5 years.[5–9] An independent peer review[10] examined the proposal and found it to be unnecessarily complicated in terms of system performance, reliability, and regulations. Specific concerns of the review panel were obtaining representative samples, controlling the thermal unit while processing recycled effluent, regulations governing release of captured offgas, treatment of noncondensible gases such as nitrogen and NO_x, and reliability of a complex system. Most important, the review panel felt that a well-designed offgas system, put through the proper sequence of scale-up tests to ascertain system performance, would perform at or above all current and anticipated

regulations applicable to Rocky Flats. Perhaps with the advent of new continuous emissions monitors (CEMs), a version of this strategy could be useful to divert offgas during an uncontrollable upset of the thermal treatment system.

Many other sources of air pollution control technology information are available if the reader is interested. Some suggested readings are

Conference Proceedings:

- 1992 and 1993 Incineration Conference
- Pre-1987 Incineration Conference
- (Interim Incineration Conference covered in first Offgas TASR[1])
- EPA Conferences
- Electric Power Research Institute (EPRI) conferences
- Air and Waste Management Conferences
- DOE Model Conferences
- Waste Management Conferences
- Spectrum Conference Energy Research and Development Administration (ERDA) Air Cleaning Conferences
- Toxicon Incineration Conferences
- National Metals Conferences

Journals:

- *Pollution Engineering Journal*
- *Journal of Chemical Engineering*
- *Journal of Chemical Engineering Progress*
- *Environmental Science and Technology*

Reports:

- DOE reports
- EPRI reports
- EPA literature
- Perry's Handbook
- Air and Waste Management reports
- National Technical Information Service

Other:

- Academia
- Patent searches (patent office and Chemical Rubber Co. books)
- Other professional societies

2. PERFORMANCE REQUIREMENTS OF OFFGAS SYSTEMS FOR DOE MIXED WASTE TREATMENT

2.1 OFFGAS TREATMENT FUNCTIONAL REQUIREMENTS

The technologies covered in this report treat gaseous and particulate-laden effluents from waste destruction technologies to meet discharge regulations. The technologies must perform the following functions (noting that APCE often performs more than one function):

- gas cooling,
- volatile organic compound (VOC) destruction or removal,
- Acid gas removal,
- NO_x destruction or removal,
- initial particle removal,
- final particle removal,
- volatile metal removal,
- dioxin avoidance (temperature, time dependence), and
- radionuclide capture and control.

2.2 SYSTEM PARAMETERS THAT AFFECT POLLUTANT GENERATION AND TREATMENT

In designing an APC system, system parameters, both upstream and downstream of the APCE must be considered. System parameters include an adequate description of the type of effluent to be treated, which is a function of the waste stream and the waste destruction technology; a definition of secondary waste stream treatment options (e.g., waste water treatment); and final effluent regulations.

The waste streams of interest to the MWIP are the mixed waste streams at sites designated to be treated under the Federal Facilities Compliance Act (FFCA) of 1992.[3]

2.3 AIR POLLUTION CONTROL REGULATIONS

Air pollution is regulated under the following acts:

- Resource Conservation and Recovery Act (RCRA).
- Clean Air Act (CAA).
- National Emissions Standards for Hazardous Air Pollutants (NESHAPs).
- DOE orders.
- BIF (Boilers and Industrial Furnaces) Regulations.
- New EPA regulations for hazardous waste disposal being established by October 1994.
- State and local regulations.

Table 1 summarizes regulations for each pollutant.

Table 1. Air pollution control regulations for emissions from thermal treatment processes[a]

Pollutant	Current RCRA limits	Proposed RCRA limits
Particulate	180 mg/m^3 corrected to 7% O_2	180 mg/m^3 corrected to 7% O_2 (final limit could be as low as 33 mg/m^3).
CO	Continuous monitoring and correction to 7% O_2 (1-h rolling average)	Continuous monitoring and <100 ppm, or >100 ppm and <20 ppm hydrocarbons (HC), or <100 ppm and demonstrate acceptable total HC risk.
Oxygen	NR[b]	Continuous monitoring.
Hydrocarbons	NR[b]	Continuous monitoring if CO emissions are >100 ppm.
Noncarcinogenic metals, HCl, and Cl_2	N/A	Maintenance of the feed rate or emission rate of each constituent below the screening limits (given below) on an hourly rolling average or an instantaneous limit basis or maintenance of constituent emissions below rates that result in acceptable ambient ground-level concentrations as determined by site-specific dispersion modeling.
Antimony[c]	NR[b]	14–31,000 gram/hour (g/h)
Barium[c]	NR[b]	2400–5000 g/h
Lead[c]	NR[b]	4.3–9200 g/h
Mercury[c]	NR[b]	14–31,000 g/h
Silver[c]	NR[b]	140–310,000 g/h
Thallium[c]	NR[b]	14–31,000 g/h
HCl[c]	1.8 kg/h or 99% removal (whichever is least restrictive)	330–720,000 g/h (emission screening limits only)
Cl_2[c]	NR[b]	19–41,000 g/h
Carcinogenic metals	N/A	The sum of the ratios of the actual feed rates to the screening limits (given below) for each metal must be maintained to less than or equal to 1.0 on an hourly rolling average or averaging period or an instantaneous limit basis; or the sum of the ratios of the actual emission rates to the screening limits for each metal must be less than or equal to 1.0 on an hourly rolling average or averaging period or an instantaneous limit basis; or metal emissions must be maintained below rates that result in acceptable ambient ground level concentrations as determined by site-specific dispersion modeling.
Arsenic[c]	NR[b]	19–240 g/h
Beryllium[c]	NR[b]	44–580 g/h
Cadmium[c]	NR[b]	6.4–86 g/h
Chromium[c]	NR[b]	33–430 g/h

Table 1 (continued)

Pollutant	Current RCRA limits	Proposed RCRA limits
Radionuclides	40 CFR 61, Subpart H, Radionuclides from DOE Facilities NESHAP. Emissions of radionuclides from DOE facilities shall not cause any member of the public to receive an effective dose equivalent (EDE) of 10 mrem/year as determined by sampling and dispersion modeling.	Stack stream must be directly monitored continuously with an in-line detector or representative samples withdrawn continuously from the sampling site per ANSI N13.1-1969.
Note: NESHAPS will be phased out (1994–1996) in favor of the new air toxics standards of the CAA. Radionuclides are specifically included as an air toxic.		
Particulate	40 CFR 60, Subpart E, Standards of Performance for Incinerators (>45 metric tons/d)	0.18 g/dscm corrected to 12% CO_2.
Criteria and noncriteria pollutants	40 CFR 52.21, Prevention of Significant Deterioration	To obtain a permit to operate an incinerator in a PSD (or attainment) area, the best available control technology (BACT) must be applied in the APC system as determined through a top-down BACT analysis.
Beryllium	40 CFR 61, Subpart C	10 g/24 h

[a]The current EPA administrator has indicated that these regulations will be modified within 18 months from May 1993.

[b]NR = not regulated.

[c]The ranges given are the lowest and the highest levels in the screening limits, corresponding to a low terrain at 4 m adjusted effective stack height (TAESH) in complex terrain (urban and rural areas) and high at 120 m TAESH in noncomplex terrain rural areas.

3. APPROACH TO DETERMINE OFFGAS TECHNOLOGY DEVELOPMENT NEEDS

This chapter provides a definition of "technology development needs" and the approach to identify those needs. The technology development needs are summarized in Chaps. 5 and 6.

3.1 DEFINITION OF TECHNOLOGY DEVELOPMENT NEEDS

A "technology development need" is any one of three "needs" that can be filled by the DOE/EM Office of Technology Development. The first, most fundamental level of need is a "functional deficiency," which is a need not met by any existing technology or new technology. The second level of need is a "testing and demonstration need" (a need for performance data on a DOE mixed waste application). The third and easiest need to fulfill is a "knowledge gap" (evaluators did not have enough information to determine if technology development is needed, but it appears likely that industry is doing sufficient technology development in this area). The third need is filled by collecting information from literature, surveys of industry, etc.

3.2 SIMPLIFIED APPROACH TO EVALUATE TECHNOLOGY DEVELOPMENT NEEDS

The Offgas TSG considered two different approaches to determine technology development needs. The first approach is a comprehensive technology-based approach that evaluates a long list of carefully compiled technologies and evaluates their performance against established criteria. The second approach is a specific systems-based approach that evaluates "typical" APC system designs and extracts both issues and needs from this system evaluation. The first approach has the advantage of creating comprehensive lists of technologies and rigorous technology evaluations. However, it does not consider "system" performance, which is crucial for series of APC technologies operating as a system. In addition, it becomes very difficult to evaluate individual technologies against criteria without considering the systems context of operation. Therefore, the TSG used the less rigorous, but more practical, second approach.

This approach assumes that the most important aspects of technology development needs can be identified by evaluating "typical" APC systems. Eleven conceptual "state-of-the-art" APC designs were evaluated to treat effluent from nine waste treatment systems (two systems warranted two different APC designs). These systems were evaluated from both an operational and design viewpoint. Technology development needs and operational issues were extracted from these evaluations. An important by-product of this approach is documenting the design process itself. Many important system and technology parameters must be defined, or assumed, to develop a conceptual APC system design. The design process is outlined in the design guides, described in Sect. 4.3.

Table 2 describes the 11 designs used to evaluate offgas technology needs. Flowsheets showing these conceptual designs are included in Appendix B of this report.

Table 2. APC system designs used to evaluate offgas technology development needs

Design basis	Waste treatment technology	APC system for specific waste treatment technology
Nine designs based on effluent from the MWTP	Three for incinerators	• One to treat effluent from rotary kiln or controlled air incinerator (CAI) using a semiwet APC system using a spray dry absorber (SDA). • One to treat effluent from rotary kiln or CAI using a wet APC system using a blowdown evaporator. • One to treat effluent from car bottom furnace.
	One for a vitrifier	• One to treat effluent from vitrifier with negligible acid gas precursors (e.g., Cl) in waste feed.
	Two for a nonmetallic melter	• One to treat effluent from nonmetallic melter using a dedicated offgas system (afterburner and quench before removing mercury). • One to treat effluent from nonmetallic melter using multiuse offgas system (remove mercury first).
	Mercury roaster	• One to treat effluent from a mercury roaster—assuming a dedicated offgas system.
	Ventilation gas	• One to treat building ventilation gases (including offgas from vents, hoods, and process units).
	Emergency ventilation	• One to treat gases from emergency ventilation.
One design based on the plasma hearth furnace		• One to treat effluent from plasma hearth furnace.
One design based on the Rocky Flats fluidized bed unit (taken directly from EER[a] design)		• One to treat effluent from fluidized bed incinerator.

[a]Energy and Environmental Research Corporation, Irvine, California.

Conceptual designs were developed for each system. Each design was evaluated to identify functional deficiencies (none found), technology testing and demonstration needs (seven of the ten recommendations), knowledge gaps (three of the ten recommendations), and other design and operational considerations (documented in Sect. 4.5).

4. DESIGN GUIDES FOR MIXED WASTE AIR POLLUTION CONTROL SYSTEMS

4.1 BACKGROUND AND RATIONALE FOR A MIXED WASTE APC DESIGN GUIDE

The purpose of the air pollution control design guides is to document and analyze the process used to develop an APC system to treat effluent from mixed waste treatment units. The guides are particularly useful as MWIP progresses toward system demonstrations of mixed waste treatment technologies such as the joule melter and plasma hearth furnace. State-of-the-art APC systems will be designed and tested for each of these treatment systems. Even more important, the key decision points that determine the best type of APC system are highlighted in these design guides. These key decision points define test data that are needed from technology development programs to optimize the APC design.

The Offgas TSG has developed a series of nine design guides to define selection criteria for APC systems. The need for this guide stems from the following assumptions:

1. Waste characterization data for DOE's mixed waste streams are probably not reliable enough to form the basis for design and selection of an APC system. The current waste characterization data reflect an average, homogeneous waste composition. Final designs based on such an approach would almost certainly prove to be unsatisfactory.

2. Even if all waste streams were well characterized, possible swings (however short in duration) in the composition of waste within a given waste category would probably have a severe impact on the effectiveness of the system selected. Some degree of conservative (not necessarily "worst case" but maybe "worse case") design will probably need to be incorporated into all designs, depending on the waste constituent(s) for which data are unreliable. Waste streams identified as highly variable in one or more constituents will require more conservative design than waste streams that are more consistent.

3. Characterization of the offgas effluent into the APCE is not determined solely by either the waste composition or the thermal treatment technology but by the combination of the two.

4. A guide that is general in nature, rather than specific to only current waste stream/thermal technology combinations, could continue to be appropriate for the long term.

5. Cost is a major issue facing DOE mixed waste treatment. A technology (or integrated offgas treatment flowsheet) that can perform more than one function or accept a wider variety of offgas compositions via conservative ("worse case") design might be a legitimate way to save money in the long run.

Although the design guide will be useful, commercial vendors of offgas treatment systems should and will be relied upon to provide commercially available equipment components for mixed waste treatment systems. However, individual commercial vendors who supply equipment in the size range applicable for treatment of DOE mixed waste generally provide specific types of offgas treatment systems and technologies, as compared to

completely integrated systems. The design will be best if it uses expertise within the DOE laboratories, from independent consultants, and from commercial vendors.

4.2 DATA REQUIREMENTS FOR A MIXED WASTE APC DESIGN

The following data are used by the design guides. Depending on the level of design detail required, (i.e., conceptual design vs design for equipment specification), not all the data listed here will be required.

1. Define system upstream of air pollution control equipment.

Waste Stream	——>	Pretreatment and Waste Destruction	——>	Second-Stage Destruction	——>	Effluent into APCE

- Identify waste stream, pretreatment, and waste destruction technology to characterize effluent into APCE.

- Identify properties of effluent to be treated in APC system pollutants:
  — composition (organics, particulates, NO_x, acid gas, metals, radionuclides, and carbon),
  — flow rates and required turndown ratios,
  — temperature, pressure,
  — other (particle stickiness, etc.).

- Second-stage destruction system specifications require the following information:
  — frequency of use (i.e., continuous or backup to primary combustion chamber),
  — residence time or length-to-diameter ratio,
  — VOC destruction efficiency.

- Tertiary VOC destruction can be specified if second-stage destruction does not meet effluent requirements.

- Determine if the primary waste treatment unit or second-stage destruction unit is amenable to recycling carbon from the APC system. Would this option invoke any special criticality concerns or other concerns?

2. Define system downstream of APCE.

Effluent from APCE	——>	Final Waste Form Disposal	AND	Secondary Waste Treatment

- What is the availability (cost, proximity, etc.) and suitability of a system to treat secondary waste streams (i.e., a wastewater treatment facility)? Secondary waste streams to be considered include water, carbon, ash, scrubber blowdown, salts, packed-bed material, particulates (baghouse dust, etc.), etc.

- What compatibility difficulties are anticipated between secondary waste streams and preferred final waste forms (e.g., are salt and carbon compatible with glass as a final waste form)?

- What federal, state, and local regulations are in effect now and expected in the future (e.g., NESHAP, RCRA, CAA)?

- Is a vapor plume acceptable?

3. Define other system constraints for APCE.

   - What type of radiation control will be mandated when this design is implemented?

   - What are the physical requirements of the APC system (e.g., footprint, height, electrical load)?

   - Are there public concerns that should be considered when choosing APCE (e.g., precedence set by other systems)? Does the public have any preconceived notions about technology choices?

   - How can accidental overpressure of an APC system be accommodated, from a technical, regulatory, and public acceptance viewpoint? What is the suitability of thermal relief vents, which are not always acceptable to the public but provide an important element of safety?

   - What is the minimum acceptable "availability" of the APCE to function effectively in a waste treatment system? This affects maintenance requirements, which affects choice of materials of construction and other cost-related elements of the system.

   - What are the highest quality materials that can be specified to minimize maintenance and increase safety and reliability? A life cycle cost analysis should answer questions.

   - What redundancy and reliability requirements exist, and how should these requirements be designed into the system? This is a safety and an availability issue.

   - What is the available skill level of operators and maintenance crews for the APCE?

   - What type of continuous emissions monitoring above and beyond those required by regulations (e.g., NO_x, etc.) would be useful to consider for control and performance assessment of the APC system?

   - How can secondary waste streams be minimized (e.g., using a spray dryer absorber)?

4. Consider factors that influence type of APC system: wet, semiwet, semidry, or dry offgas system.

   - Wet—A system that uses water, saturates the offgas with water vapor, and generates a liquid blowdown stream.

- Semiwet—A system that uses water and saturates the offgas with water vapor but does not generate a liquid blowdown stream.

- Semidry—A system that uses water but does not saturate the offgas with water vapor or generate a liquid blowdown stream.

- Dry—A system that does not use water in contact with offgas for any purpose based on the following:
  - — Existence of wastewater treatment facility.
  - — Level and activity of radionuclides in effluent.
  - — Concentration of acid gas to be treated.

5. Specify performance requirements for the following.

- Gas cooling.
- VOC destruction/control.
- Acid gas removal.
- NO_x abatement.
- Initial and final particulate removal.
- Toxic metal removal.
- Dioxin avoidance (temperature, time dependence).
- Radionuclide capture and control.
- Gas reheating.

4.3 OUTLINE OF DESIGN GUIDES

The following ten design guides summarize the design process for a mixed waste APC system. The first design guide is an overall step-by-step outline of the design process, starting with a definition of the purpose and design criteria for the APC system and ending with a procured, installed, and tested system. The second design guide lays out the iterative steps required to consider each pollutant one at a time, iterating back to check the system-level effects on other pollutants. This design guide leads the user into the remaining eight design guides, one pollutant at a time. For example, the first pollutant to be examined might be volatile metals (design guide 5). Each specific pollutant design guide (3–10) begins with a list of technology options to treat that pollutant and goes through a logical series of questions to help the user decide which technology is best suited for this application. The user then returns to design guide 2. At each step, the user must decide if concerns about alpha radioactivity are acceptable before proceeding on to the next pollutant. Using this approach, the APC system is designed, step-by-step, with system considerations addressed by iterating through the steps.

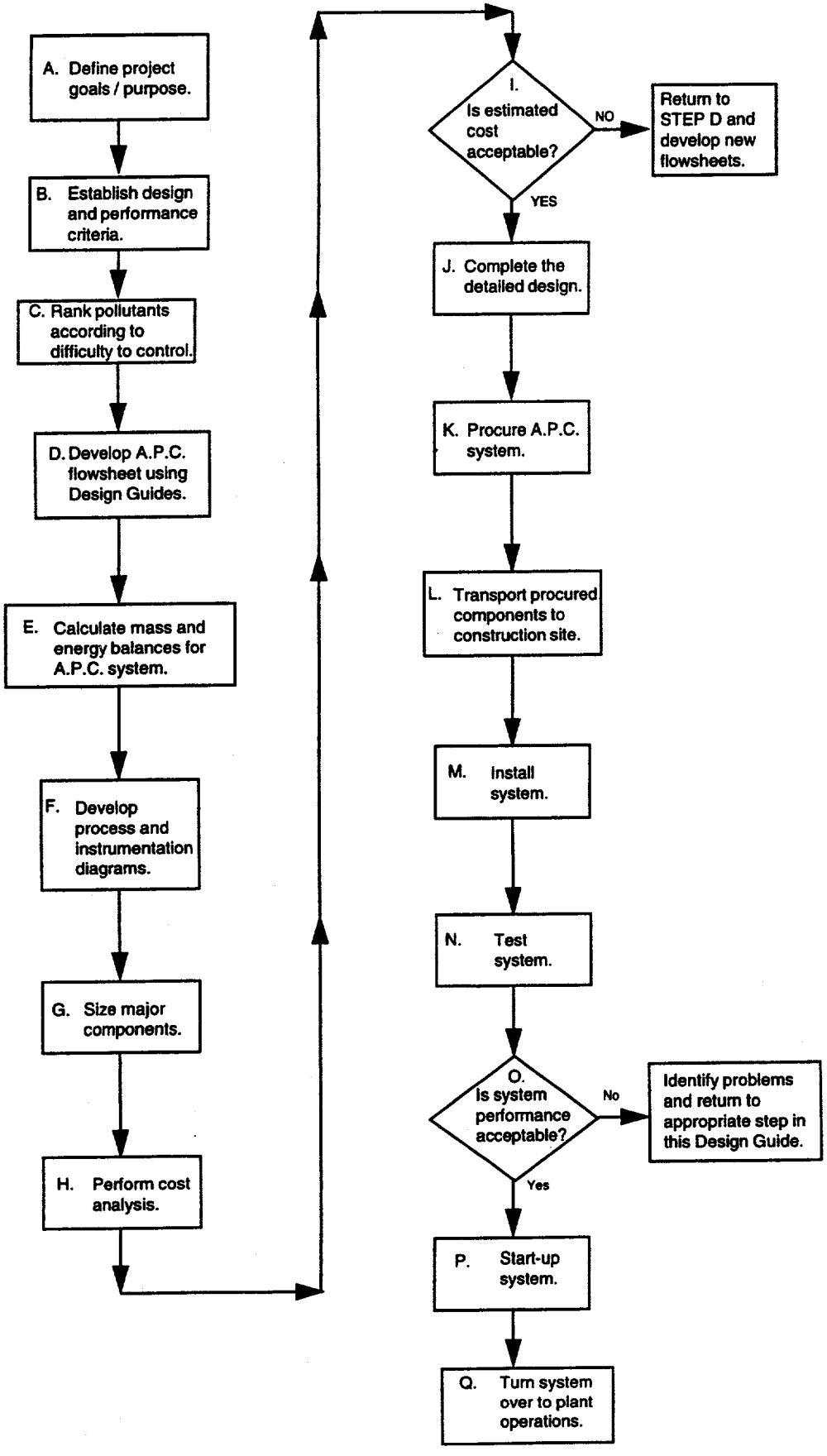
General Notes for Design Guides

1. These guides are not an all-inclusive, absolute process. They are only intended to guide the reader into asking the right questions and following the right path in the development of a pollution control system. Each situation has specific details that make it unique and therefore requires that individualized concerns be addressed. Consequently, in the design of an actual system, steps may have to be added to the design guides, subtracted from the design guides, or modified in the design guides. For example, those design steps that specify concentrations are not to be considered fixed. The actual concentrations that decisions will be based upon will vary depending on the particular circumstances.

2. Wet, semiwet, dry, and semidry refer to the amount of moisture introduced in the APC system (defined in Sect. 4.2, item 4).

3. Other definitions and acronyms used in the design guides are either defined in the guides or are defined in other locations in the TASR.

DESIGN GUIDE 1. Simplified Steps to Designing a Mixed Waste APC System



NOTES FOR DESIGN GUIDE 1

Step A. The size (i.e., bench scale, pilot scale, or full scale) and purpose of the project must be determined. Identify waste to be treated, characterize waste, define disposal criteria for the final waste forms, determine/select waste treatment technology, and determine applicable regulations and requirements.

Step B. Calculate mass and energy balances for waste treatment units, identify pollutants in the offgas, and estimate offgas characteristics.

Step C. Rank pollutants according to the difficulty in controlling pollutant emissions, based on pollutant characteristics, functional design requirements, regulatory requirements, and stakeholder concerns. The following criteria can assist in the rankings: pollutant with highest concentration, pollutant with maximum variability, pollutant with fewest options for control devices, form of by-product from pollutant removal that is difficult to treat or is benefited by being segregated from other by-products (e.g., may be beneficial to keep collected particulate separated from salts generated from acid gas removal).

Step D. Develop one or more conceptual process flowsheets using the technologies selected in the design guides; the need for redundancy should be considered. (See note H.)

Step E. Determine mass and energy balances for offgas components based upon output from waste treatment unit(s), offgas cooling, and offgas treatment additives (such as caustic).

Step F. For many processes, the instrumentation required for monitoring and characterizing the offgas for regulatory purposes can also be used for process control.

Step G. Because of poor waste characterization and the variety and range of components in the waste, it may be necessary to oversize and/or overdesign components to account for process upsets and major swings in offgas conditions (i.e., a decision must be made as to whether a worst case design is best or whether a nominal design will suffice for each component). (See note H.)

Step H. A cost-to-benefit analysis can be done at this point to determine if it is justifiable to oversize equipment or to add redundancy for various components. Previous experience has demonstrated that many failures in wet offgas components result after start-up because of the materials of construction. Although it may cost more initially, using higher grades of materials of construction may cost less over time. The cost of a material's failure should be considered in this cost analysis.

Step I. If estimated costs are not practical, given the issues involved, **steps D through H** can be repeated to develop a new conceptual design. It may also be necessary to go back to **step A** and redefine the project goals and purpose or to go back to **step B** and establish different design criteria.

Step J. This step includes all civil, chemical, mechanical, and electrical engineering. The options range from 100% owner design to 100% architect/engineer (A/E) or vendor design.

Step K. There are many options here. For example, the complete system can be bought and installed as a turnkey system; individual components can be bought and integrated by an A/E firm; or the owner/operator can fabricate or buy components and install them. This step requires identification of potential bidders, contract negotiations, and awarding the contract.

Step L. Based on the size of components, special transportation may be required, special arrangements may be needed, or components may need to be shipped in sections.

Step M. This step assumes that the building has been completed.

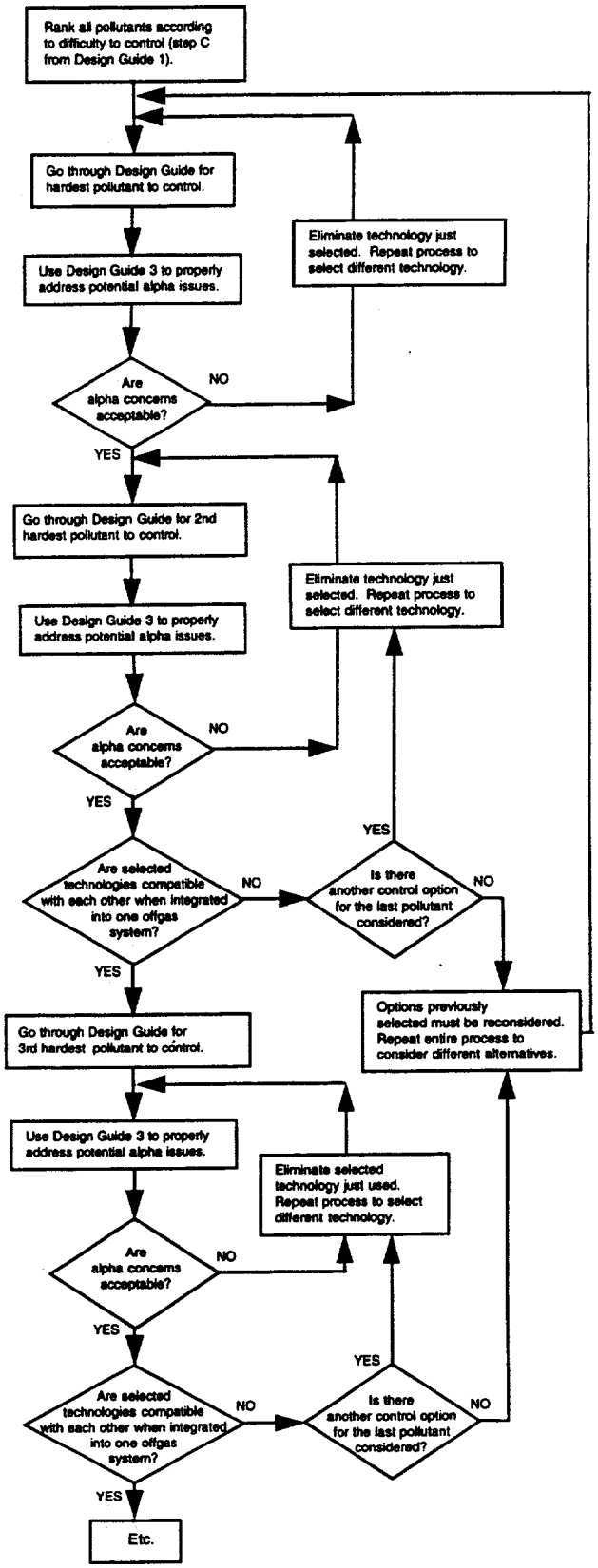
Step N. Individual components should be checked out to make sure they function properly, and the integrated system should be tested to make sure it is operable and debugged.

Step O. If the performance of a component or the system as a whole is not acceptable, some design or equipment modifications may be necessary.

Step P. During facility start-up, it is not uncommon to need to do some additional debugging and possibly make some minor modifications to the process.

Step Q. Even after the process is functioning properly and has been turned over to the operations department, engineering support will be needed for process upgrades, trouble-shooting, and maintenance.

DESIGN GUIDE 2. Simplified Process for Selecting for Mixed Waste APC Technologies

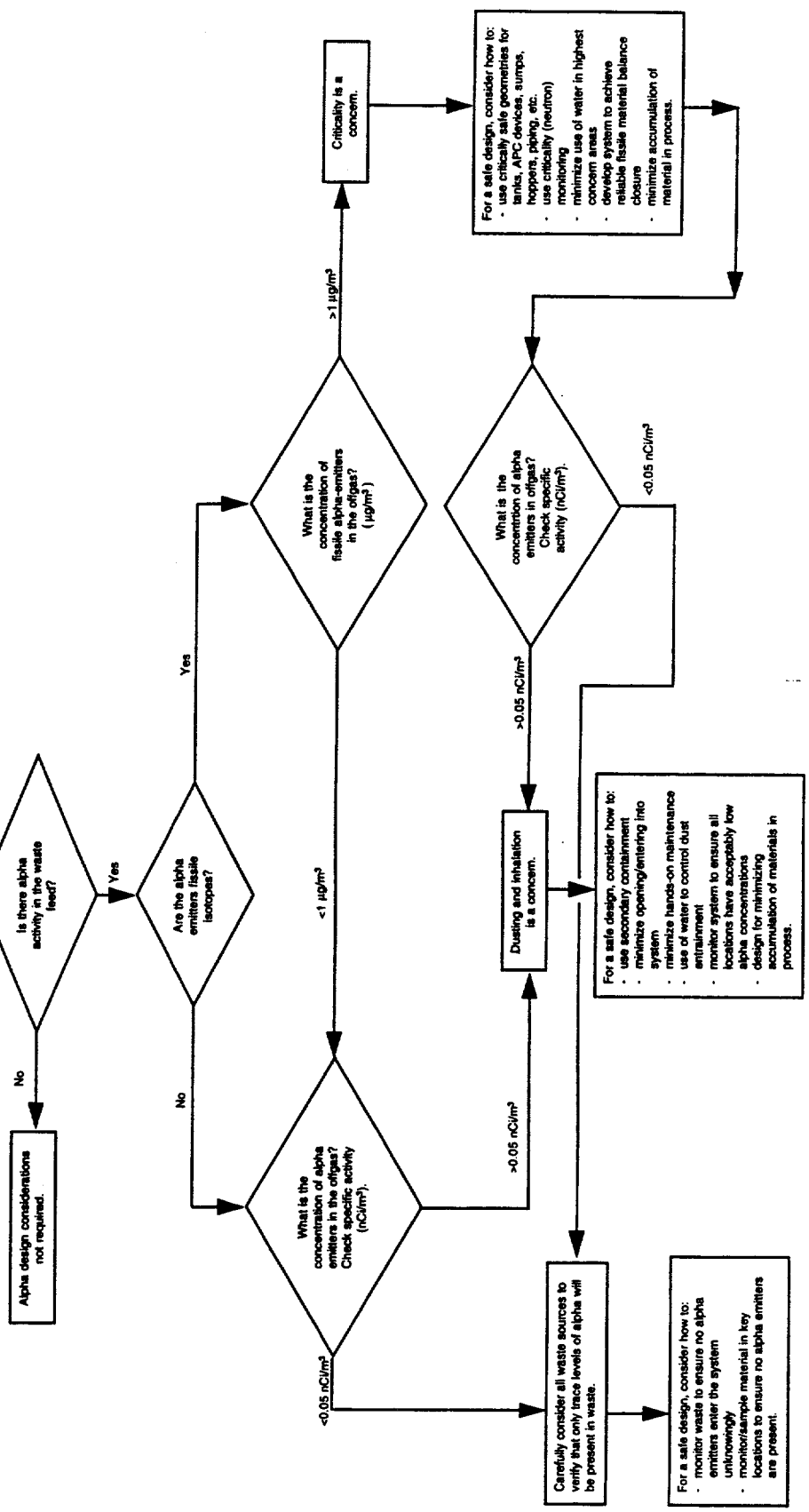


NOTES FOR DESIGN GUIDE 2

1. This design guide is intended to be an iterative process to ensure that incompatible technologies or combinations are not selected. When considering the potential problems that may arise from using different technologies, the order of the pollution control components in the offgas system is important and must be specified to determine whether a problem exists. For example, it may be acceptable to put a wet component downstream from the dry components but unacceptable to put the wet component upstream from the dry components.

2. Although there are several factors that affect the ranking of pollutants according to difficulty to control, for many thermal treatment situations the most difficult pollutant to control will be the particulate, including radionuclides and toxic metals. These pollutants can be difficult to control because of the small size of the particles, particularly those resulting from volatilization. These small particles can blind filtration media and plate out and foul the surfaces of other components. In addition, the small particles are difficult to collect using many of the technologies currently available. Nitrogen oxides are typically moderately difficult to highly difficult to control depending on the concentration of the nitrogen oxides, the ratio of nitric oxide to nitrogen dioxide, and other factors. The easiest pollutants to control from a thermal system are typically acid gases, such as hydrogen chloride and sulfur oxides, and hydrocarbons.

DESIGN GUIDE 3. Technology Selection for Alpha Radioactivity

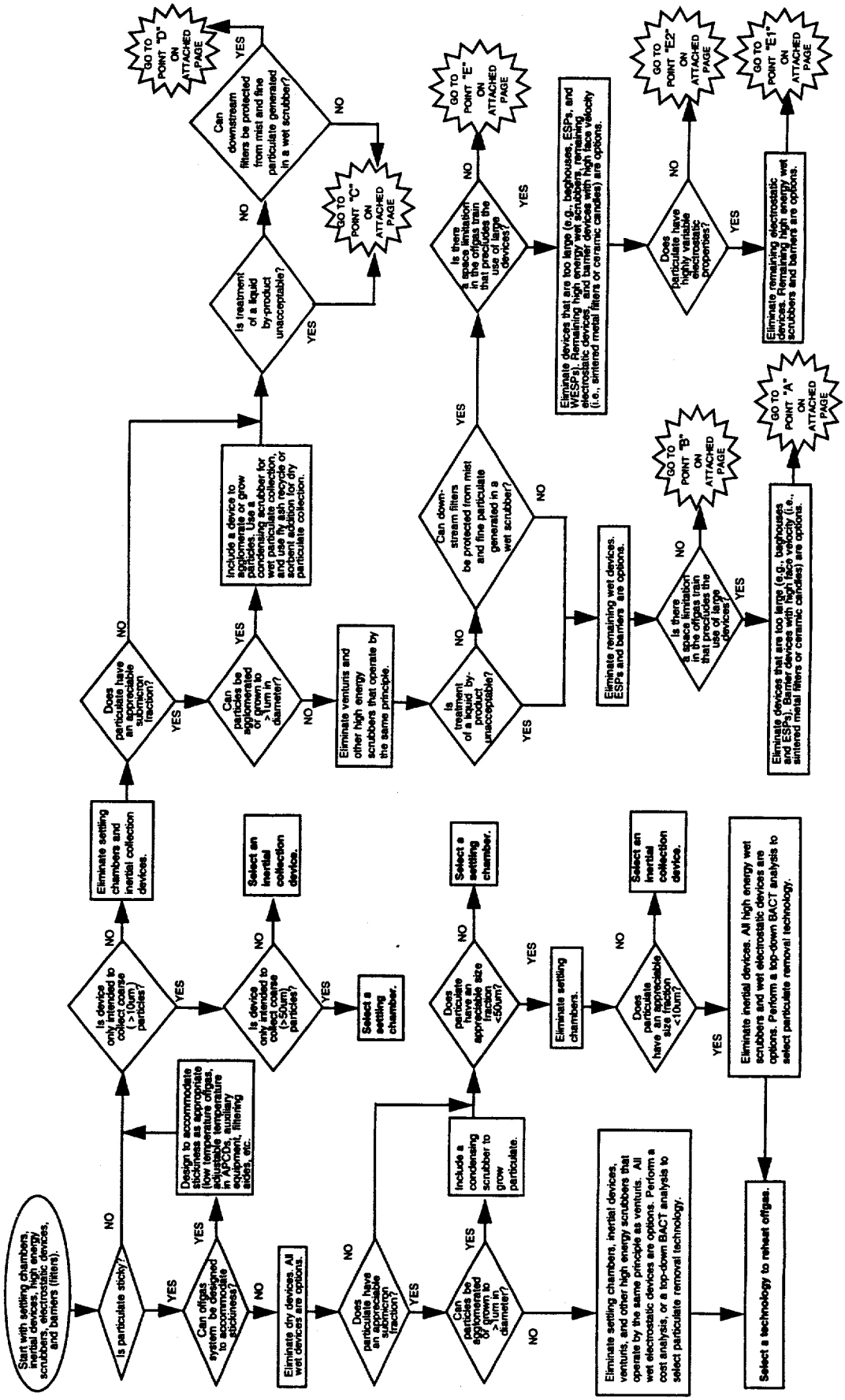


NOTES FOR DESIGN GUIDE 3

1. When evaluating the safety of a component or system for alpha concerns, all interconnections, such as piping and ducting, must be considered.

2. When evaluating the safety of a component or system for alpha concerns, consideration must be given to the potential for buildup of deposits on surfaces such as interior walls and filtration media.

DESIGN GUIDE 4. Technology Selection for Particulate Control



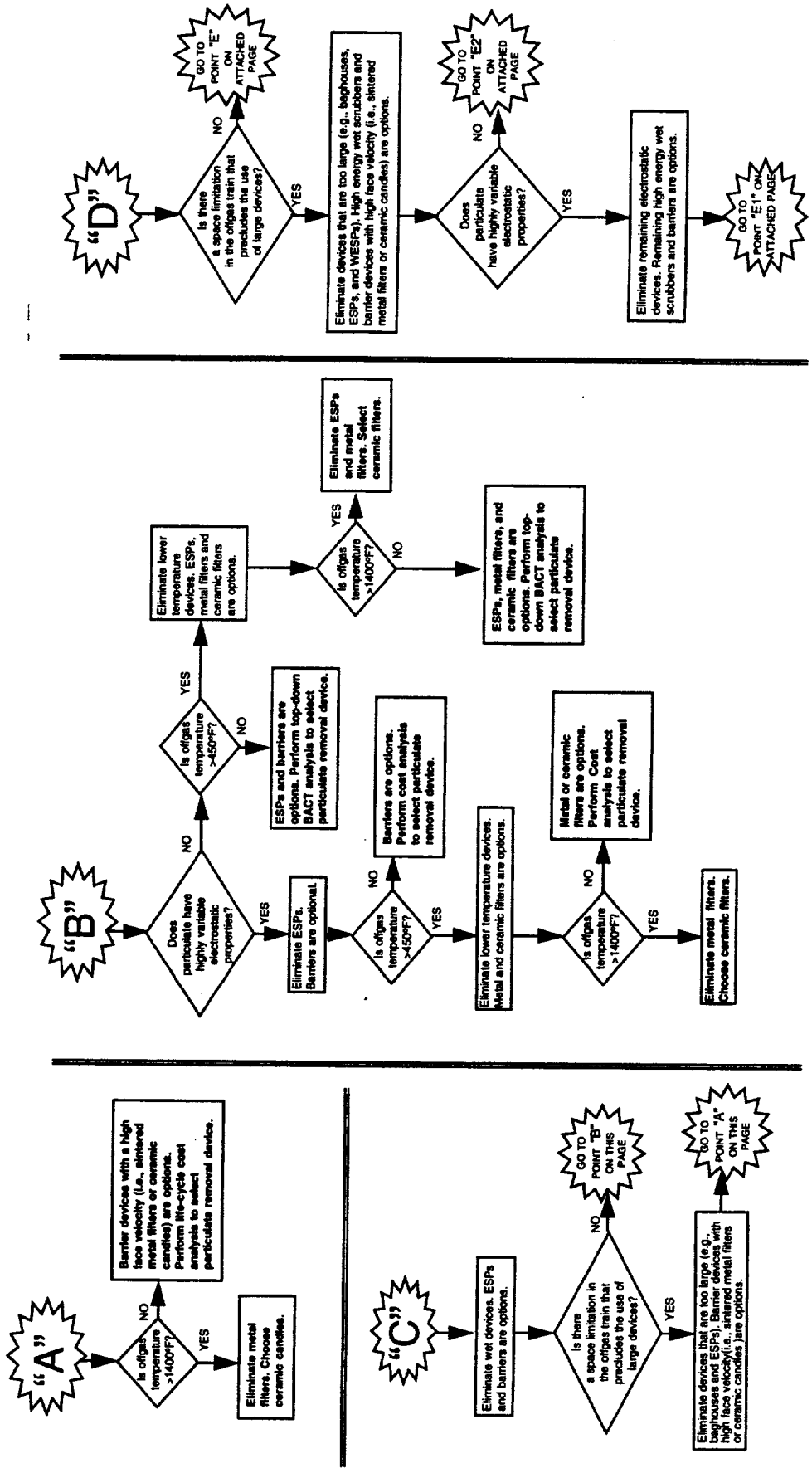
NOTES FOR DESIGN GUIDE 4

1. For mixed waste service, it is assumed that redundant high-efficiency particulate air (HEPA) filters will always be used downstream of the initial particulate collection device. In addition, to provide maximum protection to the HEPA filters, it is further assumed that at least one set of prefilters will be used upstream of the HEPA filters.

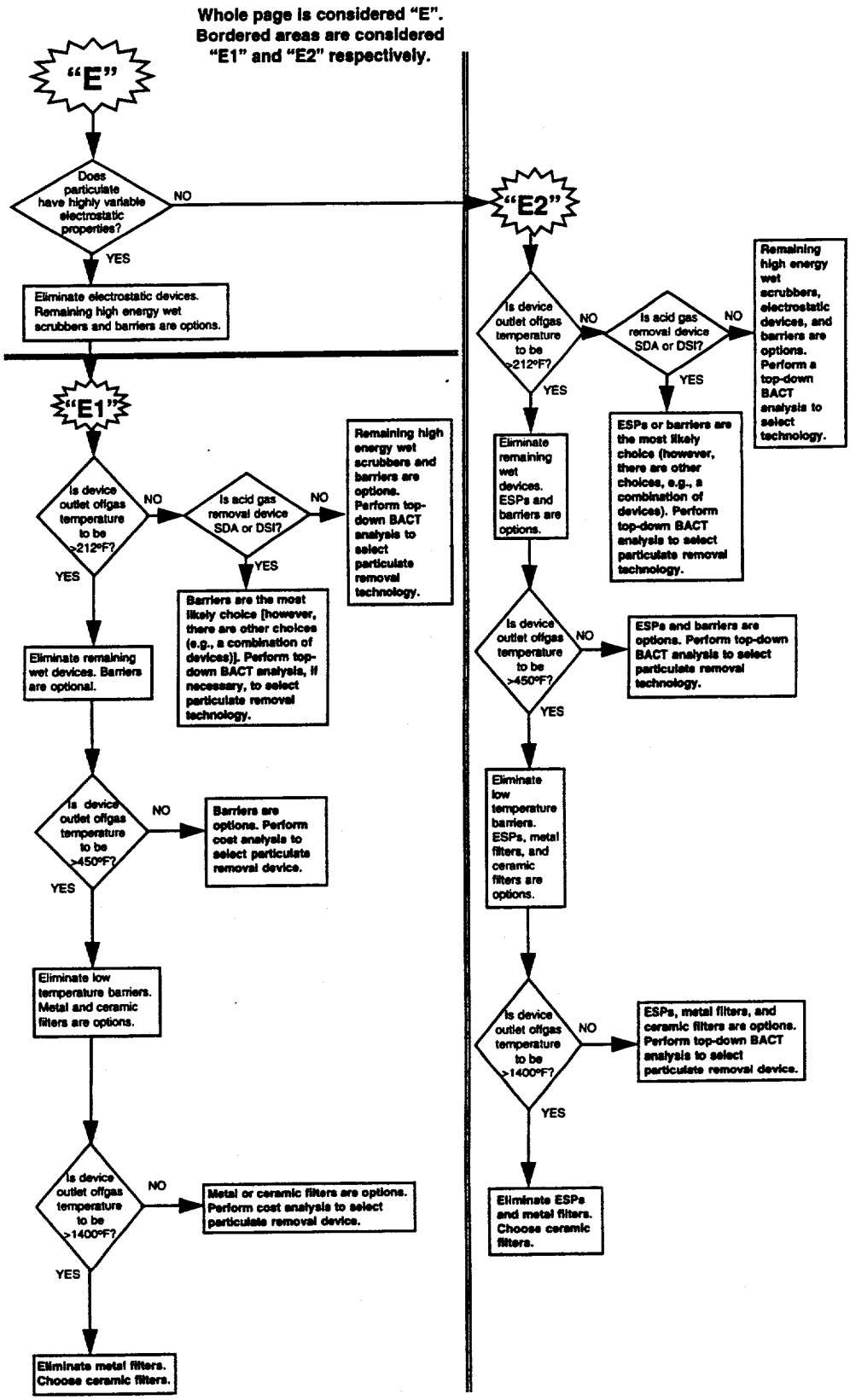
2. There are basically two potential causes of sticky particulate. First, if the particulate is hygroscopic at or below the temperature at which the particulate is collected, water from humid air and/or water formed during combustion can be absorbed into the particulate to form a paste. Second, if the temperature of the offgas is above the ash fusion temperature, the particulate may be adhesive and stick to cooler surfaces.

3. Appreciable quantities of submicron particulate is a potential problem during waste treatment. Fine, submicron particulate is, in general, more difficult to remove from an offgas stream. In addition, this fine particulate can irreversibly penetrate into filtration media, blinding the filter. There is also a concern because the fine particulate is potentially more harmful to humans. Just as with pollution control equipment, the fine particulate can more readily penetrate the body's defenses. In addition, fine particulate from a thermal treatment process tends to have a higher toxic metals mass fraction than larger particles.

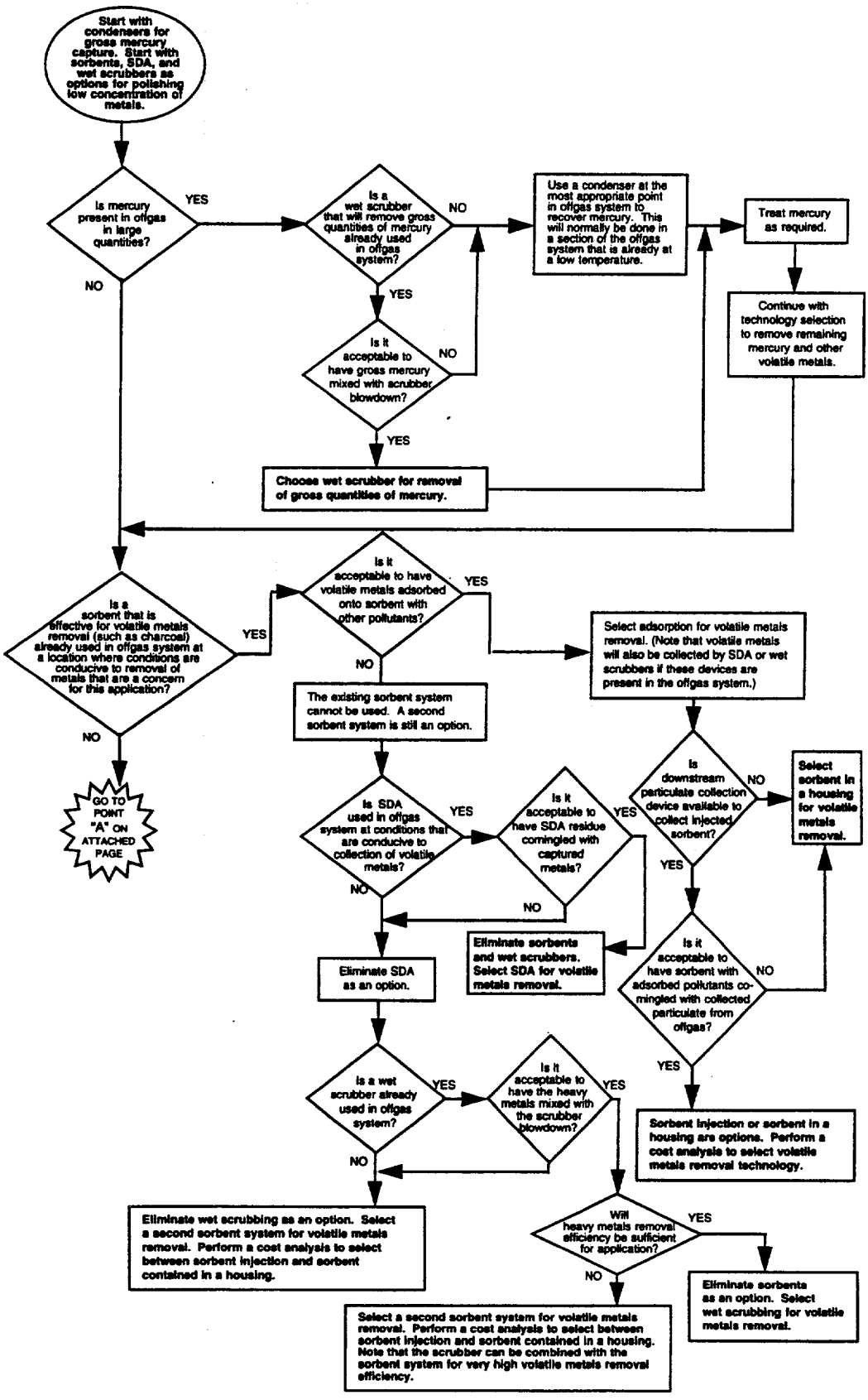
DESIGN GUIDE 4.1. Section A,B,C,&D of Technology Selection for Particulate Control



DESIGN GUIDE 4.2. Section E of Technology Selection for Particulate Control



DESIGN GUIDE 5. Technology Selection for Capture of Volatile Metals



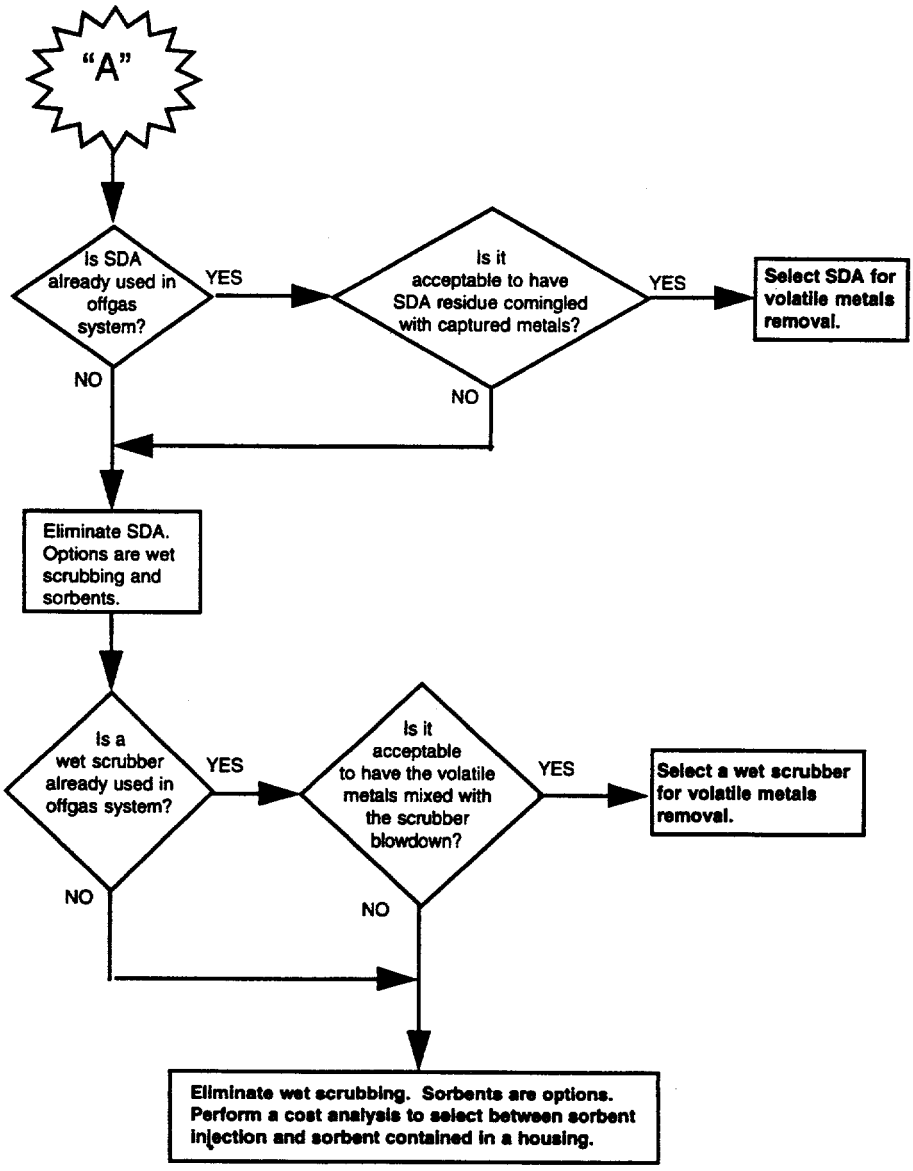
NOTES FOR DESIGN GUIDE 5

1. There are some pollution control technologies for toxic metals that are mainly used in Europe that have been omitted from this design guide because of a lack of information and the resulting uncertainties about the processes. These omissions include sodium sulfide injection and selenium filters. Both of these processes involve handling potentially hazardous materials.

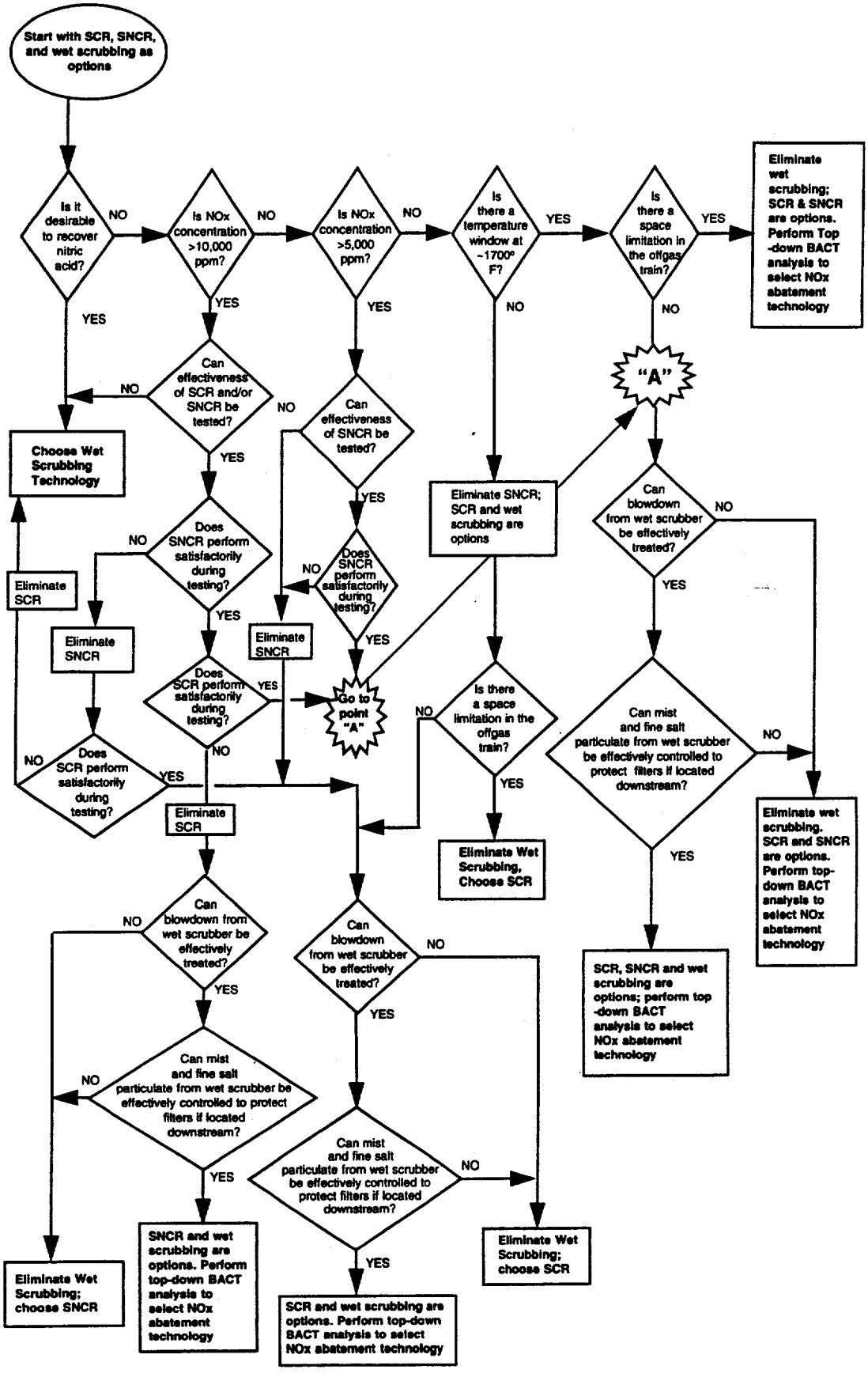
2. Technologies such as dry sorbent injection (DSI), SDA, and activated carbon adsorber will collect toxic metals as well as other pollutants. If these technologies are intended to be used to remove multiple pollutants, the operating conditions of the device must be selected on the basis of the requirements to collect each pollutant.

3. Toxic metals should not be collected on or with the residue from pollution control devices used for other pollutants if this residue is to be burned or if the residue is incompatible with the additional treatments that may be required for the collected toxic metals such as encapsulation.

DESIGN GUIDE 5.1. Section A of Technology Selection for Capture of Volatile Metals



DESIGN GUIDE 6. Technology Selection for NO_X Abatement



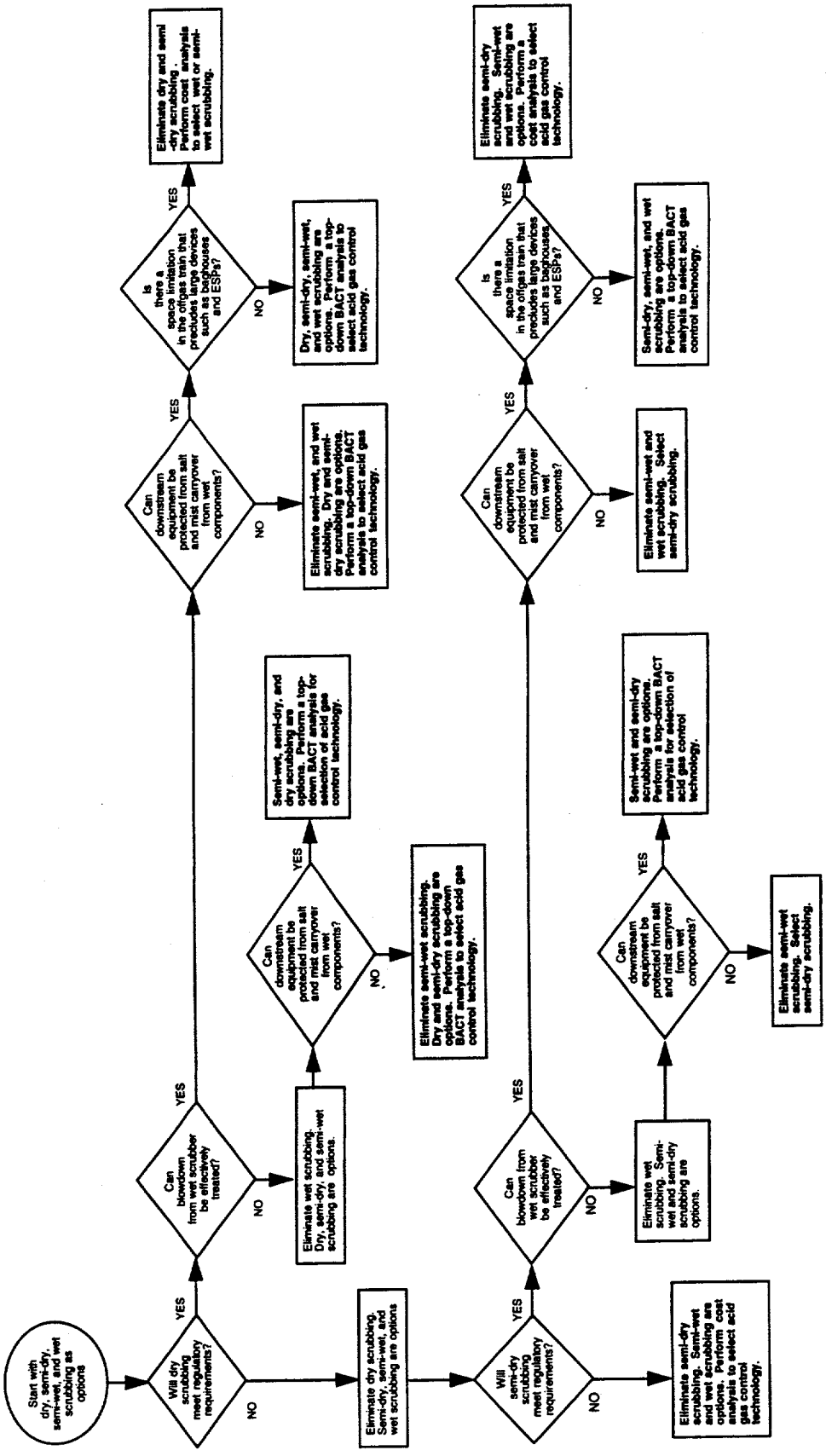
NOTES FOR DESIGN GUIDE 6

1. Selective catalytic reduction (SCR) provides a high NO_x removal efficiency at a moderate cost in comparison to other NO_x abatement technologies. SCR has lower ammonia slip in comparison to selective noncatalytic reduction (SNCR); however, ammonia by-products can foul surfaces in the offgas system. Catalyst poisoning can also be a problem, and the spent catalyst is a secondary waste stream.

2. SNCR provides a moderate removal efficiency but, in general, has lower costs than other NO_x abatement technologies. SNCR does not generate a secondary waste stream, and there is no catalyst to worry about poisoning or fouling. SNCR has the problem of ammonia by-products fouling surfaces in the offgas system. SNCR has higher ammonia slippage than SCR.

3. Wet scrubbers used for NO_x removal have the highest removal efficiencies but also have higher costs. Nitric acid can be generated as a by-product if there is a need for nitric acid. If there is no need for nitric acid, then there is a liquid secondary waste that must be treated. This not only complicates the process but adds to the cost.

DESIGN GUIDE 7. Acid Gas Control



NOTES FOR DESIGN GUIDE 7

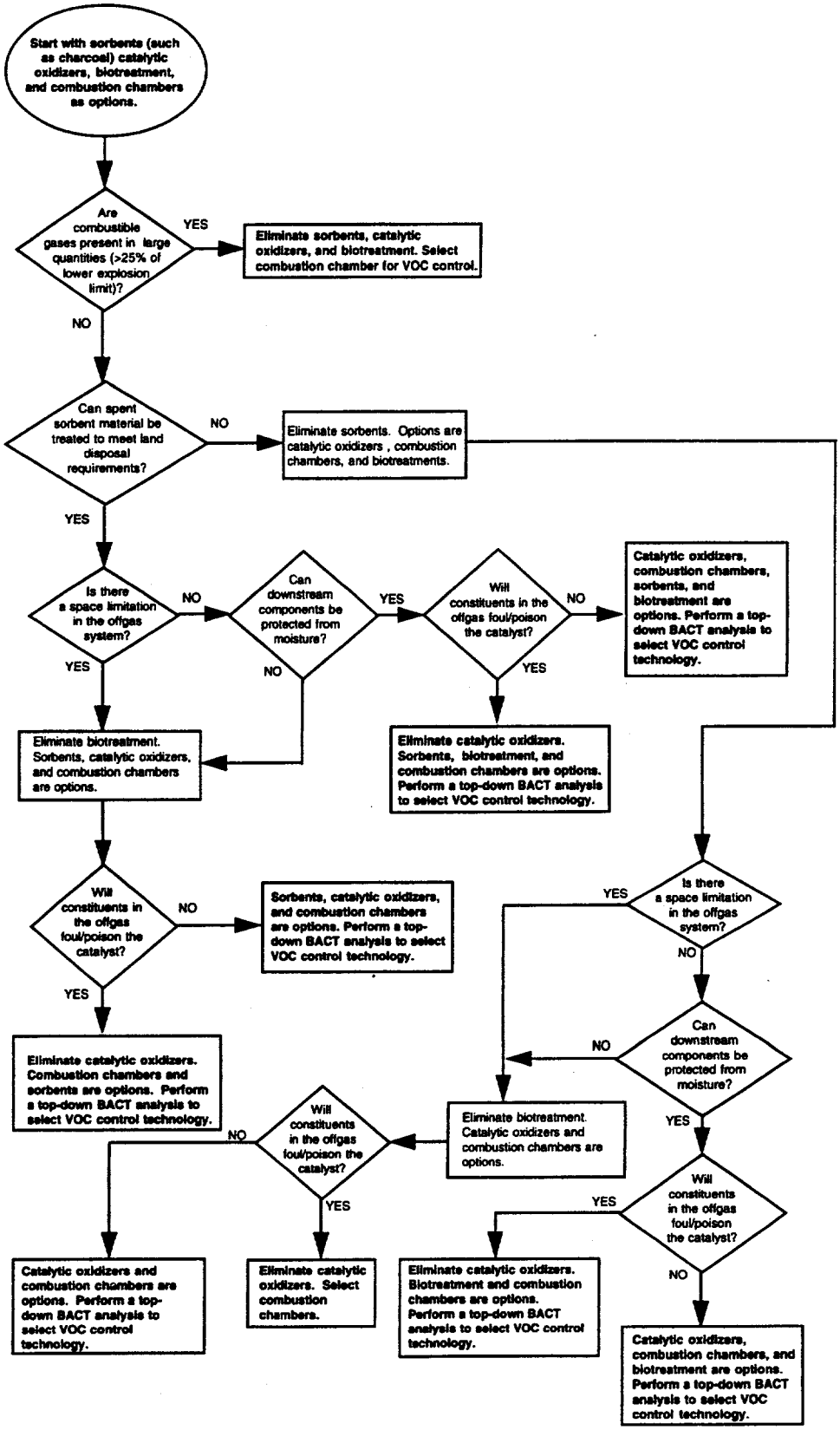
1. Wet scrubbing has the highest acid gas removal efficiency and is most capable of handling spikes or excursions of acid gas concentration. Wet scrubbing has the high utilization of the scrubbing reagent and therefore results in the lowest generation of secondary waste. However, the secondary waste that is generated is a liquid and may require some extra treatment. Wet scrubbing can generate a wet mist and fine particulate as the mist dries. The mist and the particulate can be very detrimental to the performance of downstream equipment and may even require additional equipment. Flooding and fouling in the scrubber can also be a problem.

2. Semidry scrubbing refers to SDA technology. This technology has good acid gas removal efficiency and produces a dry secondary waste. Reagent utilization is not as high as wet scrubbing or semiwet scrubbing but is higher than dry scrubbing. SDA will also serve to cool the offgas and has good particle agglomeration capabilities. SDA does require a particulate collection device, but this can be the same device that is used to collect particulate from the waste treatment unit as long as it is acceptable to mix the particulate from the waste treatment unit and the SDA residue. Because of the need for a particulate collection device and the large reactor vessel necessary to dry the spray, semidry scrubbing requires a significant amount of space in comparison to wet or dry scrubbing.

3. Semiwet scrubbing is basically the same concept as wet scrubbing except that the liquid blowdown is dried in either an SDA located upstream of the wet scrubber or in some auxiliary equipment. When combined with an SDA, the highest reagent utilization is obtained, good volatile metal removal is obtained, and additional cooling equipment is not required. This concept does require a lot of space in comparison to other acid gas removal technologies.

4. Dry scrubbing has the lowest acid gas removal efficiency but is typically very low cost in comparison to other acid gas control technologies. In the simplest form, an alkali reagent is added upstream of a baghouse as a precoat for the bag filters. In its more complicated form, the alkali reagent is recycled through the process, and a large reactor vessel is used in addition to the particulate collection device. This technology has the lowest reagent utilization and therefore generates more secondary waste than other acid gas technologies. One of the advantages to dry scrubbing is that the secondary waste is already dry. Dry scrubbing is also advantageous in that it has good particulate agglomeration capabilities.

DESIGN GUIDE 8. Technology Selection for VOC Control



NOTES FOR DESIGN GUIDE 8

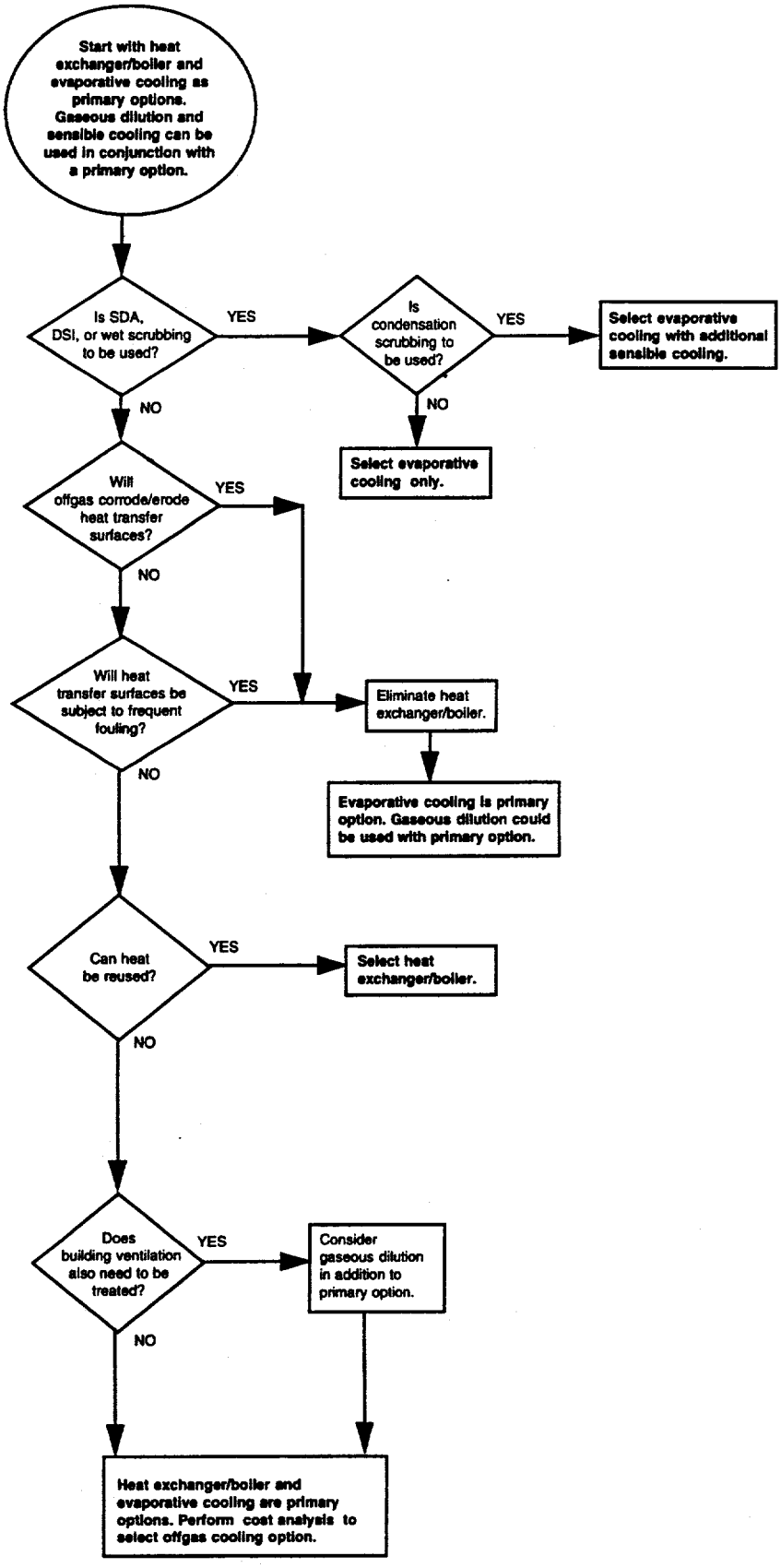
1. For thermal waste treatment processes, it is assumed that a properly designed secondary combustion chamber is in use. In such a case, additional hydrocarbon pollution control equipment would not be necessary. However, if this is not the case, this design guide can be used for the selection of pollution control equipment for hydrocarbons.

2. It is assumed for this design guide that the pollution control system is needed for a waste destruction process. Therefore, it is assumed that recovery of the hydrocarbons for reuse is not desirable. As such, solvent recovery technologies are not considered in this design guide.

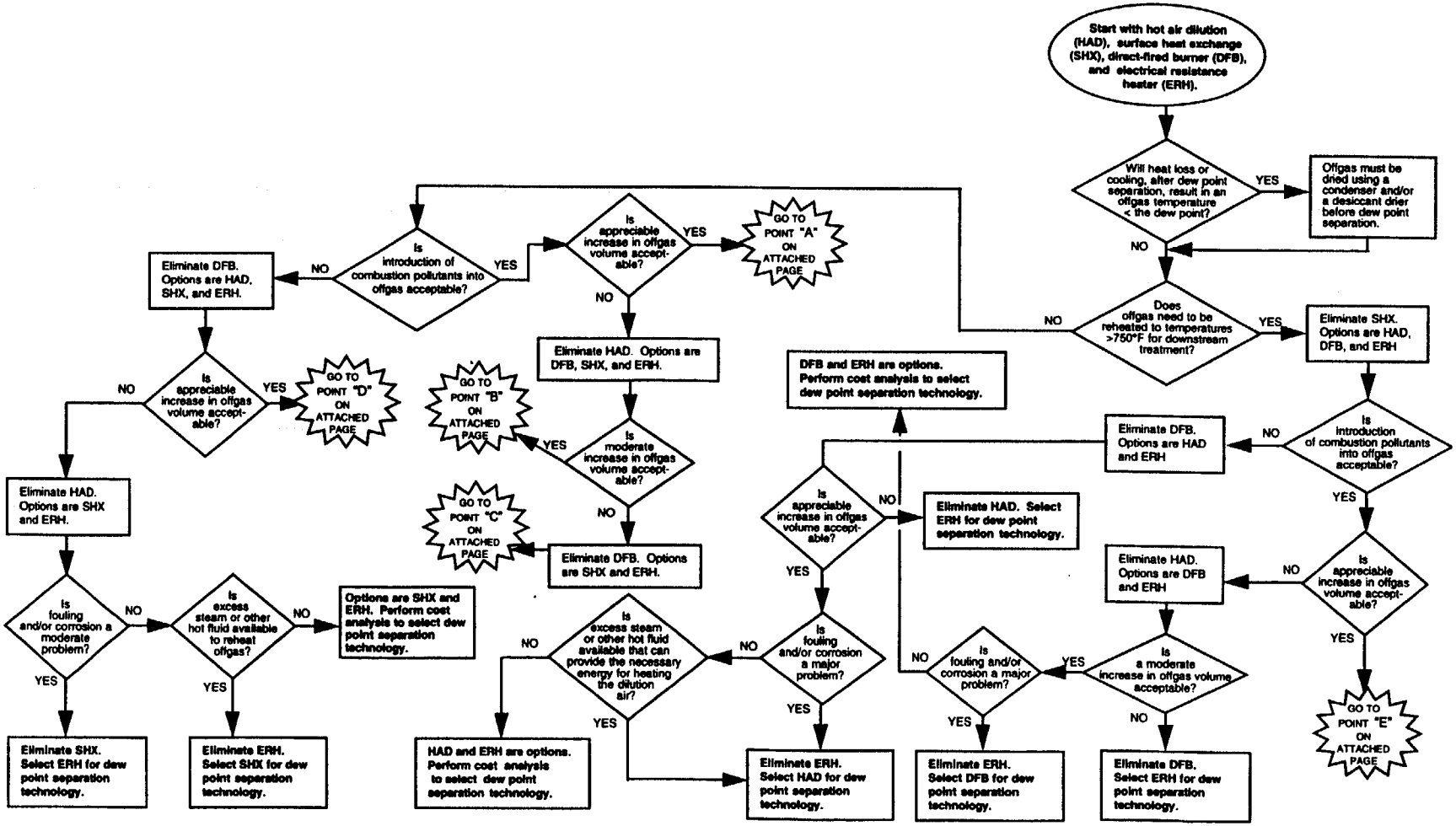
3. In very general terms for hydrocarbon removal from a gas stream, activated charcoal is not used if the hydrocarbon concentration is greater than ~1% to 3% of the lower explosion limit unless the carbon is regenerated; catalytic oxidizers are used when the hydrocarbon content is less than ~25% of the lower explosion limit; thermal oxidizers are used when the hydrocarbon content is greater than ~25% of the lower explosion limit. These comments should not be considered absolute rules. For many situations, the process can be engineered to use any of these technologies regardless of the hydrocarbon concentration.

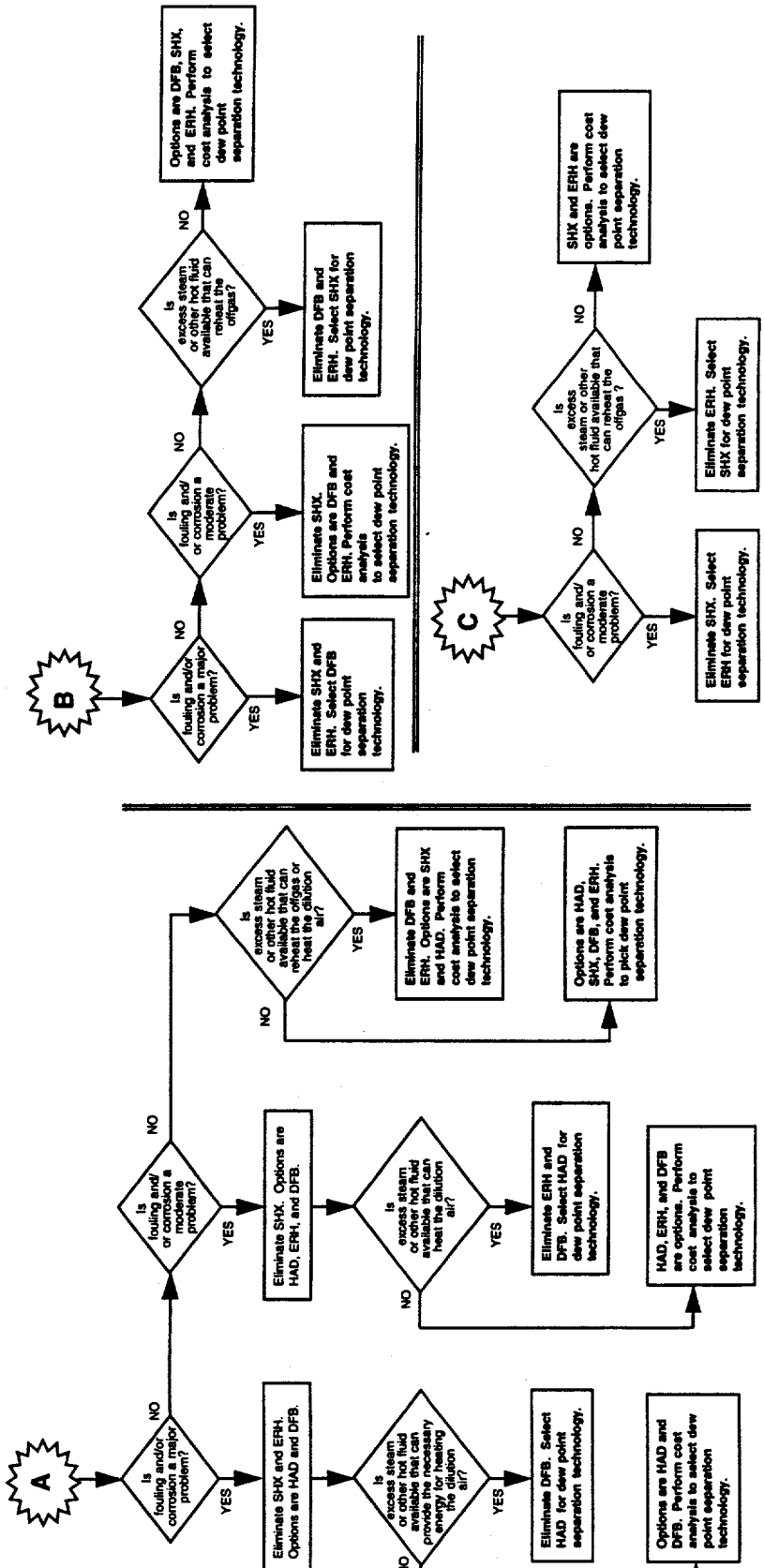
4. Additional factors that affect the performance of activated carbon for hydrocarbon removal include the volumetric flow rate of the gas stream, the temperature of the gas stream (i.e., how close the gas stream temperature is to the dew point of the hydrocarbons in the gas stream), concentration of hydrocarbons in the gas stream, concentration of other adsorbable compounds in the gas stream, type of hydrocarbon species in the gas stream, and the quality of the carbon.

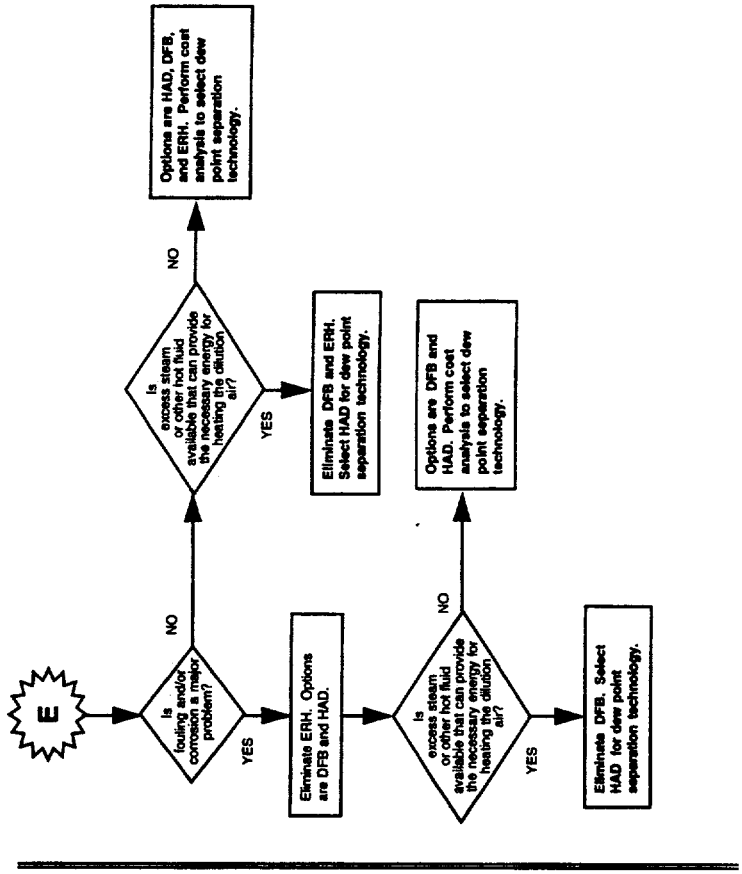
DESIGN GUIDE 9. Technology Selection for Offgas Cooling

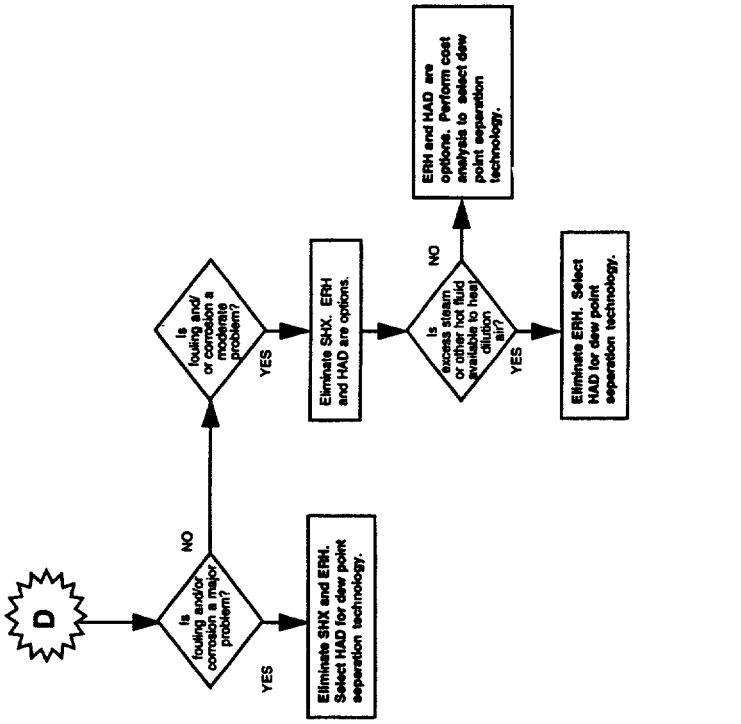


DESIGN GUIDE 10. Technology Selection for Dew Point Separation (Offgas Reheating)




A
Is fouling and/or corrosion a major problem?
YES
Eliminate SHX and ERH. Options are HAD and DFB.
Is steam or other hot fluid available that can provide the necessary energy for heating the dilution air?
YES
Eliminate DFB. Select HAD for dew point separation technology.
NO
Options are HAD and DFB. Perform cost analysis to select dew point separation technology.
NO
Is fouling and/ or corrosion a moderate problem?
YES
Eliminate SHX. Options are HAD, ERH, and DFB.
Is excess steam or other hot fluid available that can heat the dilution air?
YES
Eliminate ERH and DFB. Select HAD for dew point separation technology.
NO
HAD, ERH, and DFB are options. Perform cost analysis to select dew point separation technology.
NO
Is excess steam or other hot fluid available that can reheat the dilution air?
YES
Eliminate DFB and ERH. Options are SHX and HAD. Perform cost analysis to select dew point separation technology.
NO
Options are HAD, SHX, DFB, and ERH. Perform cost analysis to pick dew point separation technology.
B
Is fouling and/or corrosion a major problem?
YES
Eliminate SHX and ERH. Select DFB for dew point separation technology.
NO
Is fouling and/ or corrosion a moderate problem?
YES
Eliminate SHX. Options are DFB and ERH. Perform cost analysis to select dew point separation technology.
NO
Is excess steam or other hot fluid available that can reheat the offgas?
YES
Eliminate DFB and ERH. Select SHX for dew point separation technology.
NO
Options are DFB, SHX, and ERH. Perform cost analysis to select dew point separation technology.
C
Is fouling and/ or corrosion a moderate problem?
YES
Eliminate SHX. Select ERH for dew point separation technology.
NO
Is excess steam or other hot fluid available that can reheat the offgas ?
YES
Eliminate ERH. Select SHX for dew point separation technology.
NO
SHX and ERH are options. Perform cost analysis to select dew point separation technology.


E
Is fouling and/or corrosion a major problem?
NO
YES
Is excess steam or other hot fluid available that can provide the necessary energy for heating the dilution air?
NO
YES
Options are HAD, DFB, and ERH. Perform cost analysis to select dew point separation technology.
Eliminate DFB and ERH. Select HAD for dew point separation technology.
Eliminate ERH. Options are DFB and HAD.
Is excess steam or other hot fluid available that can provide the necessary energy for heating the dilution air?
NO
YES
Options are DFB and HAD. Perform cost analysis to select dew point separation technology.
Eliminate DFB. Select HAD for dew point separation technology.


D
Is fouling and/or corrosion a major problem?
NO
YES
Is fouling and/ or corrosion a moderate problem?
YES
Is excess steam or other hot fluid available to heat dilution air?
NO
YES
Eliminate ShX and ERH. Select HAD for dew point separation technology.
Eliminate ShX. ERH and HAD are options.
ERH and HAD are options. Perform cost analysis to select dew point separation technology.
Eliminate ERH. Select HAD for dew point separation technology.

4.4 ADDITIONAL RECOMMENDATIONS FOR MIXED WASTE APC SYSTEMS

The following Design and Operational recommendations stem from the Offgas TSG design process.

1. A need exists to implement a preventative maintenance and inspection program for all equipment in a mixed waste treatment facility (e.g., monitor vibrations in fans to anticipate failure).

2. A need exists to determine the best way to handle/treat evaporated solids from an SDA.

3. LDRs for final waste form are important—it is important to know how to treat salts and radionuclides.

4. The highest quality materials of construction should be used in all APCE. These choices should be formalized and presented in terms of initial cost vs avoided costs. The choices will be driven by maintainability, reliability, lifetime, and safety requirements. A corrosion monitoring and testing program using standard American Society for Testing and Materials (ASTM) procedures should be instituted. Power plants, chemical plants, etc., do this routinely using a variety of methods.

5. There is a possible research need of tracking plumes and coordinating an evacuation upon emergency. Rocky Flats has done much work in this area.

6. A level of radionuclides (e.g., ^{239}Pu) in the waste feed stream should be able to be translated to a level coming into the APCE. Throughput and accumulation are important questions, as well as radionuclide volatilization and partitioning to the bottom ash and flyash. Carryover is a function of the waste destruction technology and the feed type.

7. Fissile-contaminated solids need to be cleaned from a scrubber, either in place or by removing and replacing components. If component removal is the option, we need a modular design. This need is strongly tied to the level of radionuclides in the APCE; if the level is lower, then these issues are not as important for optimized design. Some ideas are to minimize buildup: using conical bottoms on sumps and tanks to avoid criticality; using angled tanks, pencil tanks, etc., for operational ease. Easy inspection, using neutron monitors, is also important. Another solution is to backflush with acid to clean the scale, but then materials of construction must be able to withstand the acid wash.

8. Westinghouse Savannah River Corporation (WSRC) and the Idaho National Engineering Laboratory (INEL) have modified waste streams to minimize the chlorine and other "bad actors" in the waste by finding a suitable replacement for polyvinyl chloride (PVC) and other waste precursors that form acid gases. A similar program has been developed in the commercial sector for low-level power plant waste, waste from commercial laboratories, fuel fabricator's waste, etc.

9. The availability of APCE should be maximized (90% is desirable). However, facility shutdowns for maintenance, accountability, etc., need to be accounted for, making 50% availability more realistic. Availability is also a function of the number of shutdown interlocks. Industry policy is to design modular units with 25% to 50% excess modules.

If six modules are needed to handle all the flow, build eight so that two can be shut down for maintenance without shutting down the process.

10. The turndown requirements for the waste destruction process need to be known.

11. Methods to control temperature should be considered. Addition of air is not necessarily the best way to do this.

12. Facility designs should consider new technologies. This ensures that recent advancements and improvements to old technologies are incorporated. For example, verifying advanced materials of construction and process control equipment are used regardless of the pollution control technology selected. This same concept applies to other improvements in process equipment (i.e., mechanical seals, pumps, etc.).

13. Generation of secondary waste should be considered (i.e., spent sorbents, SCR catalysts, filter bags, etc.) This is especially important in "hot" applications.

14. Start-up procedures could be critical in the selection of APCE. For some industrial processes, it is necessary to bypass some of the APCE until the furnace is up to temperature. This would not be acceptable in a mixed waste application and would preclude use of some types of equipment.

15. A need exists to match the conservatism in the APC design with the degree of uncertainty in waste feed characterization.

16. When a wet system with blowdown is considered, the waste water discharge limits must be determined, especially for soluble radionuclides such as cesium and strontium.

In addition to selecting the optimum second-stage destruction and pollution control equipment, there are technical issues related to the design and operation of a waste treatment facility. Some of these issues that have already been identified include the following:

- The use of safety relief vents on combustion systems.
- The use of one offgas train for multiple waste processing units.
- Addressing criticality control in pollution control equipment.
- How much redundancy should be incorporated and where.
- Operational parameters in the offgas equipment that promote dioxin and furan formation.

4.5 SUMMARY OF COMMERCIALLY AVAILABLE APC SYSTEM DESIGN TOOLS

A survey was conducted to determine how offgas system vendors, A/E firms, and industry support organizations conduct process designs. We found one example of a design guide used in industry.

Electric Power Research Institute State-of-the-Art Power Plant.

The Electric Power Research Institute (EPRI) has developed a process that provides computer assistance for APC system design and technology selection. This design tool is called State-of-the-Art Power Plant (SOAPP).

Some of the goals of the SOAPP project reflect what we think should be our goals, such as reduced capital costs (20% less than current typical costs); fast-track construction; improvements in plant operability, reliability, and performance; integration of advanced plant controls, performance monitors, and diagnostics; and compliance with prospective future environmental regulatory requirements. It is our understanding that elements of the software program help to achieve these goals.

The EPRI project team is supplemented by a vendor advisory committee of ~70 equipment manufacturers and vendors who are responsible for the completeness and timeliness of information on the technologies and design concepts.

The software is divided into technology modules. The modules present an overview of the basic principles of a process, along with detailed information on two to eight alternate technologies. Interactive equipment sizing, costs, and construction schedules are provided for each of the alternative technologies as a function of up to nine sensitivity parameters. Technology modules involve numerous technologies, but the modules of interest to us include ESPs, baghouses, wet and dry flue gas desulfurization (FGD) systems, SCR, SNCR, combustor NO_x control, and CEMs. The computer programs are user friendly and make extensive use of some powerful graphics.

The project is developing some base-case conceptual designs that include all of the advancements that have been previously described. This base-case can then be tailored to meet the specific needs of individual sites. In addition to the integration of the appropriate advanced technologies, the base-case SOAPP conceptual designs are being structured to fully support advanced construction techniques.

4.6 RECOMMENDATIONS FOR DEVELOPMENT OF DESIGN GUIDES

If developed beyond its current stage, the design guide could serve the following functions:

1. For a given thermal treatment technology, the guide could discuss the relationship between waste feeds and pollutant species in the offgas.

2. The design guide could include selection criteria for thermal treatment technology for a given waste stream.

3. The guide could expand on the current "decision tree" format by making the logic more rigorous and perhaps by even entering the methodology onto a computer. Its function should remain focused on issues unique to mixed waste treatment that are <u>not</u> found in classical chemical engineering textbooks on unit operations design.

4. Technology "holes" would continue to emerge from the analysis used to develop the guides. Promising emerging technologies and deficiencies in existing technologies would continue to be identified.

5. The mixed waste treatment waste stream categories and process flowsheets could be used to develop specific, integrated APC flowsheets as examples to illustrate the guide's methodology. These design examples would verify the guide's soundness for specific situations.

6. If developed in a general way, but covering specific cases of waste composition and thermal treatment technologies, the guide could be pertinent to designers well into the future. Emerging proven technologies could be continually incorporated into the guide. The manual could continue to serve as a useful guide instead of a document that only satisfies a current need.

5. CHARACTERIZATION REQUIREMENTS FOR OFFGAS FROM MIXED WASTE TREATMENT

5.1 BACKGROUND

The following guidelines for characterization of process parameters are applicable to all offgas systems used on mixed waste treatment and stabilization processes. As such, these guidelines can be used to provide direction in offgas monitoring and characterization when designing test programs for alternative mixed waste treatment technologies. However, these guidelines are mainly intended for facilities that are already operational. In addition, these guidelines focus on continuous monitoring and sampling. Periodic or noncontinuous sampling and analyses (e.g., grab samples) are not discussed.

The monitoring and characterization requirements discussed in this TASR are driven by federal regulations, safety concerns, and process control. Section 5.2 addresses parameters that require characterization and monitoring for regulatory compliance. Many of these parameters are also monitored for safety reasons and for process control. Section 5.3 discusses the remaining monitoring and characterization needs of an offgas system for control and/or safety purposes. These parameters are not normally monitored for regulatory compliance; however, on a case-by-case basis, permit writers can include them in the permit. Section 5.4 describes state-of-the-art radionuclide monitors and associated public and regulatory issues.

Section 5.5 discusses the waste assay requirements as they relate to pollutant generating materials. Although these assay requirements pertain to the waste prior to treatment, they are briefly discussed here because they are required, in most cases, for regulatory compliance and because the species to be identified in the assay are precursors to pollutants that must be monitored in the offgas. In some situations, it may be more viable to determine the total quantity of precursor in the waste stream and use this value to demonstrate that even if all of the pollutant formed were released, the emissions would still meet regulatory requirements.

Note that there are additional waste monitoring and characterization requirements in addition to those discussed in Sect. 5.1. Although these other monitoring and characterization requirements can impact the selection and performance of offgas pollution control equipment, these requirements are not discussed in this document since the parameters involved are primarily considered to be process parameters for other areas such as the waste feed system or the waste treatment system.

5.2 MAJOR SPECIES REQUIRING CHARACTERIZATION

5.2.1 Oxygen (O_2)

Continuous monitoring is required by regulations to correct carbon monoxide concentrations from the thermal treatment unit to a standard basis of 7% oxygen by volume. Oxygen continuous monitoring is also necessary for control purposes and will be tied into the thermal treatment unit control system. Regulations allow the O_2 monitor to be located anywhere in the offgas system between the secondary combustion chamber (SCC) exit to the stack, though preferably as close as possible to the SCC exit. For combustion control purposes, the O_2 monitor should be located at the SCC exit. Monitoring conditions are as follows:

- O_2 range from 0 to 25% (air is 21% oxygen by volume but the expanded range is required by regulations);
- temperature range from ambient to ~2200°F;
- depending on monitor location and offgas equipment, normal operating pressure could range from about −100 in. W.C. to atmospheric pressure (some positive pressure surges from upset conditions in the thermal treatment device are expected);
- offgas environment is generally oxidizing with "puffs" of a reducing environment expected;
- offgas will contain acid gases such as HCl, HF, SO_2, SO_3, and nitrogen oxides (NO_x) at levels generally below a few hundred parts per million (ppm) but could be as high as 10% for certain wastes and certain thermal treatment devices;
- particulate in the form of inorganic oxides, inorganic salts, carbon (soot), and elemental species will be present at loadings that can exceed a concentration of 5 grains per dry standard cubic foot (5 grains/dscf).

The current state-of-the-art for oxygen monitors is analysis of an extractive sample or the use of a probe for an in situ analysis. Because of the harsh conditions in the offgas at the SCC exit, monitors at this location are subject to frequent maintenance and calibration.

5.2.2 Carbon Monoxide (CO)

Continuous monitoring is required by regulations to determine the amount of CO emitted and as an indication of the combustion efficiency of hydrocarbons. Although the CO monitor is not normally tied into the thermal treatment unit control logic, it is frequently used by operators as an indicator of changes that need to be made or how well changes that have been made affect operations. As with the O_2 monitor, the CO monitor can be located anywhere in the offgas system but near the SCC exit is desirable from both a regulatory and an operational standpoint. Monitoring conditions are as follows: CO content ranges from essentially 0 CO to over 1000 ppm with the normal operating range between 40–100 ppm. The EPA requires a dual-range CO monitor with ranges from 0–200 ppm and 0–3000 ppm. All other conditions are the same as those for the O_2 monitor.

5.2.3 Carbon Dioxide (CO_2)

Monitoring is required when burning polychlorinated biphenyl (PCB) liquids or waste contaminated with PCB liquids. The CO_2 is not required to be continuous but must provide a data point at least every 15 min. The CO_2 concentration is required to be determined so that a combustion efficiency can be calculated. As with the CO and O_2 monitor, the CO_2 monitor can be located anywhere in the offgas train. The conditions encountered in the offgas system would depend on the location of the monitor, ranging from the harsh conditions at the SCC exit to the significantly milder, but potentially wet, conditions at the stack. Normally, when burning PCB waste, the CO_2 content can vary from essentially 0% to ~20%. If, however, the waste matrix is nearly pure carbon, such as contaminated charcoal or graphite, and the oxidant is pure oxygen rather than air, then the CO_2 content in the offgas would approach 100%.

5.2.4 Radionuclides

Monitoring at the stack is required for regulatory purposes. Current regulations do not require real-time monitoring, but the offgas must be continuously sampled. A continuous real-time monitor would be ideal. One of the important improvements that could be made in radionuclide monitoring is the development of monitors that can detect radionuclides that are converted to gases when thermally treated (e.g., tritium that is converted to gaseous water, ^{14}C that is converted to carbon dioxide, and radioiodine that is converted to elemental iodine or an organic iodide such as methyl iodide). Current methods to detect these nuclides rely on absorption or adsorption with media that also collects other combustion products and are rapidly spent.

At a minimum, nuclide monitoring should include a beta/gamma scan down to picocurie levels. Depending on the type of waste and local/regional regulatory requirements, it may be necessary to monitor for alpha and difficult to control nuclides such as tritium, ^{14}C, radioiodine, and noble gases. Since alpha-emitting radionuclides are usually attached to particulate, real-time continuous alpha monitoring could probably be performed between HEPA filters in series and serve essentially as an upset or filter breakthrough monitor. The downstream HEPA filter(s) would provide additional protection should an upstream filter fail. Conditions in the stack will be substantially milder than at the SCC exit: temperature will range from about 150–500°F; system pressure will be slightly below or above atmospheric; acid gases will be 100 ppm or less downstream of a scrubber; particulate loadings will be below 0.015 grains/dscf (significantly lower than this figure downstream of HEPA filters); and the offgas may be saturated with moisture depending on the type of APCE used.

5.2.5 Hydrochloric Acid (HCl)

Continuous emissions monitoring at the stack is not required by regulations but is recommended for process control purposes, particularly in dry and semidry offgas treatment systems for alkali reagent addition. Conditions will be the same as for radionuclide monitoring.

5.2.6 SO_x and NO_x

Continuous monitoring at the stack may be required if prevention of significant deterioration (PSD) concerns exist. Low sulfur levels in the waste and the small size of thermal treatment unit will likely preclude the need for SO_x CEM. An NO_x CEM may be needed because of the high levels of nitrogen in some waste feed streams and may also be needed because of the thermal NO_x generated by the thermal treatment device. Where waste with a high nitrogen content is being treated, an NO_x abatement technology will be required and likely an NO_x CEM as well. Monitors should be able to monitor levels as high as 10,000 ppm in an abatement equipment failure situation. The conditions in the stack will be the same as for radionuclides.

5.2.7 Particulates

Monitoring in real-time will not likely be required if redundant HEPA filters are used. Stack particulate sampling, including that for radionuclides attached to particulate, should be conducted at isokinetic conditions. Under normal operation, strictly from a technical standpoint, isokinetic sampling downstream of HEPA filters would not be required. However, should the HEPA filters fail, allowing larger particulate to be emitted, then isokinetic sampling may be required to measure the actual particulate emission. Some upstream particulate removal subsystems are efficient enough not to require isokinetic sampling, for example, free jet scrubbers and high-efficiency mist eliminators (HEMEs).

5.2.8 Heavy (Toxic) Metals

Although current EPA regulations do not require monitoring for heavy metals from hazardous waste incinerators, boilers and industrial furnaces burning hazardous waste are required to determine the emissions of heavy metals using one of three optional approaches. To standardize the requirements of all hazardous waste combustion facilities and to protect the public and the environment, this same three-tier approach is being enforced (at the regional level) for hazardous waste incinerators. Under the three-tier approach, the facility must either determine what the heavy metals content is in the waste feed or what the heavy metals content is in the offgas at the stack. Ideally, heavy metals monitoring would be done on a continuous, real-time (or near real-time) basis, but continuous extractive sampling, followed by analysis in a laboratory, is currently an accepted method. For a future mixed waste treatment facility, continuous, real-time monitoring for mercury, because of its high volatility, may be desirable both for emissions performance and internal process control. Development of a continuous monitor for emissions of the toxic metals regulated by the EPA is considered a high priority. Monitoring for metal levels down to a mass emission rate of a few grams per hour will be necessary. Conditions at the stack will be the same as for radionuclide monitoring.

5.2.9 Organics

Monitoring is currently required by the BIF Regulations for total hydrocarbons (THCs) depending on the demonstrated CO levels in the offgas. THC monitoring is usually performed in the high-temperature zone of the thermal treatment unit, such as at the SCC exit. Real-time, continuous monitoring for a variety of organics in the offgas such as principal organic hazardous constituents (POHCs) and products of incomplete combustion (PIC) is currently not required, but improvements and developments in CEMs for organics would be beneficial. As such monitoring instrumentation at the required detection limits becomes available, its use should be encouraged to help future mixed waste treatment processes become more acceptable to the public.

5.2.10 Trial Burn Monitoring

Trial burn monitoring requires measurements of particulate and, in most cases, HCl and heavy metals emissions at the stack. A determination of the destruction and removal

efficiency (DRE) of the POHCs will be required, and measurement of the emissions levels of PIC may also be required. There are standard EPA methods for measurement of these species.

5.2.11 Temperature

The temperature of the offgas should be measured at various points throughout the offgas system, starting at the thermal treatment unit. Conditions will vary from about 2200°F with high levels of primary pollutants (acid gas, NO_x, particulate, heavy metals, radionuclides) to nearly ambient conditions at the stack with the majority of the pollutants removed. Depending on the type of offgas system, the offgas at the stack could be near water saturation. The temperature of the gas at each combustion chamber exit must be measured to verify that the operating conditions stay within the operating envelope established during the trial burn so as to ensure that the required organics destruction is achieved. In general, the inlet temperature to APCDs must be monitored if the APCD is required to meet permit conditions and if the APCD has a temperature limit for proper operation. For example, in offgas systems having a baghouse for particulate removal, the baghouse inlet temperature must be monitored to ensure that the bags are not damaged by high temperatures. In addition to monitoring temperatures for regulatory purposes, temperatures at various locations in the offgas system should also be monitored to ensure proper operation, which, in turn, can have a direct effect on meeting permit conditions. For example, the quencher exit temperature is a monitored variable in a wet offgas system to verify that the offgas is being adequately cooled to maintain the integrity of downstream process equipment, including HEPA filters. Likewise, where offgas reheaters are required to raise the offgas above the dew point prior to HEPA filtration, temperature differential across the reheater unit is a necessary control variable to ensure that the HEPA filters are not damaged by moisture.

5.2.12 Pressure and Differential Pressure

Absolute pressure and differential pressures must be monitored and controlled at various points throughout the offgas system. Process conditions will be the same as described for temperature measurements. Control of the thermal treatment unit's internal pressure, slightly below atmospheric, will be required for operational safety purposes. Differential pressures across specific APCDs must be controlled to stay within the operating envelope established during the trial burn and to maintain high particulate removal efficiencies. The pressure of the liquid flow to the scrubber must also be monitored. For other APCDs such as packed tower scrubbers, the differential pressure must be monitored to avoid upset conditions such as flooding. Baghouses typically require monitoring of differential pressure to monitor for cleaning of the bags and bag filter failure. For HEPA filters, a measurable minimum pressure drop indicates the integrity of the filter; a maximum allowable particulate loading is indicated by high pressure drop and the subsequent need to change filters.

5.2.13 Gas Flowrates

Flowrate measurements for both input gas streams into the thermal treatment unit and for the offgas at selected points in the offgas train, including the stack, are important. Input gas

streams are essentially air but can contain contaminants, such as in chemical venting operations. The gas may be wet, contain relatively high concentrations of organics, and have a relatively high dust loading. Input gas flow pressures will be slightly negative or slightly positive with respect to atmospheric, depending on the location of the monitor, and temperatures will be near ambient. The SCC exit offgas flowrate must either be monitored directly or readily determined through calculation to determine the average gas residence time in the SCC. Final stack offgas flowrate monitoring is useful for material balance purposes and is required to calculate mass emission rates of monitored pollutant species as well as for isokinetic particulate sampling. Conditions at the stack are the same as those described above for radionuclide monitoring.

5.2.14 Liquid Flowrates

For wet or semiwet offgas systems, the flowrate of circulating scrubber liquid at various points in the system is an important process control parameter and, in some cases, must be monitored. For example, the flowrate of scrubber liquid to many APCDs such as particulate and acid gas scrubbers affects the removal efficiency of these pollutants and must be monitored to verify that flowrates are reflective of operating conditions used during the trial burn. The proper flowrate of liquid to an offgas quencher is the variable that controls the quencher exit temperature. Emergency water addition to a wet offgas system may also be controlled by scrubber liquid flowrate. For regulatory purposes, monitoring of the scrubber liquid blowdown flowrate is almost always required and is useful for overall process material balance closure. Scrubber liquid conditions are generally as follows: slightly caustic (pH of 8–9 optimally, but periodically higher or lower) and slightly elevated temperature (80–180°F). The aqueous liquids normally contain dissolved solids (salts such as NaCl, NaF, and Na_2SO_4) and suspended solids (primarily flyash consisting of soot, metal oxides, and inorganics in elemental form).

5.2.15 pH of Scrubber Liquid

The pH of scrubber liquid is an important system control variable and also happens to be one of the most difficult process parameters to control satisfactorily. The pH must be controlled within a prescribed range, typically 8 to 9, to maintain acid gas removal efficiency, avoid precipitation of gelatinous metal hydroxides, and meet scrubber blowdown pH discharge requirements. The scrubber liquid pH is the measured variable that controls caustic addition. Conditions are the same as those described for liquid flowrate measurements.

5.2.16 Power and Voltage

Monitoring is required for certain APCDs that rely on electrical input to create electrostatic forces for the collection of particulate. These monitors are used to ensure that the particulate removal equipment is operated under the same conditions as those used during the trial burn so that the particulate removal efficiency will be nearly the same as that obtained during the trial burn. The primary APCDs that will be required to monitor these variables are: ESPs, WESPs, electrodynamic venturis (EDVs) and ionizing wet scrubbers (IWSs). Obviously,

these monitors will not be in contact with the offgas and will not be subjected to the extreme conditions associated with the offgas.

5.3 GENERAL MONITORING NEEDS FOR CONTROL PURPOSES

5.3.1 Density and/or Conductivity of Scrubber Liquid

Continuous monitoring and control of density or electrical conductivity is a means of controlling dissolved solids concentration of the recirculating scrubber liquid. Blowdown of scrubber liquid is normally based on controlling either or both of these two parameters at a specified set point. The liquid blown down is replaced with fresh makeup water to maintain a constant inventory of liquid in the system. Conditions are the same as those described for liquid flowrate measurements.

5.3.2 Liquid Level

The level of scrubber liquid in APCD sumps and surge tanks must be controlled to avoid dry pump suction and the loss of flow of liquid to APCDs. Level control is also required to avoid overflow of process vessels.

5.3.3 Fissile Material Monitoring

For avoidance of criticality concerns, especially in wet offgas systems processing waste with fissile materials, a means of monitoring key process areas that could expect holdup of material should be provided. Such areas include APCD sumps and scrubber liquid recirculation tanks.

5.3.4 Vibration Monitoring of Rotating Equipment

Key rotating machinery in an offgas system includes induced draft blowers and liquid pumps. To maintain safe operating conditions, monitoring for vibration should be considered at a minimum for induced draft blower performance to anticipate maintenance requirements and avoid failure of equipment during operations.

5.3.5 Monitoring of Chemical Species in Selected Gas Streams

For various gas streams within the MWTP flowsheet as it currently exists, additional monitoring may be indicated for control purposes. Following are species that have been identified at this time which would likely require monitoring for process control.

5.3.5.1 Organics

Measurement of the organics content of input gas streams to the thermal treatment unit, though not critical, can provide information concerning heat input into the thermal treatment

unit. Conditions will be similar to those described for flowrate measurement of input gas streams.

5.3.5.2 Acid gas

Acid gas (primarily HCl and SO_x) content of stack gases may need to be measured if a dry or semidry offgas system is used. This measurement would be used for control of the addition of alkali reagent for acid gas scrubbing in such a system.

5.3.5.3 Chlorine gas

Chlorine (Cl_2) gas monitoring in the exhaust from chlorine gas scrubbing is needed for control purposes. Gas temperature will be slightly above ambient (120–160°F). The gas will be fairly clean but will be saturated with moisture.

5.3.5.4 Mercury

Mercury monitoring in the offgas from a mercury cleanup scrubber and from the activated carbon bed adsorber downstream of the mercury vacuum still is needed for control purposes and may be beneficial in demonstrating regulatory compliance. Such monitors would indicate proper operation of the scrubber and approach to breakthrough of the carbon bed.

5.4 CONTINUOUS RADIOACTIVE EMISSIONS MONITORING

The greatest public concern with incineration, and most likely with any future thermal waste treatment system, is that the system might not be operating within a "safe" range of emissions. The monitoring of radioactivity in the offgas from mixed waste thermal treatment units can be accomplished either by continuous measurement or by sampling and analysis. The latter approach does not constitute a real-time measurement. However, in almost all cases, radioactive monitoring in real-time sacrifices the sensitivity of the measurement or the detection limit. Particulate radionuclide concentrations are extremely low in offgas that has been filtered through one or more HEPA filters in series. Real-time monitoring of HEPA filtered offgas at a detection limit that can quantify actual radioactive emissions is simply not possible. In these situations, actual radionuclide concentrations in the offgas can be up to six orders of magnitude below the monitor's detection limit. However, state-of-the-art radioactive monitors are capable of detecting the maximum permissible concentration (MPC) or derived air concentration (DAC) for virtually all radionuclides (a gas sample is continuously passed through a filter, and the filter is continuously counted to give a real-time cumulative radioactivity measurement).

When monitoring offgas downstream of HEPA filters, the most sensitive continuous, real-time monitors for radioactivity associated with particulate can only provide a reading of "zero" during normal process operation. Such a monitor can detect radioactivity in real time only in the event of process upset conditions such as a failure of one or more HEPA filters upstream. Monitoring for upset conditions is a viable approach in conjunction with additional protection by final HEPA filters downstream of the monitoring point prior to release to the atmosphere.

Sampling of offgas followed by analysis provides greater sensitivity and lower detection limits than any real-time monitoring methods. A portion of the stack gas is routed through filter paper, and a particulate sample is allowed to build up over a period of time, usually in the range of hours to several days. The sample is then transferred to a laboratory for counting, and a determination is made of total radioactivity collected during the sample time. Sampling followed by analysis can provide actual cumulative radionuclide release information but not in real time.

The limitations of radioactive sampling and monitoring technologies must be communicated to the regulatory agencies so that physically impossible performance requirements are not imposed on treatment facilities. The ability to detect an internal process upset condition in real time while avoiding any increased release of radioactivity should go a long way toward reassuring the public that it is being protected from potential releases. Wide public acceptance of incineration and other mixed waste treatment technologies will depend on the proper implementation of continuous radioactive emissions monitors. Good communication to the public about how monitoring is being implemented will be far more important than the continued development of more sensitive monitors. After all, a monitor that can detect a single atom is of little use if there is no waste treatment process in which to install it.

5.5 WASTE ASSAY REQUIREMENTS

Many of the characteristics of the waste feed to the thermal treatment device can impact the APC system and should be determined if practical. However, this is not always possible. Many of the candidate waste streams for treatment in the MWTP will be difficult or impossible to completely characterize because of difficulties in obtaining representative samples of heterogeneous waste packages.

Nonetheless, the halide (mainly chlorine), heavy metals, and ash content of the waste are required to undergo some means of characterization before processing. In addition, the radioactivity of the waste should be determined for ALARA (as low as reasonably achievable) purposes to ensure that concentration of the activity will not create safety problems and to account for radionuclides that may have a feed limit such as tritium, ^{14}C, and radioiodine. There are other parameters related to the waste feed treatment device that are also required to be monitored for regulatory compliance or for operational control. These parameters (which include waste feed rate, weight of containerized waste, waste chemical and physical properties, etc.) are not discussed in this document. Monitoring and characterization of these parameters, although they can affect the offgas system, is generally considered a need of the waste destruction and stabilization system.

Detailed characteristics of DOE waste streams can be found in the DOE Mixed Waste Inventory Report.[2]

6. TECHNOLOGY DEVELOPMENT NEEDS AND DESIGN AND OPERATIONAL RECOMMENDATIONS

6.1 PRIORITIZATION OF NEEDS

All of these needs are considered important for second-stage destruction and offgas treatment; however, the TSG assigned a priority in this list, to note a relative importance. Where a range of priorities is given, a consensus was not reached among TSG members.

6.2 SUMMARY OF NEEDS

The table below contains a short description of each "need," the basis for that need, and the technical difficulty of the task.

It is recommended that testing and demonstration of APC technologies address site-specific design issues as well as the 10 broad issues identified in the following table. In addition, characterization of the effluent to be treated is crucial to designing, testing, and implementing APC systems. Effluent characterization is discussed in Chap. 5 of this report.

As a result of evaluating the eleven "typical" APC systems shown in Appendix B, no "technology holes," or functions that cannot be met with existing APC technologies, were identified. Rather, recommendations suggest technology testing and demonstration areas to improve *implementation and operation* of waste treatment systems in DOE.

We defined three knowledge gaps, or areas in which our group did not have enough information to proceed. These gaps can easily be addressed with a survey of industrial technologies.

Rank	Need	Basis	Technical difficulty
Higher	Continuous emissions monitoring	Real-time feedback to improve operation and ease trial burn process. Some improved public acceptance. Real-time data useful for equipment performance characterization.	Metals monitoring—difficulty TBD. Technically risky. Potential technologies lab-scale only. Radionuclides monitoring—TBD.
Medium–Higher	Extend life of HEPA filters	Plugging HEPA filters creates significant maintenance and handling problems and generates secondary waste that can be cumbersome to dispose of. Two approaches: prevent plugging upstream of HEPAs and/or develop cleanable HEPAs.	Prevent plugging upstream—medium difficulty. See other technology needs below. Develop cleanable HEPAs—Medium difficulty.

Rank	Need	Basis	Technical difficulty
Medium–Higher	Characterize performance of "new" technologies for initial removal of fine particulates (e.g., CHAEF filters, Froth columns).	Particulate removal is extremely important (see topic above and below). The payback for reliable, high performance is great. Data not available for some "new" commercial technologies.	Not difficult. Need to define appropriate system for testing.
Medium–Higher	Demonstrate performance of APCE systems and components for radioactive, metal, and particulate removal efficiencies.	Although experience and, to some degree, data allow APC system designers to predict the performance of equipment, most should be tested at a smaller scale prior to full-scale implementation. This is simply a measure to protect the DOE investment in equipment and is common practice in industry today, especially the utility industry, which relies heavily on state-of-the-art APC equipment. Another basis for this need is operational flexibility. For example, how tolerant is the mercury cleaning equipment to low levels of acid gas?	Not difficult on a component-by-component basis. Substantial effort, but not technically risky, for system demonstration for the entire national program. System demonstrations should be carefully coordinated among sites to avoid duplication.
Medium	Investigate commercial and emerging technologies for high temperature particulate removal. (e.g., ultrafiltration, ceramic bags, ceramic candles, molten glass scrubbers.)	Normally, particulate removal is performed at lower temperatures, downstream in the APC system. If particulate removal could be accomplished upstream, it would keep most of the radionuclide contamination upstream, which results in a safer, easier to maintain system.	Medium difficulty.

Rank	Need	Basis	Technical difficulty
Medium	Study state of the art in NO_x abatement technologies.	In the professional opinion of the TSG, DOE probably does not need to invest money in new NO_x abatement technologies. The payback for a major technology improvement in this area is large, but the probability of finding a major improvement seems small. Industry is working very hard to improve catalysts, etc. We propose surveying R&D in the electric power industry.	Not technically difficult. Survey only.
Medium	Study state of the art in second-stage destruction technology.	Good mixing is imperative for organics destruction in a second-stage unit. If this unit functions properly in a system, there is no need for further equipment (e.g., catalytic devices) to assure VOC destruction. Degree of completion of combustion reactions can be inherently improved by a plug-flow geometry and possibly other techniques combined with traditional burners. We need to know what industry is doing.	Not difficult—industry survey only.
Medium	Evaluate "new" commercial technologies to minimize secondary waste streams without sacrificing pollutant removal efficiency. Possible technologies include acid gas removal, using "amine" solutions that can be recycled, and new mercury capture technologies.	Treating secondary waste generated in a mixed waste treatment system is not trivial, especially for liquid secondary waste streams. The benefits of implementing technologies that minimize secondary waste generation must be evaluated in a systems analysis that includes a formal technology selection logic accounting for factors such as cost, risk, and performance. However, we should at least be familiar with the options available and use our site-specific analysis to consider their applicability to DOE systems.	Initial survey of technologies not technically difficult. Technical evaluation with respect to mixed waste treatment needs may be challenging.

Rank	Need	Basis	Technical difficulty
Lower to Higher (lack of consensus)	Analytical modeling of metals partitioning in waste treatment and air pollution control equipment. Primarily thermodynamic equilibrium models. Coordinate with ongoing work already funded by EM at Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, and Rocky Flats Plant (through EPA at Energy and Environmental Research Corporation).	It is helpful for designers of APC systems to know the physical form of the metals that must be captured and what operational factors affect the capture.	Medium difficulty—equilibrium models are easy to calculate. The challenge is obtaining thermodynamic data for the species of interest and incorporating kinetic effects. Note that quite a bit of work is currently ongoing in equilibrium modeling.
Lower–Medium	Determine radionuclide surrogates for systems and component testing.	Hot testing is difficult to implement and data are required to show the capture efficiency of radionuclides prior to full-scale implementation. Selection criteria include molecular weight, volatility, and thermodynamic properties and will depend on the feature being tested.	Unknown. Depends on radionuclide, test configuration, desired test data, etc.
Higher	Provide technologies that address issues affecting public opposition/concern toward mixed waste treatment facilities.	This issue is partially addressed by stating the need for CEMs, but any other technical solutions to this important problem will be considered.	Unknown difficulty. This is a very broad need, and we will evaluate proposals on a case-by-care basis.

6.3 DETAILS ON TECHNOLOGY NEEDS FOR FINE PARTICULATE REMOVAL

Fine, submicron particulate collection has proven itself to be a challenge in APC. APCE has lower removal efficiencies for submicron particulates. Submicron particulates can blind cleanable, coarse filtration media (e.g., fabric filters) by penetrating into the media rather than collecting on the surface. In addition, particulate emission regulations are becoming more strict. Fine particulate frequently contains a higher concentration of toxic heavy metals, and it is more easily inhaled by humans than coarse particulates. When alpha-emitting radionuclides such as plutonium are associated with fine particulates, the health hazard is further increased.

The two main sources of fine particulates include the thermal treatment device and wet pollution control equipment. The fine particulates from the thermal treatment device are

usually either bits of ash entrained into the airflow or minute aerosols of condensed volatile matter. Fine particulates from wet pollution control equipment are carried over from mists generated in the quencher and scrubber. These particles are usually salty and/or dirty residues of the liquid left after the offgas is heated.

One of the best collection devices for fine particulates is the HEPA filter. However, HEPA filter operability problems can be summarized as follows:

1. Overloading due to lack of control of upstream particulate load and particle size of entrained particulates in off-gas stream. This is a design task failure that occurs in cases where adequate sampling/analysis and special thermal treatment assessment of the waste characterization are not done in concert with APC unit operation specification and flowsheet sequencing.

2. Overloading by salt when recycle water from the quench is evaporated.

3. Loss of availability due to water condensation stemming from lack of control of combustion gas flow/composition range in association with APC reheater operation upstream of HEPAs. Properly designed insulated/heat-traced ducting to prevent condensation/fogging is very important.

4. Overloading due to droplet carryover and subsequent excessive reevaporation of water from the dissolved salts in recycle scrubber liquor loop in contact with APC unit operations downstream of quench operation but upstream of the HEPA filters.

5. Droplet carryover, from last stage, actually reaching and wetting the HEPA filters (mist eliminator problem).

6. HEPA filtration not routinely used in the hazardous waste incineration industry. The primary industrial use of HEPA filtration is to filter clean rooms for electronics manufacturing.

Several mixed waste incineration systems that have generated APC HEPA filter operating data (such as change-out frequency, lessons learned on redundancy to maintain needed availability, root cause of upset conditions leading to loss of production, etc.) include incinerator facilities at INEL (WERF and PREPP); Savannah River (CIF); Los Alamos National Laboratory (Controlled Air Incinerator); and Rocky Flats (Fluidized Bed Incinerator). Failure to control HEPA operations can have dramatic impact on overall unit availability, production rates, and emissions control.

RDT&E needs in the area of fine particulate removal include the following:

1. Thermal treatment devices should be optimized to meet waste destruction requirements and still generate as little as possible fine particulate. This optimization can be accomplished by using various operating parameters (e.g., temperature and oxygen content of primary chamber) or by controlling the waste feed composition using blending, segregating, or feed additives to capture volatile species chemically.

2. Tests should be conducted to determine optimum operating conditions for wet pollution control equipment. For example, variations in the salt content in the scrubber/quench liquor, the location for clean makeup water, and the type of scrubber/quench solution

recycle loop could be studied to determine conditions resulting in the best overall process.

3. Methods to grow and agglomerate fine particulates should be investigated.

4. Development of a cleanable, high-temperature HEPA filter would be very beneficial. Ideally, such a filter could tolerate moisture, could be cleaned during operations, and could be cleaned off-line with a solution that can penetrate the filter media and remove/dissolve the fine particulate.

5. Determine if an irrigated aerosol filter can extend the life of HEPA filters without generating an unacceptable secondary waste. Compare the performance to the best HEMEs. Could the two be used in conjunction to further enhance aerosol and droplet removal?

6. Filters using materials rated for higher temperatures should be developed.

7. Filters using materials more resistant to corrosion and moisture (especially salty moisture from an acid gas scrubber) should be developed.

6.4 TECHNOLOGY DEVELOPMENT NEEDS FOR OTHER MWIP TECHNICAL AREAS

One of the most important pieces of information needed to design an offgas system is a good description of the effluent to be treated, including the phase and species of pollutants such as metals. Different degrees of effluent characterization are required for different levels of tests; it is important to be consistent between overall test objectives and the amount of effluent characterization performed. Effluent characterization is expensive, especially hot-gas and isokinetic sampling. Each test plan should include a list of pollutants to be measured and the technique to be used. Data should be collected under a reasonable variety of operating conditions (including turbulence level, if appropriate) and for representative waste streams. Note that the chloride concentration in the waste stream will have a big effect on the effluent composition. DOE test programs should incorporate industrial experience, such as commercial contractors, to extract samples and perform chemical analyses.

APCE residue, especially salts, mercury, soluble metals, carbon, PICs, and POHCs, need to be treated and/or separated in other parts of the waste treatment system. These secondary waste streams could contain any of the following:

- Particulate sizes from submicron to greater than 100 μm.
- Spent scrub liquor containing unused caustic agent, dissolved salts, and particulate matter (undissolved solids such as soot and metal oxides).
- Spent alkali reagent from SDA or DSI consisting of unused alkali reagent, salts, and flyash.
- Flyash alone.
- Used filters from dry offgas systems, such as HEPAs, fabric filters, sintered metal filters, and roughing filters for a HEPA bank.
- Used filters from scrub liquor recycle loops.

- Dried salt/ash mixture from treatment (evaporation) of scrubber blowdown.
- Spent catalysts from organics destruction and NO_x abatement.
- Used charcoal adsorbent from organics and heavy metals capture.

6.5 MWIP FY 1994 CALL FOR PROPOSALS FOR OFFGAS TREATMENT

6.5.1 Emissions Monitoring

Real-time feedback of stack emissions is needed to improve system operation and ease the trial burn permitting process. Real-time data (with required sensitivity levels of parts per million to parts per billion) and system control should improve public acceptance of thermal waste treatment systems. The real-time data would also be useful to establish equipment performance and waste stream characterization. Monitoring is required for organics, metals, and radionuclides. Proposals should clearly describe current commercial capabilities and how the proposal will expand/enhance these capabilities. Industrial partners should be solicited as appropriate. Deliverables include the following:

A. Test plan and technology development approach.
B. Results of laboratory-scale tests, including radionuclide monitoring.
C. Plans for full-scale testing, including implementation of an operating system.
D. Results of full-scale tests and interface with system pilot plant(s).

EM's earliest schedule for development of prototypical treatment requires that deliverable A be completed early in FY 1994 and that deliverable B be drafted by the end of FY 1994. Deliverable C must be started by FY 1995 and preliminary results for deliverable D must be available by the end of FY 1995 and will continue as necessary.

6.5.2 Public Concerns

echnologies must be provided which address issues affecting public opposition/concern regarding mixed waste treatment facilities. This issue is partially addressed by the above need for CEMs. Other technical solutions to this problem are of interest to the MWIP. This is an extremely broad need; ideas for resolution are sought. Deliverables include methods for obtaining technically based public support for mixed waste treatment. EM-30's earliest schedule for development of prototypical treatment and FFCA-based regulatory drivers require that this deliverable be completed by the end of FY 1994.

6.5.3 Extending Life of HEPA Filters

Plugging HEPA filters creates significant maintenance and handling problems and generates secondary waste that can be cumbersome to dispose of. There are two approaches to extending the life of HEPA filters: preventing plugging upstream of the filter and/or developing cleanable HEPA filters. Deliverables include the following:

A. Test plan and technology development approach.
B. Results of laboratory-scale tests.

C. Plans for full-scale testing, including implementation on an operating system.
D. Results of full-scale tests.

EM-30's earliest schedule for development of prototypical treatment and FFCA-based regulatory drivers require that deliverable A be completed early in FY 1994 and that deliverable B be drafted by the end of FY 1994. Deliverable C must be started by FY 1995, and preliminary results for deliverable D must be available by the end of FY 1995 and will continue as necessary.

6.5.4 Emerging Technology Development

There is a need to quantify the performance of emerging technologies for initial removal of fine particulates during mixed waste treatment. The potential for reducing overall system cost and improving system performance by removal of fine particulates is significant. Reliable, high-performance systems are needed. Deliverables include the following:

A. Test plan and technology development approach, including appropriate system for testing and justification for selection of emerging technology.
B. Results of laboratory-scale tests, including radionuclide monitoring.
C. Plans for full-scale testing, including implementation on an operating system.
D. Results of full-scale tests.

EM-30's earliest schedule for development of prototypical treatment and FFCA-based regulatory drivers require that deliverable A be drafted early in FY 1994 and that deliverable B be drafted by the end of FY 1994. Deliverable C must be started by FY 1995, and preliminary results for deliverable D must be available by the end of FY 1995 and will continue as necessary.

6.5.5 APC Equipment Demonstration

The performance of commercially available APC equipment systems and components must be demonstrated for radioactive, metal, and particulate removal efficiencies. Although experience, and to some degree data, allows APC system designers to predict the performance of equipment, most equipment should be tested on a small scale prior to full-scale implementation. Such demonstrations protect DOE's investment in equipment. Industry routinely demonstrates equipment prior to full-scale implementation. For example, the utility industry with its heavy reliance on state-of-the-art APCE commonly tests proposed systems. The operational flexibility of APC for mixed waste streams must be tested. For example, the tolerance of mercury cleaning equipment to low levels of acid gas must be determined. Demonstrations of APC systems must be carefully coordinated between DOE sites to avoid duplication of effort. Deliverables include the following:

A. Test plan and technology development approach, including appropriate system for testing mixed low-level waste with justification for selection of APC system.
B. Results of small-scale tests, including radionuclide monitoring as appropriate.

EM-30's earliest schedule for development of prototypical treatment and FFCA-based regulatory drivers require that deliverable A be drafted early in FY 1994 and that deliverable B be completed by the end of FY 1995 and continue as necessary.

6.5.6 High-Temperature Particulate Removal

There is a need to investigate commercial and emerging technologies for high-temperature particulate removal. Normally, particulate removal is performed at lower temperatures after the offgas has been cooled. If particulate removal could be accomplished upstream, it would keep most of the radionuclide contamination upstream (e.g., prior to wet scrubbing, resulting in reduction in radioactivity contaminated scrubber blowdown). Development of high-temperature particulate removal systems has the potential to result in safer, easier to maintain systems with reduced generation of radioactivity contaminated secondary waste streams. Deliverables include the following:

A. Test plan and technology development approach, including appropriate system for testing and justification for system selection.
B. Results of laboratory-scale tests, including radionuclide monitoring as appropriate.
C. Plans for full-scale testing including implementation on an operating system (either surrogate or radioactive system).
D. Results of full-scale tests.

EM-30's earliest schedule for development of prototypical treatment requires that deliverable A be drafted early in FY 1994 and that deliverable B be initiated by the end of FY 1994. Deliverable C must be started by FY 1995 and preliminary results for deliverable D must be available by the end of FY 1995 and will continue as necessary.

6.5.7 Metals Partitioning Models

Analytical modeling of metals partitioning in waste treatment and APCE is needed to improve thermal treatment system performance since it is helpful for designers of APC systems to know the physical form of the metals that must be captured and the operational factors that affect the effectiveness of metal capture. This modeling is considered basic science, including primarily thermodynamic equilibrium models. A major segment of this work is the collection of thermodynamic data for the species of interest. MWIP has funded limited work in this area during FY 1993. This task should be coordinated with work ongoing at Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, Rocky Flats Plant, and work funded through the EPA with industrial participation. Deliverables include the following:

A. Data from laboratory-scale tests on metals partitioning.
B. Results of modeling, including development of theory.

EM-30's earliest schedule for development of prototypical treatment requires that deliverables A and B be drafted by the end of FY 1994, with continuation as necessary.

6.5.8 TTP Evaluation Criteria—Sample Review Form

TECHNICAL REVIEW AND FEEDBACK FORM
FY 1994 TTPs
Mixed Waste Integrated Program
Offgas Treatment Technical Specification Group

TTP Number: XX000000	Functional Area: OGT - VOC destruction
Title: XXXXXX	
Principal Investigator: Joe Smith, SNLL	Phone Number: 510-123-4567
	Fax Number: 510-123-4567
Requested Budget: FY94 $200 K: FY95 $300 K; FY96 $0 K; FY97$0 K	

Criteria	Points (Max.)
Responsiveness to stated need MWIP need addressed: Applicability to priority waste stream(s) (Table1): Schedule to implement technology vs stated need: QA/QC provisions for test data:	(10)
Technical Quality of Proposal Clearly written project outline with objectives, tasks, milestones, etc.: Does proposal establish a feed acceptance criteria? Does technology generate secondary waste stream? Process/technology effectiveness—how well does technology perform and how much better is it than existing technologies? Collaboration with industry/other labs/universities: (technical contributions, leveraged input, etc.) Potential CRADAs/Plans for commercialization: Demonstration of commercially available technology on identified site waste stream: Permitting requirements of technology and/or demonstration (including public participation plans): Appropriate Budget, Consistent with Requested Funding:	(10)
Qualifications of Proposed PI / Institution Appropriate PI? Unique capabilities of facility:	(5)
Total	(25)

A = fund if at all possible
B = fund consistent with other priorities
C = fund only if more information makes compelling case
D = do not fund at this time

Bin (Check only one). ☐ **A** ☐ **B** ☐ **C** ☐ **D**

Checklist of Disallowed Items		
Restriction (A "Yes" renders a proposal unacceptable.)	Yes	No
Is not responsive to stated need for MWIP		X
Does not conform to TTP format, or TTP is incomplete		X
Duplicates project funded by another DOE ID or IP		X
Duplicates commercially available technology		X
Duplicates research currently being funded by private industry or other gov't agency		X
Requires more than two years to reach a useful stage of completion.		X
Does not lead to demonstration in approx. 2 years.		X

A COPY OF THIS EVALUATION HAS BEEN PROVIDED TO THE PRINCIPAL INVESTIGATOR
THE FINAL EVALUATION IS COMPLETE

MWIP/OGT Team Leader Signature: _____

6.6 MWIP OFFGAS FUNDING FOR FY 1994

The MWIP has funded $3.2M of technology development in the Offgas technical area for FY 1994. This includes projects to evaluate two different technologies for cleanable HEPA filters, a vapor-phase mercury capture technology, and three CEMs: one for VOCs, ammonia, and acid gases (based on tunable diode lasers); one for mercury; and one for alpha radioactivity.

7. CONCLUSIONS AND RECOMMENDATIONS

This report provides a summary of APC technologies, technology development needs, regulations, and a design guide for air pollution control systems for mixed waste treatment. Supporting details can be found in the two appendices at the end of this report.

During FY 1994, the Offgas Technical Group will use the design guides to design and specify an APC system for the plasma hearth furnace project funded by the MWIP. This should prove to be a challenging exercise for the persons using design guides.

The MWIP has funded $3.2M of technology development in the Offgas technical area for FY 1994. This includes projects to evaluate two different technologies for cleanable HEPA filters, a vapor-phase mercury capture technology, and three CEMs: one for VOCs, ammonia, and acid gases (based on tunable diode lasers); one for mercury; and one for alpha radioactivity.

8. REFERENCES

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APPENDIX A

TABLE OF AIR POLLUTION CONTROL EQUIPMENT, FUNCTIONS, AND SUPPLIERS

Table of Air Pollution Control Devices, Functions, and Suppliers
Particulate Control

APC Function	Technology Name	Details	Source/Contact
Particulate removal	Microporous filters, then HEPA filters with dust buckets, air locks, gates, etc.	>1.0 g/m^3 to 0.1–0.05 mg/m^3 to <0.001 mg/m^3.	Jet Air Technologies (B&U Corporation) 401 Miles Dr. Adrian, MI 49221 517-263-0113 Fax 517-263-0038
Particulate removal	Ceramic fiber filter bags for industrial process hot gas streams.	Removes 99.99% solids. Can operate at up to 1400°F.	Timm Genrich 3M Company 219 1501 St. Paul, MN 55144-1000 612-733-4013
Fine dust removal	CALWIR scrubbing system	0.05-μm diam of dust particles increased to 0.24 μm by condensation of water vapor. These then form larger droplets between 10 and 20 μm. Collection efficiency for droplets is 30–90%.	Caldyn Inc. 1916 Third Ave. New York, NY 10029 212-427-6347 or 212-860-2632 Fax: 212-360-7011
Particulate removal	Inorganic microporous filters, optimized to filter contaminated particles from surface cleaning liquids and process offgases (under development at Oak Ridge K-25 Site)	Target permeabilities with design pore sizes.	
Dust removal from flue gas, ambient air	Whirl Wet dust collector: water-laden dust particles centrifugally driven into water droplets as they pass through dual-opposed blade assembly. Particles then deposited in water hopper and fed to filter press. Uses 50 lb lime/day to increase particle precipitation.	Uses 1–2 gal water per hour; no moving or high-maintenance parts like spray nozzles, pumps, or bags. Lime slightly increases pH of system. Wet collector reduces fire and explosion risk.	Tri-Mer Corp. P.O. Box 730 1400 Monroe St. Owosso, MI 48867 517-723-7838 System installed at Horween Leather Co., Chicago, IL

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Particulate Control

APC Function	Technology Name	Details	Source/Contact
Particulate removal	HEPA filters (stainless steel-/fiber reinforced polyester, currently being developed at Oak Ridge Y-12, LLNL)	Suitable for higher off-gas temps and cleanable in place when used in conjunction with acid or solvent wash.	
Particulate removal	Pleated fabric filter: ComPleat 93. Pulse jet filter is combination of fabric filter and cartridge collector. Can be installed in existing baghouses.	Capture efficiency >99.9%. 45-ft^2 filter area in 36-in.-long cartridge. Air-to-cloth ratio, 4:1–5:1.	Jim Hojnacki Flex-Kleen Corp. One Northwestern Center 165 North Canal St. Chicago, IL 60606 312-648-5300
Soluble/reactive contaminant removal	Scrubber—three spray baffle scrubbers and two packed bed scrubbers. Gas exits through demister.	Droplets <0.5 μm removed.	Roger McKinley Delatech Inc., Napa, CA 800-886-1968 or 408-262-1631 Fax: 408-262-0507
Particulate removal in medical waste incinerators	Rotary Atomizing Scrubber—high-speed rotating disc generates high-energy atomized water droplets. Droplets make a dense liquid curtain equivalent to a filter pad; system acts as a liquid baghouse. Three-stage demister with mesh pads dries the flue gas.	Controls particulates to a level of 0.009 grain/dscf at 7% O_2. Removes particulates in the submicron range, and hydrogen chloride emissions are below 5 ppm.	Hank Marschall Emcotek Corp. 8220 Doe Ave. Visalia, CA 93291 209-651-2000 Fax: 209-651-2007
Particulate removal	Tubular wet electrostatic precipitator—produces a strong electrical field (corona) that provides high-efficiency collection.	In wet conditions, has high-efficiency collection of submicron particles, including heavy metals and condensed organics. Particulate emission levels of 0.0005 grain/dscf achieved.	Dave Meier Beltran Associates, Inc. 1133 East 35th St. Brooklyn, NY 11210 718-338-3311

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Particulate Control

APC Function	Technology Name	Details	Source/Contact
Dust removal	Baghouse—double-walled design allows long service life (20 years in one case). Four inches of fiberglass insulation pressed into 3-in. space between 10-gauge steel inner skin and 14-gauge steel outer skin.	Handles 50,000 ft^3/min.	Article: *Pollution Engineering*, August 1, 1992, p. 74, "Insulation and Preventive Maintenance Extend Baghouse Life"
Particulate removal	Variable Volume Venturi (VVV) wet scrubber	Handles particulate as small as 0.5 μm and gas stream temps as high as 3000°F. Handles both soluble and insoluble particles. Uses 8 gal of water per minute per 1000 scfm. Scrubbers custom-built for specific combustion applications.	Mon-Cyr Environmental Systems
Particulate removal	Baghouses, Venturi scrubbers		W. W. Sly Manufacturing Co. P.O. Box 5939 Cleveland, OH 44101 800-334-2957 216-238-2000
Particulate removal	Cyclones, mechanical centrifugal separators, high-energy scrubbers		DUCON Environmental Technology 110 Bi-County Blvd. Farmingdale, NY 11735 516-420-4900
Particulate removal	Baghouses, HEPA filter, mechanical centrifugal separator, self-induced scrubber		American Air Filter P.O. Box 35690 215 Central Ave. Louisville, KY 40232-5690 502-637-0710

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Particulate Control

APC Function	Technology Name	Details	Source/Contact
Particulate removal	Gravity settling chambers, impingement separators		Monroe Environmental P.O. Box 806 11 Port Ave. Monroe, MI 48161 800-992-7707 313-242-7654
Particulate removal	Baghouses, self-induced scrubber		Interel Corp. P.O. Box 4676 Englewood, CO 80155 303-773-0753
Particulate removal	Cyclones, rotary atomizing wet scrubbers		TREMA North America, Inc. P.O. Box 335 357 Main St. Reisterstown, MD 21136 301-833-2922
Particulate removal	Baghouses, electrostatic precipitators		General Electric Environmental Services, Inc. 200 North 7th St. Lebanon, PA 17042 800-642-6789 717-274-7000
Particulate removal (wet)	Venturi scrubbers		Andersen 2000 306 Dividend Dr. Peachtree City, GA 30269 404-997-2000
Particulate control (wet)	High-energy scrubbers		Entoleter P.O. Box 1919 New Haven, CT 06509 203-787-3575

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Particulate Control

APC Function	Technology Name	Details	Source/Contact
Particulate control (wet)	Free-jet scrubbers		Hydro-Sonic Systems, Inc. P.O. Box 97 Lone Star, TX 75668 903-656-6317
Particulate control (wet)	Ionizing wet scrubbers		Ceilcote/Air Pollution Control 140 Sheldon Rd. Berea, OH 44017 216-243-0700
Particulate control (wet)	Flux force/condensation/collision scrubber		Calvert Environmental 5985 Santa Fe St. San Diego, CA 92109 619-272-0050
Particulate removal (wet)	High-energy scrubber		BECO Engineering Co. P.O. Box 443 Oakmont, PA 15139 412-828-6080
Particulate removal (wet)	Venturi scrubber		D. R. Technology, Inc. 11 Hidden Pines Dr. Clarksburn, NJ 08510 908-780-4664
Particulate removal (wet)	Venturi scrubbers		Air Pol Inc. 145 Cedar Lane Englewood, NJ 07631 201-871-3855
Particulate control (wet)	Froth scrubbers		Monsanto Enviro-Chem Systems, Inc. 14522 South Outer Forty Rd. St. Louis, MO 63178
Particulate removal (dry)	High-efficiency particulate air filter		BACT Engineering, Inc. 11 W. College Dr., Ste. K Arlington Heights, IL 60004 708-459-3580

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Particulate Control

APC Function	Technology Name	Details	Source/Contact
Particulate removal (dry)	Baghouses		United McGill Corp. P.O. Box 820 2400 Fairwood Ave. Columbus, OH 43216 614-443-0192
Particulate removal (dry)	Baghouses		Mikro Pul Environmental Systems 102 American Rd. Morris Plains, NJ 07950 201-606-5900
Particulate removal (dry)	Baghouse filter bags		Menardi-Criswell P.O. Box 240 (13) 1853 Martin Luther King Blvd. Augusta, GA 30901 800-321-3218 404-724-8241
Particulate removal (dry)	Baghouse filter bags		Tetratec Corp. 1731 Loretta Ave. Feasterville, PA 19047 215-355-7111
Particulate removal (dry)	Electrostatic precipitators		Beltran Associates 1133 East 35 St. Brooklyn, NY 11210 718-338-3311

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Particulate Control

APC Function	Technology Name	Details	Source/Contact
Particulate control (dry)	Ceramic candles		Industrial Filter and Pump Mfg. Co. 5900 Ogden Ave. Cicero, IL 60650-3888 708-656-7800
Particulate control (dry)	HEPA filter		Flanders Filters, Inc. P.O. Box 1708 Washington, NC 27889-1708 919-946-8081
Particulate control (dry)	Metal filters		Pall Trinity Micro Corp. Cortland, NY 13045 607-753-6041
Particulate control (dry)	Nested fiber filters		Battelle 505 King Ave. Columbus, OH 43201-2693
Particulate control (dry)	Gravity settling chambers		Parkson Corp. P.O. Box 408399 Ft. Lauderdale, FL 33340-8399 305-974-6610
Particulate control (dry)	Cyclones		Fisher-Klosterman, Inc. P.O. Box 11190 Louisville, KY 40211-0190 502-776-1505
Particulate control (dry)	Barrierless Ultrasonic Air Cleaners		S. R. Taylor and Associates 516 SW Kaw Bartlesville, OK 74003
Particulate control (dry)	Baghouses, ESPs		Research Cottrell
Particulate control (dry)	Baghouses, ESPs		Flakt
Particulate control (dry)	Baghouses, ESPs		Wheelabrator
Particulate control (dry)	Baghouses, ESPs		Lodge Cottrell

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
SO_x, NO_x Control

APC Function	Technology Name	Details	Source/Contact
SO_2 removal	Flakt SD/FF system: SD injects slaked lime slurry into flue gas. Lime feed rate controlled by SO_2 concentration. FF: filter through six Teflon-coated fiberglass bags. Continuous cleaning of bags (2 min each).	Spray dryer: flue gas leaving combustor and boiler is ducted to top of SD, distributed to three inlet dispersers, where lime is injected. Fabric filter: after SD, enters FF at 2,700 m^3/min @ 140°C. Net air-to-cloth ratio of 0.98 m^3/min-m^2.	
SO_2 removal in slagging coal combustor or industrial combined gas-steam turbine power plants	Calcium hydrate injection into slagging coal combustor	90–95% reduction of SO_2 emissions. Operates at >3000°F.	B. Zauderer Coal Tech Corp. P.O. Box 154 Merion Station, PA 10966
SO_2 removal	Scrubber—limestone injected into single loop absorber as dry material. Has grid packing, air rotating spargers, treats gas from multiple boilers.	>95% SO_2 removal from bituminous coals with 2–4.5% sulfur content. Treats flue gases from two cyclone-fired boilers with combined capacity of 528 MW.	Pure Air (Air Products and Chemicals and Mitsubishi Heavy Industries America)
SO_x removal	Lurgi circulating fluid bed FGD	SO_2 removal >95% at 400°C. NO_x removal >90% at 400°C. Ammonia is NO_x reducing agent—ammonia slip <5 ppm. 98% particulate material recirculated to fluid bed.	John Toher Environmental Elements Corp. Baltimore, MD 410-368-7000
SO_x removal from flue gas at petroleum refineries, primary non-ferrous smelters, utilities, etc.	Fabric filter, catalytic oxidation convertor, fluidized lime adsorber. End product is core of lime surrounded by shell of anhydrous calcium sulfate.	Near 100% SO_x removal. Temp. range 477–960°F, SO_x conc. up to 20,000 ppm. Exothermic process—flue gas temp. increases by 270°F for each percent SO_x in flue gas	Ping-Wha Lin Lin Technologies Inc. Angola, IN 219-665-5425

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
SO_x, NO_x Control

APC Function	Technology Name	Details	Source/Contact
SO_2 removal	FlueSorbents composed of hydrated lime supported on sand-sized vermiculite are injected into flue gas after it passes through the electrostatic precipitator. Currently working on duct injection system to deliver FlueSorbents to 5,000–6,000-acfm flue gas stream.	90+% SO_2 removal from 40°F flue gas. Lime utilization 60+%.	Sid Nelson, Jr. Sorbent Technologies Corp. Twinsburg, OH 216-425-2354 Fax: 216-425-3983
Hydrogen and sulfur recovery from hydrogen sulfide waste gas from natural gas purification and petroleum refining	Flue gas flows through microwave-generated plasma. Dissociates H_2S into hydrogen and sulfur. Sulfur recovered as liquid and recycled to refinery process.	Up to 90% conversion in a single pass, but two-pass approach with a lower conversion rate/pass is expected to be more economical.	John Harkness Argonne National Laboratory 708-252-7636 Fax: 708-252-9281
Sulfur removal	Flue gas desulfurization system		Ralph E. Keller Precision Components Corp. Box 15101, York, PA 17405-7101 717-848-1126 Fax: 717-843-5733
NO_x removal	Thermal DeNO$_x$ system injects ammonia into upper furnace		
NO_x removal	Low-NO_x concentric firing system Level 2—fuel and air introduced separately into main combustion zone and mix slowly. Some NO_x converts back to nitrogen, and in the overfire air zone, more air is introduced and burning of the coal is completed.	34–42% NO_x reduction	Developed by Combustion Engineering Inc. (*Air Tech News*, Oct. 1992, p. 139)

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
SO_x, NO_x Control

APC Function	Technology Name	Details	Source/Contact
NO_x removal	By modifying combustion chemistry in incinerator, NO_x emissions are reduced, thereby simplifying post-processing of combustion gases.	Allows incinerator operation at high temperatures while controlling NO_x emissions	Paper by A. K. Gupta and E. L. Keating, University of Maryland Dept. of Mechanical Engineering College Park, MD 20742-3035 301-405-5276 Fax: 301-314-9477 "Advanced Concepts for Waste Incineration with Special Reference to NO_x"
NO_x removal	Photocatalytic oxidation process		Takashi Ibusuki National Institute for Resources and Environment Agency of Industrial Science and Technology, Ministry of International Trade and Industry 16-3 Onogawa, Tsukuba, Ibaraki 305, Japan
NO_x removal	NO_x OUT PLUS: urea-based chemicals, water, and compressed air or steam are injected into furnace. Urea additive is processed so it creates compounds in situ that enhance NO_x removal.	<10 ppm NO_x produced. CO emissions ~0. Works at temps. of 1450–2100°F.	M. Linda Lin Nalco Fuel Tech Naperville, IL 708-983-3242 Fax: 708-983-3240
NO_x removal	Electro-Dynamic Venturi gas cleaning system (wet scrubber)—gas flows to an open spray tower, where it is saturated with scrubbing liquor injected through proprietary nozzles. Additives are injected for acid gas control and Denox.	During 9 months of testing at an incinerator handling 330 tons/day of municipal solid waste, the process lowered NO_x levels of 150–250 ppm by up to 85% without producing any detectable secondary pollution.	Gerwyn Jones Belco Technologies Corp. Parsippany, NJ 201-515-8911 Fax: 201-884-4775

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
SO_x, NO_x Control

APC Function	Technology Name	Details	Source/Contact
NO_x removal	NO_xMaster combination SCR/SNCR process. Uses SNCR in post-combustion zones of boiler furnace; then flue gas passes through catalyst bed. Ammonia created in SNCR step is used as the reducing step in the SCR stage.	SCR has high space velocity, short residence time, low pressure drop (<3 in. water pressure or as low as 1/2 in.)	M. Linda Lin Nalco Fuel Tech Naperville, IL 708-983-3242 Fax: 708-983-3240
NO_x, N_2O removal	Metal-exchanged zeolites used as catalysts for reduction of NO_x, N_2O.	100% conversion rate of N_2O in lab at temps. >400°C. Some catalysts stable at 750°C for long periods, even with a few percent water vapor.	John Armor Air Products and Chemicals, Inc. Allentown, PA 215-481-5791 or 215-481-2928
NO_x and SO_2 removal	Combination gas reburning and injection of calcium-based sorbent.	65% NO_x reduction (0.25 lb/10^6 Btu emitted), 50% SO_2 reduction with average sorbent injection rate of Ca/S molar ratio of 1.75. Ca utilization rate is 20–25%.	Leonard Angello Energy and Environmental Research Corp. Irvine, CA 216-682-4007
NO_x and SO_2 removal	Low-NO_x burners, overfire air, urea injection, dry sorbent injection using calcium and sodium-based sorbents, and a humidification system.	Urea injection reduces NO_x 30% with <5 ppm ammonia slip.	Terry Hunt Public Service Co. Denver, CO 303-329-1113
NO_x, SO_x removal	Two-stage cooling process. In first stage, 60–70% acid gas condensed through heat exchange, leaving nitric acid solution. This goes through a cyclonic centrifuge, which separates NO_2 and SO_2 from nitrogen, which is emitted.	90–99% SO_2 and NO_x removal	Fawzy Abdelmalek Abdelmalek Associates, Inc. St. Louis, MO 314-965-7000 Fax: 314-965-7021
NO_x removal (wet)			Tri-Mer Corp. 1400 Monroe St. Owosso, MI 48867 517-723-7838

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
SO_x, NO_x Control

APC Function	Technology Name	Details	Source/Contact
NO_x removal (wet)			Advanced Industrial Technology Corp. P.O. Box 555 Lodi, NJ 07644 201-265-1414
NO_x removal (wet)			Argonne National Laboratory Energy Systems Division 9700 South Cass Ave. Argonne, IL 60439 708-972-7636
NO_x removal (wet)			Heil Process Equipment 34250 Mills Rd. Avon, OH 44011 216-327-6051
NO_x removal (dry)	Selective catalytic reduction		Allied-Signal P.O. Box 580970 Tulsa, OK 74158-0970 918-266-1400
NO_x removal (dry)	Selective catalytic reduction		ARI Technologies 600 North First Bank Dr. Palatine, IL 60067 708-359-7810
NO_x removal (dry)	Selective catalytic reduction		Norton Co. P.O. Box 350 Akron, OH 44309 216-673-5860
NO_x removal (dry)	Selective noncatalytic reduction	Owns patent for Thermal De NO_x	Exxon Research and Engineering Co. P.O. Box 390 Florham Park, NJ 07932-0390 201-765-6742

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
SO_x, NO_x Control

APC Function	Technology Name	Details	Source/Contact
NO_x removal (dry)	Nonselective noncatalytic reduction		Riley Stoker Corp. 5 Neponset Worcester, MA 01610 508-852-7100
NO_x removal (dry)	Combination nonselective noncatalytic reduction and nonselective catalytic reduction Radian Corp. Hybrid Low NO_x Process		Radian Corp. 8501 Mo-Pac Blvd. P.O. Box 201088 Austin, TX 78720-1088 512-454-4797

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
VOC destruction	Filter to remove particulates. Solvent-laden air collection system, steam regenerated carbon adsorbtion, a decanter, and a solvent storage tank.	22,500 ft^3/min with 700 lb/h hexane. Zero wastewater discharge. Advanced monitors. Two years operation, 99% availability.	Barneby & Sutcliffe Corp. Columbus, OH (Pol. Eng., 6/15/92)
VOC destruction	Stand-alone oxidizer—afterburners fueled by natural gas and operated with excess air. Combustion efficiency improved by adjustable air injector and combustion blower with filter/silencer. Has Moldatherm ceramic fiber insulation.	98% VOCs destroyed, low levels of nitrogen oxides produced. Temp. adjusted to 600–2000°F System sized for 150,000, 400,000, and 500,000 Btu/h.	Jerry Novenski Linderg (unit of General Signal) Watertown, WI 800-873-4468 or 414-261-7000 Fax: 414-261-4962
VOC destruction (i.e., RCRA hazardous wastes) for high or variable VOC concentrations	Thermal incinerators with optional heat exchanger. Depending on type of heat exchanger, thermal incinerator is either recuperative (50–70% heat recovery in 2000–15,000 ft^3/min air flow) or regenerative (80–95% heat recovery in >6000 ft^3/min air flow).	Best at 100–500 ppmv, temps. 1400–1500°F, or 760–982°C (982°C necessary for 99.99% destruction for RCRA hazardous wastes). Supplemental fuel (such as natural gas) required.	
VOC destruction (i.e., painting and printing, but no RCRA hazardous wastes)	Catalytic incinerator, generally with heat exchanger for 50–70% heat recovery.	Best at 100–500 ppmv, temps. 600–700°F, or ~427°C, air flow 2000–15,000 ft^3/min. 99% VOC destruction. HCl, sulfur, or particulate-containing waste streams generally not suitable for this method.	
VOC destruction	Regenerative (ceramic) incinerators with dual heat exchangers.	Best at air flow 3000–4000 scfm, temp. 760°C, 100–400 ppmv. 98–99% destruction, thermal efficiency up to 95%.	

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
VOC destruction	Reducing process air flow rates (combining streams from several stations to make a more concentrated stream)	For sites with several stations producing low concentrations of VOC-containing effluent—makes incineration economically feasible.	
Nonchlorinated VOC destruction	Swingtherm system—a catalytic oxidation process	97–98% expected destruction efficiency. Outlet VOC concentrations are 3–5 ppm. Self-sustaining with regard to energy at contaminant conc. <0.6 g/m^3 (90% exhaust heat reclaimed).	Tom Burgess MoDo-Chemetics, Ltd. Vancouver, B.C. 604-734-1200 Fax: 604-734-0340
VOC destruction	VOC, combustion air, and gaseous support fuel premixed in an outward-fired Pyrocore burner element; then passed radially outward to burn on exterior of cylindrical burning element.	99.9+% VOC destruction	Paper by David F. Bartz, Fredrick E. Moreno (Alzeta Corp., Santa Clara, CA), and Patricia A. Duggan (Gas Research Institute, Chicago, IL) "Ultra-Low NO_x Ultra-High VOC Destruction with Adiabatic Radiant Combustors: Preliminary Results"
VOC destruction (i.e., aromatic and aliphatic organics in engine exhaust)	CONCAT: concentrated, high-activity catalyst	Emission conversion reductions observed in oxidation system burning diesel: 97% CO, 97.3% THC, 98.5% NMHC, 75% CH_4. Conversions in system burning diesel and natural gas: 95.2% CO, 92.7% THC, 97.1% NMHC, 91.9% CH_4.	Wilson Chu Johnson Matthey's Environmental Products Group Wayne, PA 215-971-3100 Fax: 215-293-1284
VOC destruction	Pulse combustion—rapid mixing and oscillating flow enhance VOC destruction.	99.95% destruction of waste stream with several thousand ppm perchloroethylene, trichloroethylene, 1,1,1-trichloroethane. Lab apparatus handles 10 scfm.	Taz Bramlette Sandia National Laboratories P.O. Box 969 Livermore, CA 94551-0969 510-294-2299 Fax: 510-294-1004

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
VOC destruction	BIKOVENT biofiltration system (filter media: composted sewage sludge for organo-sulfur compounds, composted mixed municipal waste for other VOCs). Nutrients come from filter media.	Handles 22,000–25,000 ft3/min of off-gas. Removes >95% organo-sulfur gases, >98% turpenes, >95% aliphatic compounds, >90% chlorinated solvents, >90% other VOCs.	Axel Bernau Biofiltration, Inc. Fort Lauderdale, FL 305-522-1900
VOC destruction	VOC-Abator catalytic oxidation systems—uses range of catalysts	Destruction efficiencies as high as 99.9%. Catalysts guaranteed for 1 year.	Donaldson Co. Inc. Minneapolis, MN
VOC destruction	Bed of ferroelectric pellets across which an alternate current electric field is impressed. Pellets have high dielectric constant. Porous stainless steel plates on either side—contaminated gas enters and exits through the plates.	99% destruction at bench-scale reactor which treats 20–50 ft^3/m	Wade Ponder EPA—Organics Control Branch 919-541-2818
VOC destruction	Flameless thermal oxidizer, can be used in hazardous locations (Class I, Div. 1 or 2, Group D) to destroy fugitive emissions. VOCs mixed with air and sent to ceramic matrix, where heat brings them to ignition temperature.	0.5-s residence time, 0.1-s destruction time. >99% removal efficiency observed in lab (99.99% for benzene and CCl_4).	Robert Martin Thermatrix Inc. (formerly In-Process Technology) San Jose, CA 408-944-0220
VOC destruction	Catalytic fume oxidizer destroys VOCs in exhaust from drying ovens. Catalyst is chosen for the particular application.	For air with low VOC concentrations. First installation involves a system designed to handle 500–1700 scfm of air containing nonchlorinated VOCs.	Jim Alimena Glenro Inc. Paterson, NJ 800-922-0106 or 201-279-5900 Fax: 201-279-9103

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
VOC destruction	Catalytic system with graded cell configuration—processor has a progressively staged catalyst bed. The catalyst is on a metallic substrate configured in a honeycomb structure.	Achieves 99+% destruction. Oxidation occurs at 500–800°F. The units maintain a 99+% destruction efficiency after 20,000 h. Catalyst has a 1,000+ h lifetime at 1800°F.	Frederick Moreno Alzeta Corp. Santa Clara, CA 408-727-8282 Fax: 408-727-9740
VOC, nitroaromatic, and chloroaromatic destruction	Biofiltration: microbial consortia that can metabolize nitroorganics and chloroaromatics.	Nitrobenzene utilization, up to 13.1 $g/m^3/h$. Chlorobenzene, dichlorobenzene, and biodegradable VOC utilization, 60.3 $g/m^3/h$.	Janice Olsen Beltran, Inc. Brooklyn, NY 718-338-3311 or 718-253-9028
VOC destruction	Catalytic destruction		Allied-Signal P.O. Box 580970 Tulsa, OK 74158-0970 918-266-1400
VOC destruction	Selective noncatalytic reduction		EMCOTEK 8220 Doe Ave. Visalia, CA 93291 209-651-2000
VOC destruction	Catalytic destruction		ARI Technologies 600 North First Bank Dr. Palatine, IL 60067 708-359-7810
VOC destruction	Catalytic destruction		Emission Control Systems, Inc. 1003 Clegg Court Petaluma, CA 94959-1151 707-765-1063
VOC destruction	Catalytic destruction		Johnson Matthey 436 Devon Park Dr. Wayne, PA 19087 215-341-8500

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
VOC surge control	Flares	Control 90–95% VOCs (not good enough to satisfy most environmental regulations). Used only for short-term high flow rate, high concentration surges.	
VOC control/solvent recovery	Activated carbon adsorption with Brayton cycle heat pump to regenerate carbon beds.	System demoded at 3M plant. 98% recovery of VOCs in 8000 scfm of solvent-laden air. Solvent is clean, pure, and low water content.	Nucon International, Inc. 7000 Huntley Road Columbus, OH 43229-1035 614-846-5710
VOC removal/recovery (i.e., removal of gasoline from air displaced from fuel transfer operations)	Refrigerated vapor condenser	Best at temps. around -80°C, flow rates <1000 scfm, VOC conc. at least several hundred ppm, low humidity. Recovery up to 90% at high vapor pressure or as low as 30% at low vapor pressure.	
VOC removal/recovery (i.e., controlling chlorinated hydrocarbon emissions from degreasers)	Solvent vapor adsorption—VOCs go through nonvolatile solvent which adsorbs most of the VOC. VOCs are stripped from the loaded solvent and recovered by partial condensation.	Best when VOC conc. is 100+ ppmv, flow up to several thousand scfm.	
VOC removal/recovery (i.e., water-insoluble organic compounds that are liquid at room temp. Not for organic compounds that are gases or low boiling liquids at room temp., air streams >38°C, air streams >50% humidity)	Regenerative carbon adsorption—VOCs adsorbed onto carbon; requires steam and compressed air for regenerating activated carbon beds	Best at 100–500 ppmv, 10–several hundred ppm VOCs. With two beds, can get 99.99% control.	

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
VOC removal (good for field use, but not for fluctuating air flow rates)	Once-through carbon adsorbtion. Air passes through carbon canisters	For VOC concentrations <100 ppmv. 0.3 lb VOCs per pound carbon at 100 ppm, 0.15 lb VOCs per pound carbon at 5 ppm. Steam stripping leaves 0.13–0.2 lb VOCs on the carbon.	
VOC removal/recovery (from reactors, storage tanks, dryers)	Kryoclean vapor recovery—nitrogen blanket captures VOCs and cools them into a liquid.	VOC emissions reduced 95–99%. Operating temp. –70 to –150F.	Michael Heil Airco Gases Murray Hill, NJ 908-771-1474
Biodegradable VOC removal	Biofiltration—beds of biologically active material (compost or peat 1 m thick) that metabolize air contaminants from off-gas streams in a solid phase reactor	>90% control efficiency	Gero Leson RMT Inc., Santa Monica, CA Arthur M. Winer UC Los Angeles
VOC removal	Condensation of solvents in flue gas by reverse Brayton cycle, indirect heat exchangers (Rankine or Brayton cycle refrigeration system), or direct-contact heat exchange using a cooled or cryogenic fluid	Indirect heat exchange—Reverse Brayton cycle can produce temps <–60°F more cheaply than by refrigeration.	Paper by Paul Scheihing, US DOE/OIP, and Victor S. Engleman, SAIC, San Diego, CA Presented at 84th Annual Meeting & Exhibition of the Air & Waste Management Association, Vancouver, B.C., June 16–21, 1991 "National Energy Benefits from Recovery and Recycling of Volatile Organic Compounds and the Evaluation of Control Options"
Benzene and VOC removal and recycling from refinery waste streams	Closed-loop wastewater treatment system: VOC removed by nitrogen stripping and activated carbon adsorbers. Adsorbed VOCs removed by steam stripping, then condensed and recycled.	Handles 350 gal/min wastewater with 5 ppm benzene, 21 ppm VOCs and 60 ppm total petroleum hydrocarbons. 99% VOC removal, 98% benzene removal. Closed-loop system eliminates emissions.	Developed by Texaco Development Corp., exclusively licensed to Westates Carbon, Inc. Los Angeles, CA

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
VOC removal	Carbon adsorption system, regenerable on-site. Carbon bed regenerated by steam stripping. Chemical-laden steam then passes through a condenser, and the liquid is separated by gravity separation.	99+% VOC recovery (including halogenated solvents). Standard unit handles 300-scfm flow continuously or 600 scfm in batch mode. No limits on maximum concentration.	John Haas Kelco Group, Inc. Raynham, MA
VOC removal	Mobile biofilter—compact version of stationary system used for larger projects. Contaminated air is pumped up through perforated pipes and through filter media such as compost or soil. Air is humidified before passing through filter.	Can handle air flow up to 100 scfm. 90–99.9% removal rate observed in air streams between 25 and 100 scfm, with 200–8,000 ppm VOCs.	Hinrich Bohn Bohn Biofilter Corp. Tucson, AZ 602-624-4644 Fax: 602-634-2518
Water-soluble, biodegradable VOC removal	Bioscrubber—wet scrubber loaded with microbes. Water flows down through the packing while air flows up—water recirculated at 5 gal/min. Liquid nutrient solution added daily; phosphate buffer added continuously.	>95% VOC removal from a sample with total contaminant concentration of 275 ppm (volume). Operated without biomass, scrubber removed 85% of the chemicals at a flowrate of 8 m^3/min at 37°C. Load rates range from 100–125 g/m^3/h.	Paul LeFevre Coors Brewing Corp. Golden, CO 303-277-2338 Fax: 303-277-6426
Chlorinated VOC removal	Liquid-phase absorption process—contaminated air flows upward through an absorber while a micellar absorbent flows downward.	MEA process tested on air flows of 800–2200 cm^3/min containing trichloroethylene or methylene chloride at levels ranging from 2 to 80 ppmv.	James Kittrell KSE, Inc. Amherst, MA 413-549-5506 Fax: 413-549-5788
VOC removal	Activated carbon adsorption		Flakt Inc. P.O. Box 59018 Knoxville, TN 37950-9018

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
VOC removal	Activated carbon absorption		Hugo Petersen, Philipp Holzmann/Steinmuller Group P.O. Box 45 900 19th St. 5th floor Washington, DC 20036 202-452-6078
VOC removal	Activated carbon absorption		Studsvik Nuclear Route 2, Box 399C Kingston, TN 37763 615-376-7300
VOC removal	Activated carbon adsorption		CSC P.O. Box 3 Route 92 East Bath, NC 27808 919-923-2911
VOC removal/destruction	Carbon adsorber-incinerator system: Carbon filters out VOCs, then is stripped with warm air, which is routed to incinerator.	For high-volume, low-VOC content stream. Original stream has <100 ppm VOCs, second stream has a few hundred ppm VOCs.	
VOC concentration	Concentrator: extended media surface (honeycomb structure) treated with VOC adsorbent (activated carbon or hydrophobic zeolite). Acts as rotor that continuously rotates between solvent-laden exhaust and desorption air flows.	For flows >5000 ft^3/min, <500 ppm VOCs.	*Pollution Engineering 9/15/92,* p. 32–33 article by Derrick Drohan, "Different Route to VOC Control"

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
Concentrator for VOCs, including chlorinated hydrocarbons	Cyclosorbon concentrator for removing low levels of volatile organic compounds	Removal efficiency 90+%, depending on contaminant. Can handle contaminant levels to a few thousand ppm, no lower limit. Uses carbon as sorbent but can also use zeolite for methanol, alcohols, and high-humidity exhaust. Special materials needed for chlorinated organics.	John Ruhl Dedert Corp. Olympia Fields, IL 708-747-7000 Fax: 708-755-8815
Trichloroethylene, tetrachloroethylene destruction in contaminated air resulting from soil vapor extraction and air stripping	Four annular bed reactors packed with TiO_2 pellets and operated in parallel	99% TCE, PCE conversion to CO_2 or an intermediate TCE conc. reduced to 3 ppm. Operated at 60°C. Porosities of 50–56% and specific surface areas of 160–194 m^2/g produced in TiO_2 sintered at 300°C.	Marc Anderson University of Wisconsin Madison, WI 608-262-2674 Fax: 608-262-0450
Degradation of trichloroethylene, tetrachloroethylene	Form of *Pseudomonas cepacia* G4 5223 Phe1. Bacterium produces a constitutive enzyme that mineralizes TCE without an inducer chemical.	92.1% removal. Bacterium grown in thin aqueous biofilm on an inert support. 0.51 mg TCE/h/kg of support material.	Malcolm Shields Univ. of West Florida, Gulf Breeze 904-934-2446 Bacterium licensed for commercialization to SBP Technologies, Inc., Stone Mountain, GA
Trichloroethylene, tetrachloroethylene reduction	Laboratory photocatalytic reactor—air is humidified and flowed through the reactor.	TCE level reduced to <0.2 µg/L (within only 5 min of operation). Operates at ambient temp.	Ko-Ming Wang Purdue University, Civil Engineering Rm. 3104B West Lafayette, IN 47907
Trichloroethylene destruction	Photolytic oxidation system—exposes volatilized hydrocarbons to ultraviolet light from a xenon flashlamp.	99% destruction levels of TCE during a field test. Field test involved airflows of up to 500 ft^3/min. Initial TCE concentrations about 250 ppm (volume).	Purus, Inc., San Jose, CA For further information, read EPA bulletin EPA/540/F-93/501, available from EPA at 513-569-7562

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
Trichloroethylene oxidation	Catalytic oxidation of TCE in air over 1.5% Platinum on g-Alumina	99.9% oxidation of 40–250 ppm TCE, temp. range 150–550°C.	Paper by Yi Wang,[1] Henry Shaw,[1] and Robert J. Farrauto.[2] [1]Department of Chemical Engineering, Chemistry, and Environmental Science, New Jersey Institute of Technology, Newark, NJ 07102. [2]Engelhard Corp., Menlo Park R&D, Edison, NJ 08818. "Catalytic Oxidation of Trace Concentrations of Trichloroethylene over 1.5% Platinum on g-Alumina"
Solvent recovery, especially from air containing ketones and chlorinated hydrocarbons	Carbon adsorbtion with advanced reverse Brayton cycle heat pump. Patented by 3M, called Braysorb.	>99.5% solvent recovery. Carbon adsorbers are regenerated by evacuating beds with a dedicated vacuum pump and using hot nitrogen to desorb the solvents.	Joe Anneking NUCON Columbus, OH 614-846-5710 Fax: 614-431-0858
Organic removal	Highly cross-linked styrenic polymeric adsorbent XUS 43493.01. Regenerable with steam, hot air, inert gas.	Can be used in stream with ~100% humidity. Total pore volume = 1.16 cm^3/g, BET surface area = 1100 m^2/g. Absorbency = 1.2 g perchloroethylene/g adsorbent (conc. 25,000 ppm), 0.8 g PCE/g adsorbent (conc. 5,000 vppm), 0.5–0.6 g trichloroethylene/g adsorbent (conc. 5,000 vppm). Not for hot gas temps >120°C.	Robert Goltz Dow Chemical Co. Midland, MI 517-636-6880
Halogen oxidation (works best with steam in effluent)	Platinum group metal catalysts	Experimental results: 99% destruction rates for CCl_4, chloroform, and trichloroethylene. Good at temperatures >1350°F.	Wilson Chu Johnson Matthey's Environmental Products Group, Wayne, PA 215-971-3100 Fax: 215-293-1284

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
Steam detoxification of hazardous combustibles	Synthetica Detoxifier: vaporizes liquid organics, destructs organic vapors, disposes of solid residue	Detoxifies gases, liquids, solids up to 5 drums organic waste/day. 99.99% or greater destruction.	Synthetica Technologies, Inc. Richmond, CA
Carbon tetrachloride vapor removal/recovery	Particulate air filter, compressor, condenser, and membrane modules with vacuum	95–96% CCl_4 removal. CCl_4 concentrates to 25,000 ppm on permeate side of membrane; clean air stream contains 50 ppm of contaminant. Permeate collected as liquid for reuse.	Craig King Membrane Technology and Research, Inc. Menlo Park, CA 509-376-2967 Fax: 509-373-5044
Chlorinated organic and aromatic removal	Air with contaminant is exposed to ozone and a granular catalyst; then flows through bed of sorbent, which removes acids.	99% removal in air streams containing 2000–3000 ppm contaminants by volume.	Jack Zeff Ultrox Santa Ana, CA 714-545-5557
Aromatics control	Bioscrubber—air pushed through liquid water slurry, biogrowth, and nutrients. Results in almost simultaneous biodegradation of contaminant. Theoretically, system could handle chlorinated hydrocarbons.	System handles 5,000–10,000 ft^3/min air containing primarily benzene at ppm level (can handle loads up to 2000 ppmv). Degradation occurs in a few seconds or up to a minute. 98+% benzene destruction.	Charles Chou Shell Development Co. Houston, TX 713-493-8373 Fax: 713-493-8727
Trace aromatics control	Bioscrubber—four units in parallel operation. Selected bacteria are grown on biocolumns containing activated carbon medium.	In tests, reduced 10 ppm toluene to <100 ppb. VOCs almost eliminated. Handles large volumes of air with trace levels of contaminants.	Paul Liu Aluminum Company of America Pittsburgh, PA 412-826-3711

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
Organics removal	Silent discharge plasma —a cold plasma process where large quantities of free radicals are produced by "hot" electrons. Waste gas passes between two electrodes, with alternating voltages as high as several kilohertz. The resulting microdischarges that occur in the gas create the plasma.	Prototype SDP system at LANL treats air streams up to 10 L/min. Planer cell operates at 100–1000 W. In tests, effluent with 1000 ppm trichloroethylene can be reduced to <100 ppb. Electrical energy required for 99% TCE removal was in the tens of kW-h/kg range. Future designs will reduce to <10 ppb.	John Coogan Los Alamos National Laboratory 505-665-0186 Fax: 505-665-4632
Methane emissions reduction	Noble metal catalysts for catalytic removal of methane		Paper by S. H. Oh, P. J. Mitchell, and R. M. Siewert, General Motors Research Laboratories, Warren, MI 48090. "Methane Oxidation over Noble Metal Catalysts as Related to Controlling Natural Gas Vehicle Exhaust Emissions"
Hydrocarbon treatment in effluent (either simultaneous water and air treatment or in air only)	Biopur technology—can be used to simultaneously treat hydrocarbons in water and air or can be operated as a biotrickling filter when only a gaseous waste stream must be dealt with. Biopur reactor is aerobic, fixed-film system filled with polyurethane as the carrier material of the biomass.	>98% destruction efficiency has been achieved with no VOCs detected in exhaust gas. Handles xenobiotics (BTEX, mineral oil, naphthalene). Hydraulic retention time <15 min when both vapors and groundwater are processed.	L.G.C.M. Urlings TAUW Infra Consult B.V. The Netherlands Phone: 31-5700-99707 Fax: 31-5700-99666
Halogenated hydrocarbon destruction	HDC Catalyst	250–450°C, 3,000–30,000 GHSV, water vapor 0.50–10.0% V/V, pressure drop 0.4 in. H_2O per inch bed depth @ 400°C, 250 ft/min gas velocity (STP). Destruction efficiency >99%. Not deactivated or inhibited in the presence of halides.	Allied Signal Inc. P.O. Box 580970 Tulsa, OK, 74158-0970 918-266-1440 Fax: 918-266-3251

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
VOC Control

APC Function	Technology Name	Details	Source/Contact
Halogenated hydrocarbon control	Catalytic degradation of hydrocarbons		Paper by Jong-Liang Lin and Brian E. Bent, Department of Chemistry, Columbia University, New York, NY 10027. "Thermal Decomposition of Halogenated Hydrocarbons on a Cu(111) Surface"

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Metals Control

APC Function	Technology Name	Details	Source/Contact
Mercury removal	Powdered activated carbon injection into mixed waste incinerator. Increase in carbon feed rate causes greatest increase in mercury removal and in consistency of results.)	Test data using revised method 101A. NH_3 injection, lime feed rate, and fabric filter temperature have little effect on mercury removal.	Radian Corp. EPA Research Triangle Park (paper from Air & Waste Management #92-40.06)
Mercury removal from municipal waste combustor	Powdered activated carbon injection	Carbon feed rate influences amount of mercury collected. Mercury removal not influenced by NH_3 injection, lime feed rate, or fabric filter temperature.	Paper by David M. White, Kristina L. Nebel (Radian Corp., RTP, NC) and Theodore G. Brna, James D. Kilgroe (US EPA, RTP, NC) Presented at Air & Waste Management Assoc. 85th Annual Meeting & Exhibition, Kansas City, MO, June 21–26, 1992
Mercury removal	Wet scrubbing		Boliden
Mercury removal	Carbon injection into incinerator flue gas	Carbon injection at 5.4 kg/h reduces mercury up to 98%	Article: Air & Water Pollution Report, 8/24/92, p. 266
Chromium recovery from plating wastes	Calcination (roasting); chromium oxide reacts with soda ash to form sodium dichromate, which is removed with acid leaching.	90% recovery	Paper by B.A. Bolto, M. Lotowaski, L. Pawlowaki, "Recovery of Chromium from Plating Wastes"
Capture of vapors forming metal particulates	Sorbents capture metals during incineration (FBI). Exp. 7.6 cm ID FB of sand, limestone, aluminum oxide.	20–90% capture efficiency, depending on sorbent type and incinerator operation conditions	Paper by T. C. Ho et al., "Metal Capture During Fluidized Bed Incineration of Wastes Contaminated with Lead Chloride"
Metal removal	Activated carbon adsorption		Flakt Inc. P.O. Box 59018 Knoxville, TN 37950-9018 615-693-7550

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Metals Control

APC Function	Technology Name	Details	Source/Contact
Metal removal	Activated carbon absorption		Hugo Petersen, Philipp Holzmann/Steinmuller Group P.O. Box 45 900 19th St., 5th floor Washington, D.C. 20036 202-452-6078
Metal removal	Activated carbon absorption		Studsvik Nuclear Route 2, Box 399C Kingston, TN 37763 615-376-7300
Metal removal	Activated carbon absorption		CSC P.O. Box 3 Route 92 East Bath, NC 27808 919-923-2911
Metal removal	Selenium filters		Boliden Contech AB Skelleftea, Sweden
Metal removal	Activated carbon absorption	Mercury removal and radioiodine control	Nucon International, Inc. 7000 Huntley Road Columbus, OH 43229-1035 614-846-5710

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Acid Gas Control

APC Function	Technology Name	Details	Source/Contact
Acid gas removal	Packed-bed scrubbers, spray dryer absorption		Air Pol Inc. 145 Cedar Lane Englewood, NJ 07631 201-871-3855
Acid gas removal	Packed-bed scrubber		Tri-Mer Corp. P.O. Box 730 1400 Monroe St. Owosso, MI 48867 517-723-7838
Acid gas removal	Packed-bed scrubber, tray scrubber		SWEMCO Inc. P.O. Box 680 253 West 18th St. Old Chelsea Station New York, NY 10113-0860 212-645-0440
Acid gas removal	Spray scrubber, spray dryer absorption		General Electric Environmental Services, Inc. 200 North 7th St. Lebanon, PA 17042 800-642-6789 717-274-7000
Acid gas removal	Tray scrubbers		Ceilcote/Air Pollution Control 140 Sheldon Rd. Berea, OH 44017 216-243-0700
Acid gas removal	Packed-bed scrubber, dry sorbent injection		Interel Corporation P.O. Box 4676 Englewood, CO 80155 303-773-0753
Acid gas removal	Packed-bed scrubber		Glitsch P.O. Box 660053 Dallas, TX 75266-0053

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Acid Gas Control

APC Function	Technology name	Details	Source/Contact
Acid gas removal	Tray scrubber		W.W. Sly Manufacturing P.O. Box 5939 Cleveland, OH 44101 800-334-2957 216-238-2000
Acid gas removal	Packing media		Jaeger Products, Inc. P.O. Box 1563 Spring, TX 77383 800-678-0345 713-444-9500
Acid gas removal	Packed-bed scrubber		Anderson 2000 306 Dividend Drive Peachtree City, GA 30269 404-997-2000
Acid gas removal	Packing media		Koch Engineering Co. P.O. Box 8127 4111 East 37th Street North Wichita, KS 67208 316-832-5668
Acid gas removal	Spray scrubber, dry sorbent injection		Research-Cottrell P.O. Box 1500 Somerville, NJ 08876
Acid gas removal (dry)	Dry sorbent injection		Lugi Corp. 3700 Koppers St. Suite 101 Baltimore, MD 21227
Acid gas removal (semidry)	Spray dryer absorption		BECO Engineering Co. P.O. Box 443 Oakmont, PA 15139 412-828-6080

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Acid Gas Control

APC Function	Technology name	Details	Source/Contact
Acid gas removal (semidry)	Spray dryer absorption		D. R. Technology, Inc. 11 Hidden Pines Dr. Clarksburn, NJ 08510 908-780-4664
Acid gas removal (semidry)	Spray dryer absorption		United McGill Corp. P.O. Box 820 2400 Fairwood Ave. Columbus, OH 43216 614-443-0192
Acid gas removal (wet)	Wet fluidized bed scrubbers		Airotech, Inc. Boyle Center 120 Ninth Ave. Homestead, PA 15120 412-462-4404
Acid gas removal (wet)	Wet fluidized bed scrubbers		BACT Engineering, Inc. 11 W. College Dr., Ste. K Arlington Heights, IL 60004 708-459-3580

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Control of Other Contaminants

APC Function	Technology Name	Details	Source/Contact
Recycling technology for selective catalytic reduction catalysts used in NO_x abatement	Removes contaminated catalyst coating from surfaces of ceramic honeycomb supports; then recoats with fresh catalyst. Ceramic substrates can receive multiple recoatings, and recycled catalyst has same life span as original.	Reduces catalyst life-cycle costs 20% over 6 years.	Lee Morris Engelhard Corp. 908-205-5379 Fax: 908-205-6146
Odor, fume removal	Dual-stage JH modular scrubbing system. Towers equipped to regulate concentration of scrubbing chemicals and can achieve full emissions reduction.	Air streams from 2,000–40,000 ft^3 /min. Has two 16-ft towers packed with 10 ft of plastic media. Caustic soda solution (9.5 pH) in first tower removes 80% H_2S.	Davis Process Division Tallevast, FL 800-345-3982
Ash vitrification and recycling	Combustion and melting system	For industrial and utility coal-fired boiler ashes, municipal solid waste incinerator ashes, hazardous waste incinerator ashes, postconsumer waste glasses, waste fiberglass materials, and mixed organic/inorganic-containing hazardous wastes.	Vortec Corp. Collegeville, PA 800-441-7475
Removal of sulfur from coal	Organic sulfur oxidized to organic sulfur oxide or moieties, such as organic sulfate, and enzymatic removal of the organic sulfate. Oxidation of carbon in the coal matrix is varied by varying the type of oxidant, the oxidant concentration, duration of contact between coal and oxidant, pH, temperature, and oxygen availability.	Up to 80% total sulfur removal.	Russel Stanley Houston Industries, Inc. Houston, TX 713-629-3000

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Control of Other Contaminants

APC Function	Technology Name	Details	Source/Contact
Semiconductor gas control (arsine, phosphine, organometallics, corrosives, tungsten hexafluoride)	Epigrade resin beads—dry chemical scrubber—converts semiconductor gas to nonvolatile salts or oxides.	99.99% removal efficiency. Toxics trapped in pores inside resin beads. Spent beads are considered nontoxic and nonhazardous.	Stephen Griffing Novapure Corp. Danbury, CT 230-790-0048

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Combined Functions

APC Function	Technology Name	Details	Source/Contact
Mercury and dioxin removal	Dry flue gas desulfurization with activated carbon	90% Hg, 98% dioxin	Joy Environmental Technologies, Inc. Allan D. Kissam Director of Sales Tower Park North 10700 North Freeway Houston, TX 77037 713-878-1000 Fax 713-591-2295
Gaseous alkali metal compounds and particulate removal	Pass flue gas through fixed bed of sorbent (diatomaceous earth and activated bauxite)	Capture is a function of internal surface area, temperature, gas velocity through sorbent bed.	Paper by S.H.D. Lee, I. Johnson, "Removal of Gaseous Alkali Metal Compounds from Hot Flue Gas by Particulate Sorbents"
SO_x, NO_x, and particulate removal	S_{ox} N_{ox} R_{ox} B_{ox}		Babcox and Wilcox
SO_2, NO_x, and particulate removal	Sorbent bed with proprietary, chemically modified zeolite	(In development stages) Tested on flue gas containing 100 ppb Hg. Effectiveness not influenced by flue gas temperature or humidity.	Richard Schlager ADA Technologies, Inc. Englewood, CO 303-792-5615
Hg, SO_x, selenium, and boron removal from flue gas of coal-fired power plants	Activated carbon (CHEMVIRON C with a BET surface area of 950 m^2/g) injected into gas prior to a spray dryer absorber	90% Hg removal, 90% SO_2 removal.	Richard Gleiser Joy Environmental Technologies, Inc., Monrovia, CA Karsten Felsvang Niro, Inc., Columbia, MD 410-997-8700
Scrubber for removal of miscellaneous contaminants	Horizontal, open-flow spray-type scrubber, can use ammonia gas as scrubbing medium for greater efficiency	Efficient mass contact—with ammonia as scrubbing medium, >99% SO_2 removed, 99.9% pure ammonium sulfate produced. Some NO_x also removed. Max operating temp 140°F.	B.D.E. Prazmowski Front Wave Inc., Mississauga, Ont. 416-803-8835 Fax: 416-803-8836

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Combined Functions

APC Function	Technology Name	Details	Source/Contact
Acid gas, particulate, organic, and trace element removal from coal-fired boilers, municipal solid waste incinerators, and hazardous waste incinerators	Spray dryer absorption (SDA) with particulate collection in either electrostatic precipitator (ESP) or fabric filter (FF). Acid gases removed through chemical reaction between the gas and alkaline reagent. Heavy metals (except Hg) condense on fly ash particles and are removed as part of particulate removal process. Hg, dioxin, and other organics removed by adsorbtion by activated carbon injection.	95–99% acid gas removal for HCl, SO_2, SO_3, HF, HBr, etc. 99+% metal removal for most species. 97–99% dioxin and furan removal. Can accept flue gases >2000°F.	Paper by Of B. Christians (Inc., Columbia, MD) and Bert Brown (Joy Environs. Tech., Monrovia, CA) presented at Air & Waste Management Assoc. 85th Annual Meeting & Exhibition, Kansas City, MO June 21–26, 1992 "Control of Heavy Metals and Dioxins from Hazardous Waste Incinerators by Spray Dryer Absorption Systems ad Activated Carbon Injection"
HCl, CDD/CDF and particulate removal	Application and maintenance of sorbent filter bed of sodium bicarbonate and fly ash	Emissions reduced far below levels expected by regulators or APC manufacturer. Sorbent bed maintained between 154°C and 176°C.	Paper by David C. Avina Colorado Incineration Services, Inc. 1624 Market St., Denver, CO 80202 303-534-4118 Fax: 303-534-4192 "Air Pollution Control Filter Operation to Reduce HCl, CDD/CDF and Particulate Emission"
SO_x, NO_x, metals, toxics removal	Dry adsorption—two-stage adsorber, specially manufactured activated coke flows downward, flue gas moves upward. Coke also serves as granular filter for removing flyash. AC is regenerated.	100% SO_x removal, >80% SO_x removal, 99% removal of selected toxins (90–99% Hg, 50% HCl, 99% polychlorinated dibenzo-p-dioxins, 99% polychlorinated dibenzofurans). Can be used with coal up to 4% sulfur by weight.	Rich Dague General Electric Environmental Services, Inc. Lebanon, PA 717-274-7000

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Combined Functions

APC Function	Technology Name	Details	Source/Contact
Process exhaust cleaning	CDO vertical reactor: thermal decomposition/oxidation and liquid cooling/scrubbing. Process off-gases and an oxygen source mix in thermal reaction chamber. Energy added by heating element.	CDO system achieves emission levels <10 ppm for acid gases (HCl, HF) and <5 ppm hydrides.	Roger McKinley Delatech Inc., Napa, CA 800-886-1968 or 408-262-1631 Fax: 408-262-0507
NO_x, acid gas, chlorinated hydrocarbons, Hg, and dioxin/furan removal	METHANE-deNO_x—combination of natural gas injection, flue gas recirculation, dry sorbent injection	Trial reductions: 50–60% NO_x, 40–50% CO. Goal reductions: <80 ppmv NO_x, <40 ppmv CO and total hydrocarbon emissions, HCl by 95%, SO_x by 85%, dioxin/furans to <5 ng/dscm. 12.5% or higher natural gas injection rate gives emissions of 80 ppmv NO_x, 35 ppmv CO.	Richard Biljetina Institute of Gas Technology 312-890-6418 Fax: 312-890-6419
SO_x and particulate removal	Integrated flue gas treatment technology—condensing heat exchanger is operated in a downward gas flow mode to maximize sensible heat recovery and a second unit is operated in an upward gas flow mode to serve as a wet scrubber.	In pilot-scale tests, system removed 89.3% particulates, 99.1% SO_2, 99.3% SO_3. During tests, unit treated 65% of the flue gas from a 14,000 pph rated boiler producing an average of 7,000-8,000 pph of steam at 100 psig. Fuel was 1.5% sulfur, No. 6 residual fuel oil.	Consolidated Edison Company (field tester) New York, NY Condensing Heat Exchanger Corp. (system supplier) Warnerville, NY John Heaphy 212-460-6097
Acid, base, solvent, organic and inorganic contaminants, and water vapor removal	Purifier with variety of solid scrubbing agents—in the dry scrubber, gas flows downward through a series of solid, medium-coarse grade scrubbing agents.	In tests, removal of 99% hydrochloric acid, ammonium hydroxide, methyl ethyl ketone, isopropyl alcohol, ethanol, acetone, and tetrachloroethylene.	Steven Adam McDonnel Douglas Space Systems Co. Huntington Beach, CA 714-896-5212 Fax: 714-896-331 ext. 6-9339

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Combined Functions

APC Function	Technology Name	Details	Source/Contact
NO_x, VOC removal	Econ-NO_x process—fluidized bed of metal oxide catalyst tolerates particulates, chloride, sulfur dioxide, and other contaminants. Catalyst is a shallow bed of 1/8th-in. spheres of non-noble metallic oxides on a hardened ceramic support.	Reduces VOCs, present in the flue gas at 10–200 ppm, and provides ~90% conversion of CO, present in starting concentrations of 200–3500 ppm. VOCs oxidized at inlet temperatures of 550–750°F.	Ed Addison ARI Technologies, Inc. Palatine, IL 708-359-7810 Fax: 708-359-3700
Nonmethane hydrocarbon and NO_x removal (in light-duty automobile exhaust)	Catalyst technologies		Paper by Jerry C. Summers and Ronald G. Silver, Allied-Signal Automotive Catalyst Co., P.O. Box 580970, Tulsa, OK 74158-0970. "Catalyst Technologies to Meet Future Emission Requirements for Light-Duty Vehicles"
Methanol, formaldehyde, hydrocarbon, and NO_x removal (in automobile exhaust)	Pd/Rh three-way catalyst for three-way emission control		Paper by W. Burton Williamson, Jerry C. Summers, and John A. Scaparo, Allied-Signal Automotive Catalyst Co., P.O. Box 580970, Tulsa, OK 74158-0970. "Automotive Catalyst Strategies for Future Emission Systems"
NO, NH_3 removal	Vanadia catalysts supported over titania and unsupported V_2O_5 catalysts		Paper by U.S. Ozkan, Y. Cai, and M. W. Kumthekar, Department of Chemical Engineering, The Ohio State University, Columbus, OH 43210. "Selective Catalytic Reduction of Nitric Oxide with Ammonia over Supported and Unsupported Vanadia Catalysts"

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Combined Functions

APC Function	Technology Name	Details	Source/Contact
Chlorinated hydrocarbon destruction, poison resistant VOC oxidation, odor removal, NO_x removal	PURZAUST catalysts	Air toxin destruction efficiency >99%.	Allied-Signal Inc. P.O. Box 580970 Tulsa, OK 74158-0970 918-266-1400 Fax: 918-272-4314

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Monitoring Technologies

APC Function	Technology Name	Details	Source/Contact
Particulate monitoring	Triboelectric nonoptical continuous monitor. Based on principle of frictional electrification; measures charge transfer that takes place when particles collide in a gas stream.	Signal is proportional to particulate emission rate. Not affected by temp. changes or gases that do not exhibit charge transfer characteristics. Can detect particles <0.5 μm.	Robert Newton Auburn International, Inc. Danvers, MA 800-255-5008 or 508-777-2460
Contaminant monitoring (i.e., VOCs and ammonia) (in variety of media, i.e., water, air)	Integrated optic sensors. Two-dimensional planar wave guide conducts light from source to receiver; alteration of light indicates contaminants present.	Photonic Sensor System wave guide can be coated to react only with contaminant of interest. Detection limit ~10 ppb.	John Edwards Photonic Sensor Systems Atlanta, GA 404-875-1028 Fax: 414-894-4545
VOC monitoring	CDS CAM 5000—vacuum pump pulls air into sorbent trap. Organics backflushed to a gas chromatograph for analysis.	Air flow and sampling time are variable.	CDS Analytical, Inc. Oxford, PA 800-541-6593
Volatile sulfur compound monitoring	Flame photometric detector (FPD) for Auto System Gas Chromatograph	For use in samples such as petroleum fractions and pump milling process streams. In lab, FPD used for stack gas analysis, pesticide analysis, analysis of alkyl tin compounds in sea water.	Edward Bloch Perkin-Elmer 203-761-5472
Real-time monitoring and measurement of polycyclic aromatic hydrocarbons (PAHs) bound to carbon aerosols	Photoelectric Aerosol Sensor (PAS) uses uv photoionization. Monitors in ambient air or stack. Calibration is site specific, involves running monitor simultaneously with a traditional technique.	Sensitive to nanogram/cubic meter. Monitor mostly ionizes four or more ringed PAHs. For stack emissions, sample conditioned using dilution ratio of 1:5 to 1:10.	E.D. Chikhliwala EcoChem Technologies, Inc. West Hills, CA 818-347-4369 Fax: 818-347-5639

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Monitoring Technologies

APC Function	Technology Name	Details	Source/Contact
NO_x monitoring	MCS 100 infrared laser with folded-path sample cell (has length needed to detect low levels of pollutants, can make real-time correction for CO_2 and H_2O interference). Uses gas filter correlation or singe beam, dual wavelength.	Combined interferences <4%. Detection in hot/wet instrument to 0–50 ppm NO, 0–35 ppm CO, 0–30 ppm SO_2, 0–20 ppm HCl, 0–20 ppm ammonia, 0–20% CO_2, 0–40% H_2O. In dry/cold instrument, detection to 0–50 ppm NO, 0–15 ppm NO_2, 0–35 ppm CO, 0–10 ppm SO_2, 0–20% CO_2, 0–5% H_2O.	Richard Hovan Environmental Elements Corp. Baltimore, MD 410-368-6733 Fax: 410-368-6797
NO_x monitoring	pro-NO_x 3000—offers three-point and live gas calibration. Selectable measuring ranges and various probe insertion lengths.	Operates at temps. up to 500°F and in hostile conditions. Exceeds EPA specs for major pollutants from plants burning fossil fuels, incineration, other combustion processes.	Paul T. Piergross Land Combustion 2525-B Pearl Buck Rd. Bristol, PA 19007-6807 215-781-0810 Telex: 4976004 Fax: 215-781-0798
NO_x control advice (computer program)	NO_xPERT—interactive computer program. Estimates NO_x emissions, performs a preliminary control analysis and a detailed control analysis. Select controls to meet emissions targets, provides cost estimates.	Runs on IBM PCs, ATs, and PS/2's equipped with EGA graphics and DOS 2.0 or higher. Program based on EPRIGEMS format. Not a substitute for emissions testing or detailed engineering studies.	Angelos Kokkinos EPRI 415-855-2494 Program to be released through Electric Power Software Center (article in *EPRI Journal*, 12/91, pp. 38 and 39)
H_2S monitoring for confined spaces	Portable hydrogen sulfide monitor, Model GC-701.	Flashes warning light in presence of H_2S; then sounds an alarm when toxic levels are reached.	Kathi Hunt GC Industries, Inc. 510-226-1329

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Monitoring Technologies

APC Function	Technology name	Details	Source/Contact
O_2 monitoring	Zirconia oxide detector and microprocessor-based display unit.	Automatic fault detection, relay output, rapid calibration, reliability, direct insertion in flue gas.	Paul T. Piergross Land Combustion 2525-B Pearl Buck Rd. Bristol, PA 19007-6807 215-781-0810 Telex: 4976004 Fax: 215-781-0798
CO monitoring	Model 9000 CO Monitor. Uses infrared negative gas filtration technique. Microprocessor based, simple computer interface, cross duct, self-calibration.		Paul T. Piergross Land Combustion 2525-B Pearl Buck Rd. Bristol, PA 19007-6807 215-781-0810 Telex: 4976004 Fax: 215-781-0798
Hydrocarbon monitoring for carbon-bed solvent recovery systems	Flame ionization detector	Measures in low ppm range, can establish alarm set points at outlet exhaust of the carbon system to identify need to switch from one bed to another.	Patty Gardner Control Instrument Corp. Fairfield, NJ 201-575-9114 Fax: 201-575-0013
Radioactive materials monitoring		Low, medium, and high energy gamma and x-rays (>20 keV), including I-125, I-131, Tc-99*m*, Ga-67, Cs-137, Co-57, Co-60, Ra-226	Bicron Jonathan B. Price 12345 Kinsman Rd. Newbury, OH 44065-9677 216-564-2251 Fax: 216-564-8047
Sulfuric acid dewpoint monitoring	Portable and continuous monitor models	For flue gas monitoring in plants that burn high sulfur fuels (acid dewpoint temp. must be kept low to reduce cold end corrosion of the plant and to lower acid emissions).	Paul T. Piergross Land Combustion 2525-B Pearl Buck Rd. Bristol, PA 19007-6807 215-781-0810 Telex: 4976004 Fax: 215-781-0798

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Monitoring Technologies

APC Function	Technology name	Details	Source/Contact
Continuous monitoring for ammonia, hydrogen chloride, hydrogen fluoride, chlorine, chlorine dioxide	Ion mobility spectrometry analyzer with dilution-type sampling system. Sample is diluted, ionized, then spectrum is generated. Microprocessor evaluates spectrum and determines concentration based on peak height.	Can detect 1 ppb of target compound	Tad Bacon Environmental Technologies Group, Inc. Baltimore, MD 800-635-4598
Gas monitoring	EnviroSpec 3000—on-line quadopole mass spectrometer—gases are ionized and separated according to their mass-to-charge ratio (ionization pattern is fingerprint). Ions directed into quadropole mass filter, consisting of four parallel rods in symmetrical planes. Intensity indicates concentration of compounds present.	Analysis in 10–20 s, samples analyzed for up to 32 gases or vaporized liquids. Measures gases in the ppb to 100% conc. range.	Dan Dombrosky ABB Process Analytics Lewisburg, WV 304-647-4358 Fax: 304-645-4236
Continuous emissions monitoring	FTIR—Fourier Transform Infrared Spectroscopy for use in the field. For stack or ambient measurements.	Laboratory prototype tested for vibration tolerance, ruggedness, energy throughput, potential speed, and potential maximum resolution.	Peter Solomon On-Line Technologies Inc. East Hartford, CT 209-528-9806
Pollutant monitoring (sensitive to >30 pollutants, including H_2S, CO, Cl_2, HCl, NH_3, NO, NO_2, SO_2, and combustible gases and vapors)	Polytron Hydrogen Sulfide-Turpentine Resistant Sensing Head (H_2S-TR).	H_2S measurement capability 0–50 ppm. Powered by 8–30 Vdc, sensing head may be 10,000 ft from controller.	Mary Pryslak National Draeger 412-787-8383
Gas analysis for continuous emission monitoring, process steam control, ambient monitoring	Ion Mobility Spectrometry (FP-IMS) Monitoring Systems	Can detect and measure gases in ppb range. Can operate from –40°F–122°F, and in humidity range of 1–100% RH. Measures NH_3, CL_2, ClO_2, SO_2, HCl, HF, HCN.	Lisa Watts Environmental Technologies Group Inc. Industrial Products Division 1400 Taylor Ave., P.O. Box 9840 Baltimore, MD 21284-9840 410-339-3146 or 800-635-4598 Fax: 410-321-5255 TLX: 908374

Table of Air Pollution Control Devices, Functions, and Suppliers (continued)
Monitoring Technologies

APC Function	Technology name	Details	Source/Contact
Testing/monitoring for criteria pollutants, particulates, SO_x, NO_x, CO, VOCs, metals, toxic organics, and consulting services for health risk, risk prevention, permit application, environmental impact reports, etc.	Variety of air quality management services available.		Arthur Hurtado, Jr. Almega Corporation National Air Networks, Inc. 2301 East 28th St. Signal Hill, CA 90806 310-426-4221 Fax: 310-426-1143
Gaseous substance monitoring	OPSIS system—uses differential optical absorbtion spectroscopy (DOAS) where the instrument analyzes parts of the spectra in which different gaseous molecules leave unique "fingerprints"	Measures more than 20 specific constituents. Computer collects more than 100 spectra per second for a given wavelength. The computer compares these spectra with a calibrated reference spectrum, wavelength by wavelength.	M. Dale Sands ABB Environmental Services, Inc. Article in *Environmental Science and Technology,* Vol. 26, No. 4, 1992
Opacity monitoring	Dual-beam measuring technique with original optics design. Features: double-pass monitoring, fully automatic zero and span calibration, air-purge system	Helps with EPA compliance, optimum boiler efficiency, clean stack emissions. Accurate cross stack measurements up to 65 ft in ranges of 0–100% opacity. Measures exhaust stack paths up to 30 ft.	Paul T. Piergross Land Combustion 2525-B Pearl Buck Rd. Bristol, PA 19007-6807 215-781-0810 Telex: 4976004 Fax: 215-781-0798

Sources/contacts listed are not the only suppliers, and mention of a specific product is not an endorsement of that product.

Information for this table was collected from journal articles (*Environmental Science and Technology,* 1992; *EPRI Journal,* 1991; *Pollution Engineering,* 1992; *Waste Tech News,* 1993); *Air TECH News,* 1992-1993; research papers and abstracts, advertisements, and brochures; and EPA and DOE reports.

A list of literature concerning regulatory issues and public concerns is available through the MWIP library.

An additional list of air pollution control products and equipment vendors is available through the McIlvaine Company: 2970 Maria Ave., Northbrook, IL 60062, USA. Telephone: 708-272-0010 Fax: 708-272-9673

The McIlvaine *Air Pollution Monitoring and Sampling Catalog* includes an index of U.S. and non-U.S. products and a buyers' guide of product descriptions for U.S. and non-U.S. companies.

The McIlvaine *Air Pollution Monitoring and Sampling Newsletter*, issued monthly to subscribers to their Knowledge Network, includes recent news concerning new air pollution control products, companies, and methods.

APPENDIX B

ELEVEN "TYPICAL" MIXED WASTE AIR POLLUTION CONTROL DESIGNS USED TO EVALUATE TECHNOLOGY DEVELOPMENT NEEDS*

*These flowsheets were developed in a very short time frame, in the absence of important information. Many assumptions have been made, and the designs are not intended to be optimum.

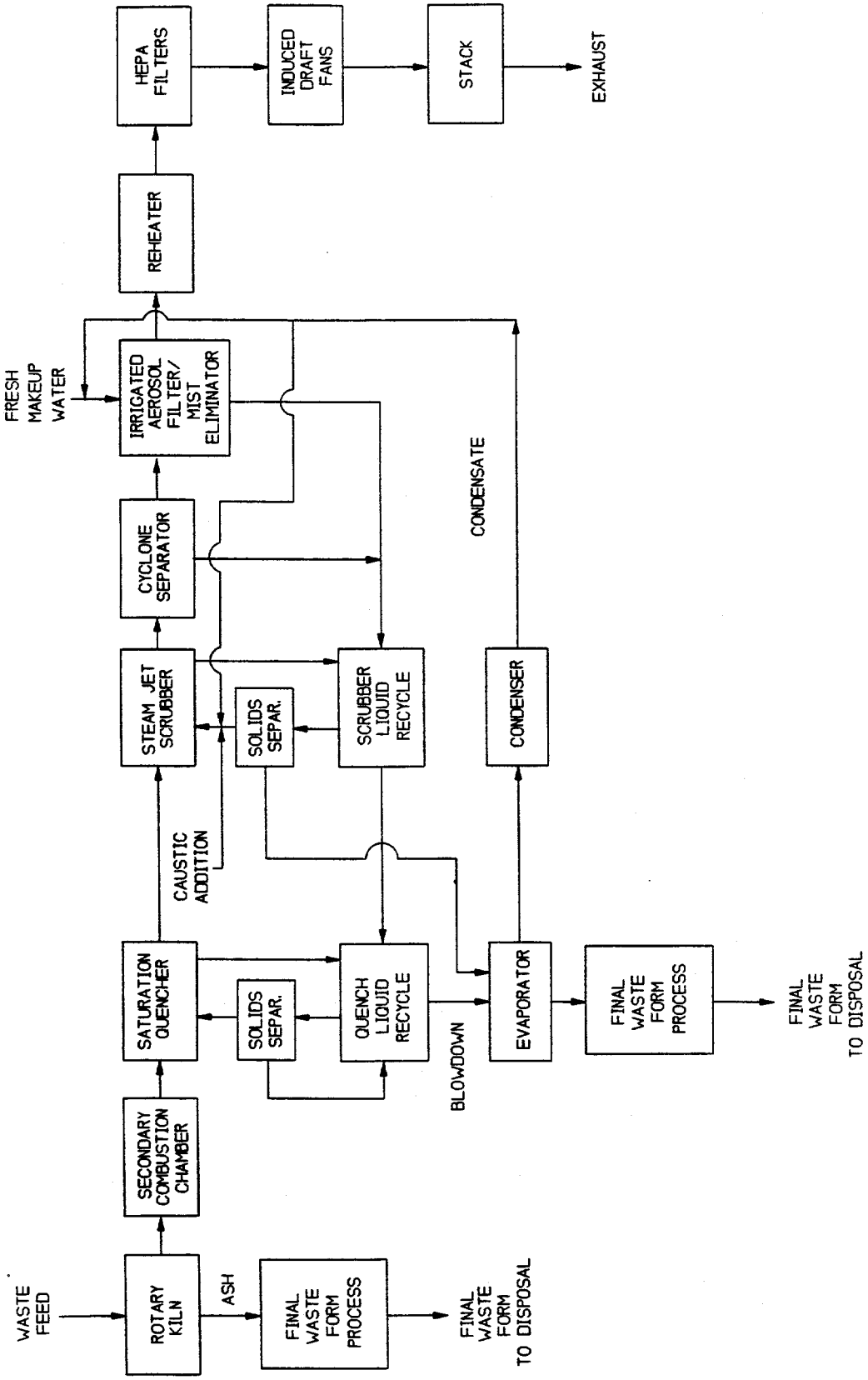


Fig. B.1. APC system design for rotary kiln incinerator using wet system with blowdown evaporator.

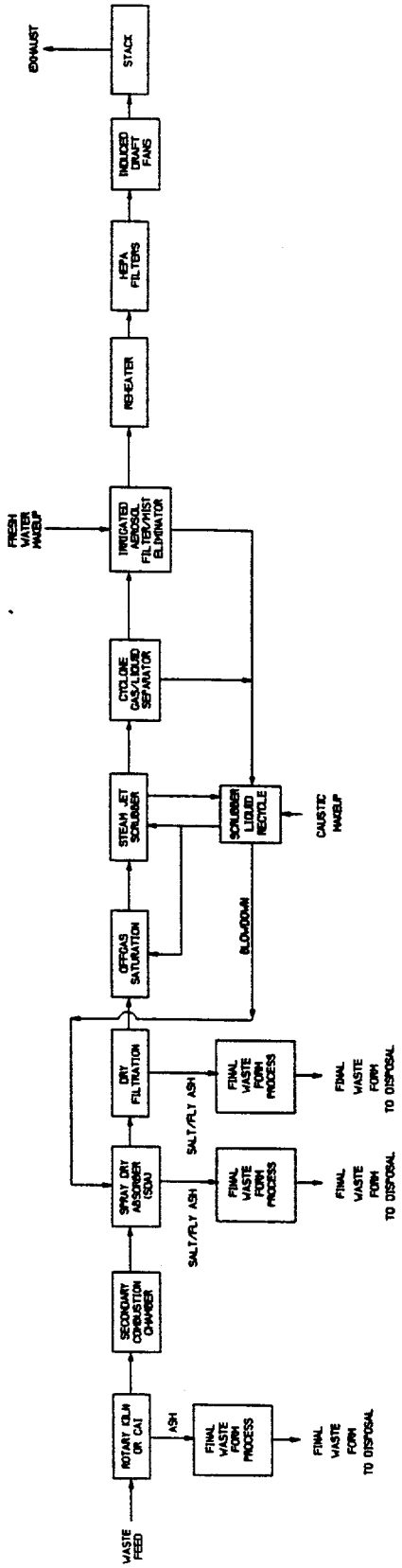


Fig. B.2. APC system design for rotary kiln incinerator using semiwet system with spray dryer absorber.

ROTARY KILN AND CONTROLLED AIR INCINERATOR: DESCRIPTIONS, ASSUMPTIONS, AND DESIGN CONSIDERATIONS

As a baseline, it was assumed that the waste feed to the thermal treatment units would have high halide (primarily chloride) content, beta/gamma radioactive contamination due to fission and activation products, and alpha contamination due to transuranic nuclides, primarily plutonium. It was also assumed that external liquid blowdown treatment capability would not be available. If such capability is available, a purely wet system without blowdown evaporator would be the preferred flowsheet. In both flowsheets, parallel redundant HEPA filter trains and induced draft blowers are recommended to provide on-line changeout capability and increased operational safety. It was concluded that the flowsheets for rotary kiln and controlled air incinerator (CAI) would be identical with the capability to accept low to high particulate loading in the flue gas exiting either incinerator.

WET SYSTEM WITH BLOWDOWN EVAPORATOR

High chloride concentration in the waste feed led us to consider a system that provides wet contacting for acid gas removal. The presence of high alpha contamination raised the concerns of potential secondary containment, maintenance, and solids discharge difficulties associated with an SDA for offgas cooling and acid gas/metal removal. Hence, for the case of high alpha contamination, a wet offgas system configuration was chosen. Since wet contacting was selected for acid gas removal, the system would operate at saturation, and the cooling and particulate removal operations would most conveniently also operate below saturation. A saturation quencher was selected for the cooling method and a steam jet scrubber was selected for primary coarse and fine particulate removal. The steam jet scrubber offers enhanced removal of submicron particulate over a conventional high-energy venturi scrubber. In addition, it has demonstrated the ability to remove >99% HCI at high acid gas loadings in one equilibrium mass transfer stage. An additional countercurrent scrubber such as a packed tower would probably not be required though it may need to be considered for upset acid gas spike situations.

A major issue with regard to use of wet systems in radioactive service is HEPA filter life. Efforts should be made to maximize HEPA filter life to minimize personnel exposure during changeout, minimize downtime due to maintenance and changeout, and minimize secondary waste generation. Causes of reduction in HEPA filter life include (1) inability to remove incinerator-generated fine submicron particulate in the primary particulate removal device(s), (2) entrainment in the offgas of scrub solution droplets containing dissolved and suspended solids, (3) wetting and swelling of HEPA filter media due to incomplete evaporation of entrained droplets by the reheater, and (4) wetting of the filter media due to inadequate insulation and heat tracing of the inlet ducting and filter housings. These problems have indicated an RDT&E need to develop reliable methods of maximizing HEPA filter life when the HEPA filters follow a wet offgas system. This flowsheet shows an irrigated aerosol filter that could serve the function of removing additional fine particulate and entrained droplets from the scrubber. The aerosol filter is irrigated with fresh water and condensate from the evaporator. The cleanest water should contact the most downstream device in the offgas system prior to the HEPA filters. This is to ensure that any droplet entrainment from this device would have the lowest dissolved solids concentration and would hence reduce the likelihood of salt buildup on HEPA filters and prefilters.

A double-loop scrubber liquid recycle system was chosen to ensure that the cleanest liquid would contact the furthest downstream wet steps in the process prior to the HEPA filters. Conversely, the dirtiest liquid would contact the first saturation step, the quencher. A substantial fraction of the fine salt particulate generated in the saturation quencher due to evaporation of "dirty" scrubber liquid would be removed in the steam jet scrubber and secondarily in the aerosol filter. Suspended solids in the recirculation streams should be continuously removed in both loops using a device such as a hydrocyclone. The purpose would be to avoid reintroduction of solids into the offgas system and avoid plugging of spray nozzles in the quencher and scrubber. Liquid blowdown from the scrubber liquid loop would be transferred to the quench liquid loop. Overall process blowdown would come from the quench loop and be pumped to an evaporator. Condensate from the evaporator would be used as makeup water for either the aerosol filter or the steam jet scrubber. Any offgas from the evaporator could be routed into the incinerator offgas system at an appropriate point (not shown on flowsheet). The final waste form generated from this flowsheet would be wet solids (salt/ash mixture) from the evaporator.

SEMIWET SYSTEM WITH SPRAY DRY ABSORBER

As mentioned above, if the design concerns associated with alpha contamination can be adequately addressed, then a semiwet offgas system should be considered which incorporates an SDA. The advantages are potentially enhanced volatile metal removal and the ability to use waste heat from the incinerator to evaporate scrubber liquid blowdown.

Scrubber blowdown would be fed into the SDA, and the SDA exit temperature would be controlled by scrubber blowdown flowrate. The exit temperature would be maintained compatible with a dry particulate removal step just downstream. This filtration operation could consist of fabric, sintered metal, or ceramic filters. The reason for inclusion of a dry particulate removal step is that the downstream offgas treatment operations would be greatly reduced in radioactive contamination. This applies only to radioactivity attached to particulate. (Exceptions would be volatile radionuclides such as tritium, ^{14}C radioiodine, and noble gases). A saturator would be required to guarantee that the offgas is saturated before entering the steam jet scrubber. In this flowsheet with a particulate filter upstream, it is possible that the steam jet scrubber could be substituted with a countercurrent low-energy scrubber since its function would be primarily acid gas removal. The steam jet scrubber would not be expected to remove much additional particulate over what was removed by the particulate filter. Again, an aerosol filter is included for further fine particulate and droplet removal prior to the HEPA filters.

The amount of liquid required to cool the offgas in the SDA exceeds a typical blowdown rate. The steady-state salt concentration in the scrub solution would be relatively low because of the increased makeup water required. Also, the suspended solids concentration would be very low because of the use of a particulate filter upstream. Solid/liquid separation in the recirculated scrubber liquid would also probably not be required. Therefore, a single scrubber liquid loop should suffice here. Dry salt/ash mixture would be discharged from two locations in the offgas system, the SDA and the dry particulate filter.

DESIGN CONSIDERATIONS (W = WET, SW = SEMIWET)

1. Secondary containment of alpha contamination for all access points in the system. (W, SW)
2. Criticality safety when accepting fissile material—inventory accountability, passive neutron monitoring, critically safe design, design for minimum holding of fissile material. (W, SW)
3. Waste characterization, specifically for alpha, beta, and gamma content, is critical to flowsheet selection. (W, SW)
4. SDA outlet temperature control method to avoid wet SDA bottom. (SW)
5. Can irrigated aerosol filter extend the life of HEPA filters with acceptable secondary waste generation resulting from spent filter media? (W, SW)
6. Operation of scrubber liquid recycle system to minimize salt buildup throughout the system and minimize carryover of salt into the HEPA filters, thus reducing their life. (W, SW)
7. When only a countercurrent low-energy scrubber is required for acid gas removal, what are the most appropriate concepts? (W, SW)

RDT&E NEEDS

1. Can an irrigated aerosol filter extend the life of HEPA filters with acceptable secondary waste generation resulting from spent filter media? Can it do a better job than the best HEMEs? Could irrigated aerosol filters be used in conjunction with HEMEs to further enhance aerosol and droplet removal? (W, SW)
2. When a wet system with blowdown is considered, the waste water discharge limits must be determined, specifically for soluble radionuclides such as cesium and strontium. The impacts on flowsheet selection must be assessed. (W)

ROTARY KILN—WET APC SYSTEM

1. Using Packed Tower—backup for acid, improve public perception, direct contact heat exchanger. Use in conjunction with cooling tower.
2. Concerned about suspended solids removal from recycled scrubber liquor.
3. Still an issue of where to put makeup water (i.e., minimize salt carryover).
4. Use a very dilute salt concentration in recycled scrubber; use evaporator/dryer or water treatment to control salt concentration.
5. Verify whether irrigated aerosol filters generate droplets that need mist elimination to back up.
6. Secondary waste generation from irrigated aerosol filters is not known.

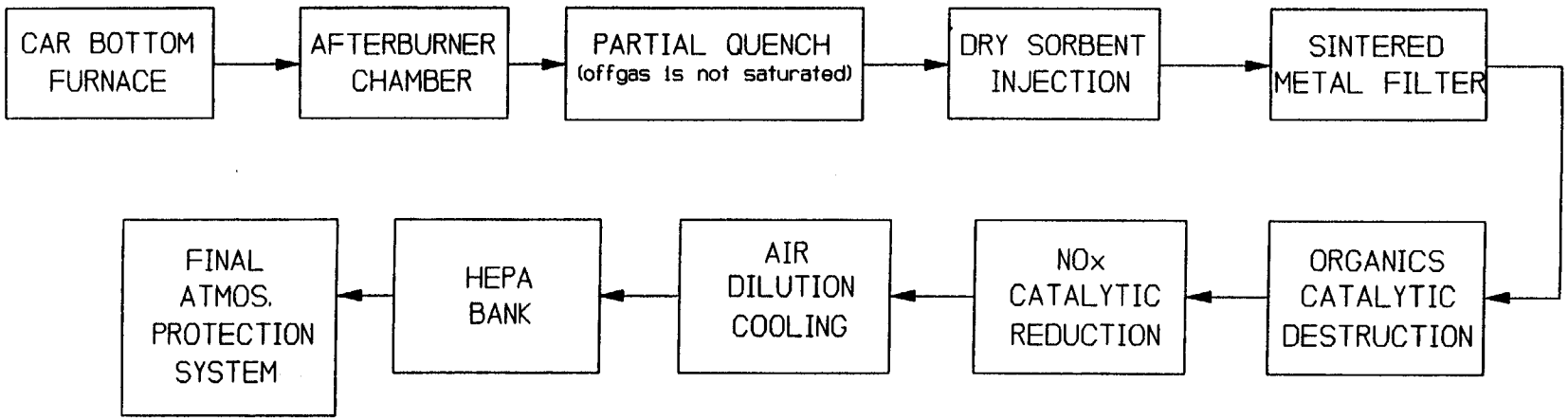


Fig. B.3. APC system design for car bottom furnace.

CAR BOTTOM FURNACE OFFGAS SYSTEM: DESCRIPTIONS, ASSUMPTIONS, AND DESIGN CONSIDERATIONS

1. Assume Feed Stream
   - Highly variable flow rate
   - High variability of gas composition, which could open the possibility of some VOC downstream of a well-designed afterburner
   - Probably low halogen content (not a lot of PVC and chlorinated solvents)
   - NO_x could be moderate because of nitrates in sludges
   - Particulate—generally low but highly variable

2. Product requirements
   - VOC removal (low concentration)
   - Acid gas removal (low concentration)
   - NO_x destruction (moderate levels)
   - Particle removal
   - Cooling from 2000°F to adequate for HEPA filtration

3. NO_x removal selected first because of limited options—thermal, catalytic, and aqueous scrubbing
   - Catalytic selected because of
     — capability to handle moderate NO_x level (up to 10,000 ppm)
     — offers good compatibility with catalytic VOC removal
   - Thermal was rejected because of lower NO_x destruction efficiency (may not treat the anticipated level)
   - the aqueous scrubber was rejected because
     — larger equipment and higher cost
     — generates secondary waste
   - If catalytic is selected, this imposes positioning in a stream at +500°F and a low level of particulate. Therefore, particulate removal should be upstream of NO_x removal.

4. VOC removal selected next because of the number of options—carbon bed, catalytic oxidation, and thermal incineration
   - Thermal incineration rejected because this has been accomplished in afterburner to the limit of reasonable design.
   - Carbon bed rejected because of secondary waste; however, it is acceptable.
   - Catalytic selected because
     — minimal secondary waste
     — can be operated at the same temperature as catalytic NO_x removal (component compatibility)
     — no secondary waste generated other than small quantities of spent catalysis
     — operates at lower O_2 level than thermal

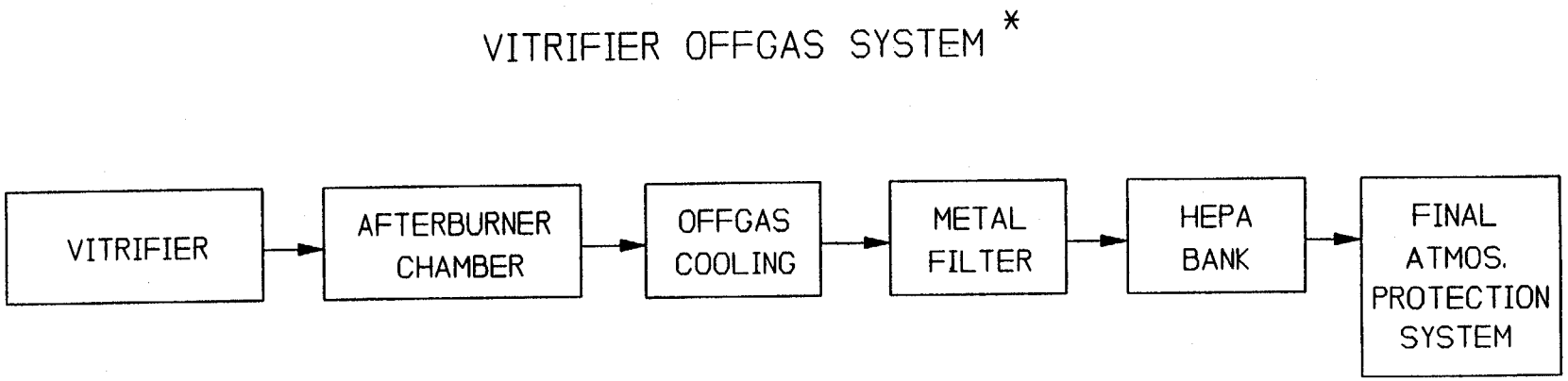
5. Acid gas removal then selected with the primary restriction that a system that operates at 500–1000°F be designed.
   - Aqueous systems rejected because
     — lower operating temperature of scrubber would necessitate considerable reheat of effluent stream for NO_x and VOC destruction

  - — poor turndown, except for ionizing wet scrubber
- Selected dry injection with solids recycle to improve utilization of sorbent
  - — system operates at desired temperature range
  - — adequate acid gas removal at the low level expected
  - — reasonable turndown to handle variable flow conditions
  - — a partial quench with water could lower feed temperature to desired range (500–1000°F)
  - — no aqueous secondary waste for processing; solid secondary waste should go directly to final form treatment
- The dry injection will impose that a high temperature particulate removal device is necessary.

6. Particulate removal operating at elevated temperature and high dust loading from acid gas removal system.
   - candidate systems considered: bag filter, sintered metal, and ceramic candles
   - bag filter rejected because lower temperature limit would probably require some reheat after bag filter (could still be used)
   - ceramic may be acceptable—more data may be needed and the only advantage compared to sintered metal is a higher operating temperature limit (that may not be required)
   - sintered metal selected (may need more thought) because of
     - — adequate operating temperature up to 1000°F
     - — demonstrated under similar conditions of sorbent particulate at same temperature range at RFP-FBU
     - — some concern of sintered metal with the potential levels of VOC

RESEARCH AND DESIGN NEEDS

1. Sintered metal needs demonstration on dry injection particulate removal with flue gas from conventional afterburner.
2. Considerable calculations and /or demonstration need to be done to define the variability of flow and composition from car bottom furnace.
3. Need better definition for waste to be burned in car bottom furnace.



* Assumes negligible acid gas precursors in waste feed to vitrifier and, therefore, negligible acid gases in offgas.

Fig. B.4. APC system design for vitrifier.

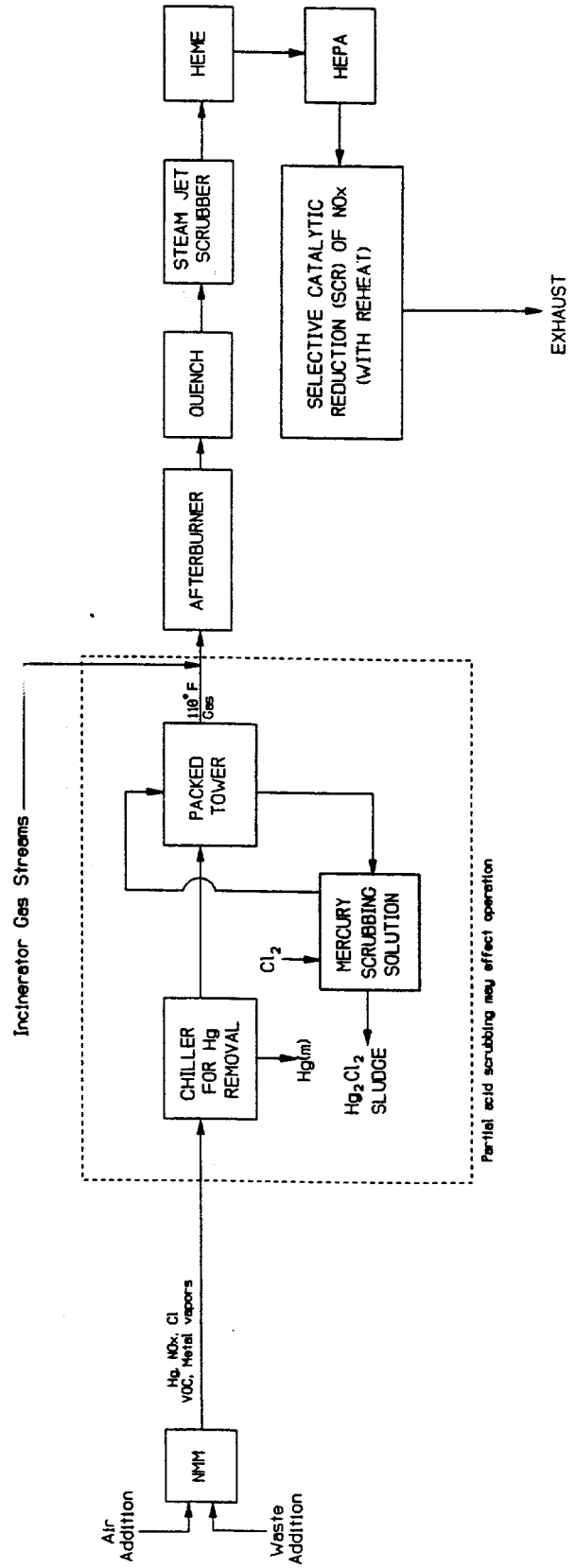


Fig. B.5. Multiuse APC system design for nonmetallic melter (combined treatment of effluent from nonmetallic melter and incinerator).

NONMETALLIC MELTER: MULTIUSE SYSTEM (COMBINED TREATMENT OF NONMETALLIC MELTER AND INCINERATOR OFFGAS): DESCRIPTIONS, ASSUMPTIONS, AND DESIGN CONSIDERATIONS

Waste Characteristics:
- Sludges containing high levels of nitrates (Majority)
- Contains small quantities of Hg, Cl, and organics

Offgas Characteristics:
- High concentrations of NO_x
- Significant quantities of mercury compounds, VOCs, metal vapors
- Temperature about 400°C because dilution air is added at the offgas exhaust port to prevent plugging.

DEDICATED OFFGAS CONSIDERATIONS

1. Mercury cleanup required early to minimize handling in all the secondary waste streams.
2. Acid gas scrubbing needed so a wet system was chosen.
3. HEPA filtration needed for semivolatile metal compounds (i.e., CdCl, $CrCl_3$).
4. NO_x destruction chose catalytic destruction, which was put downstream of the HEPA to minimize fouling and provide easier maintenance of system not considered as reliable as other parts of system.

This design scrubs mercury first and then combines with incinerator offgas for further treatment. This could affect performance of the HgCl scrubber. If so, combine NMM and incinerator offgas, scrub acid gas first, and scrub mercury. SCR implies a catalyst bad and a preheater. The preheater is integral to operation of the bed, not just protection or convenience.

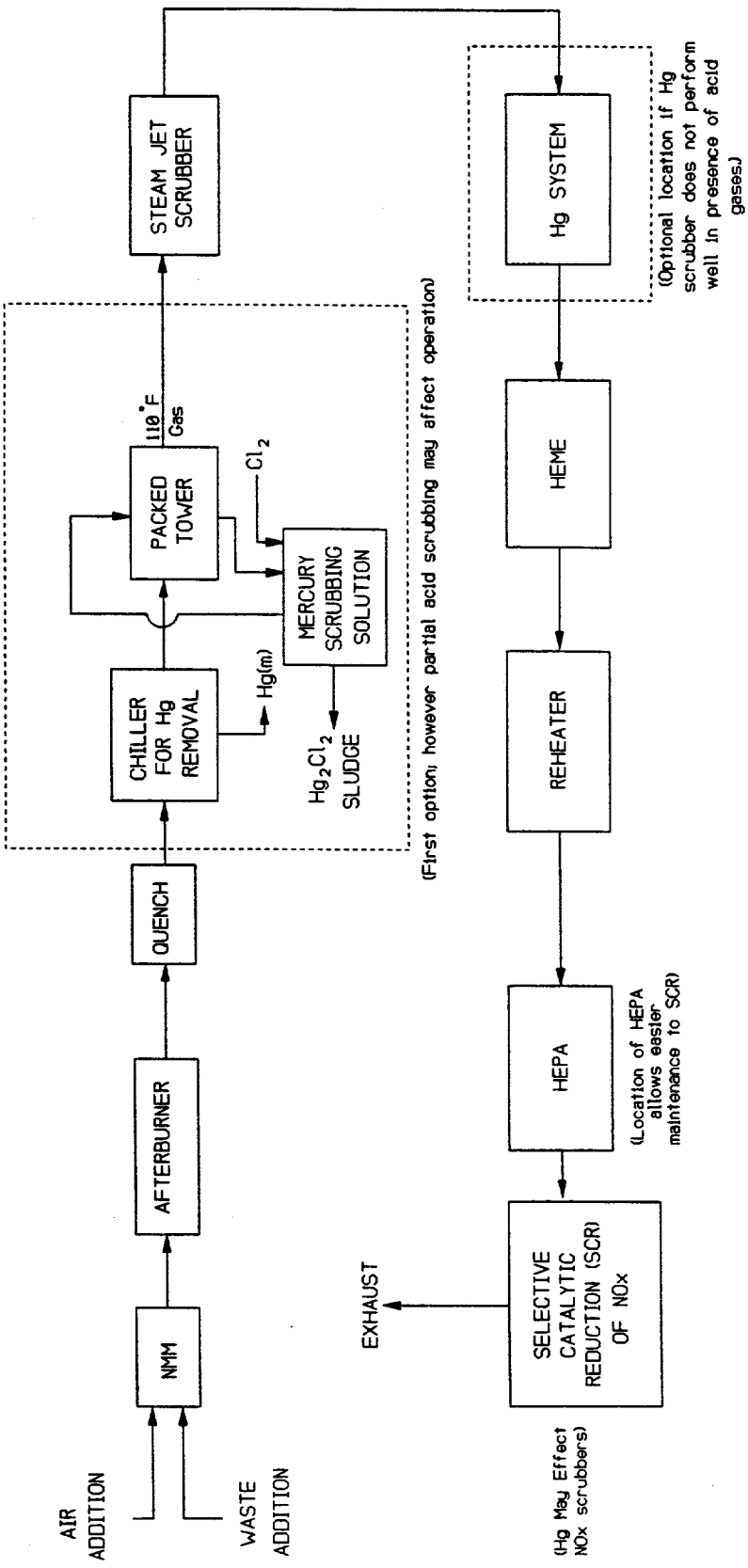


Fig. B.6. Dedicated APC system design for nonmetallic melter with two options for location of mercury scrubber subsystem. Dedicated system does not combine treatment of nonmetallic melter offgas with incinerator offgas.

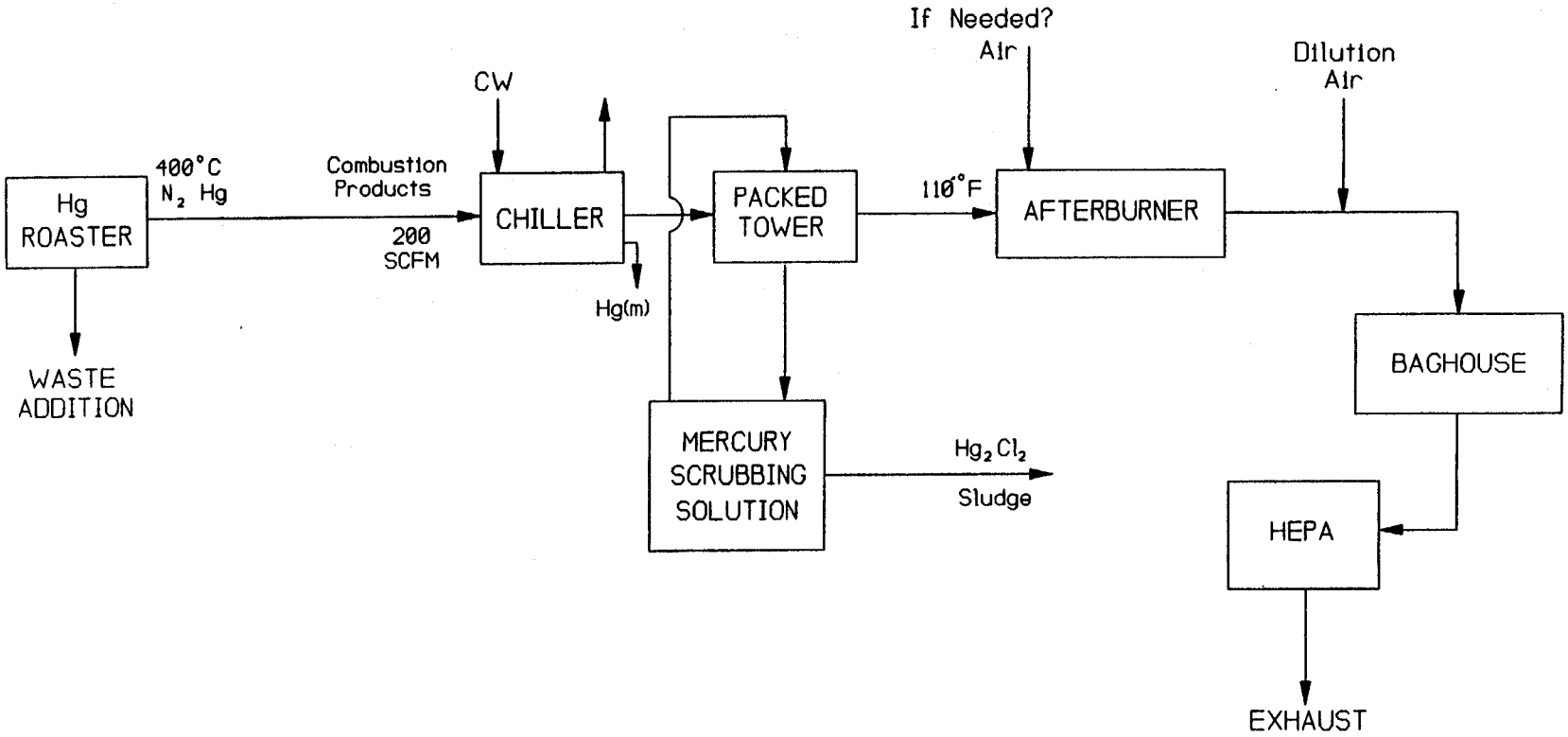


Fig. B.7. Dedicated APC system design for mercury roaster.

DEDICATED MERCURY ROASTER OFFGAS SYSTEM: DESCRIPTIONS, ASSUMPTIONS, AND DESIGN CONSIDERATIONS

Dedicated system means not treating effluent from melters. Some concern that heavy metals and contaminants could affect HgCl scrubber.

Assume low Cl and NO_x in effluent, so system should be dry after the mercury scrubber.

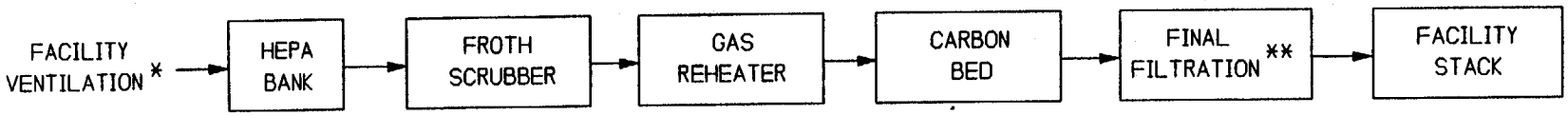
Mercury is cleaned first to minimize contamination of downstream components.

Using dilution air to cool gives more flexibility than dry spray quench. Low volumes of effluent to be treated make dilution a viable alternative.

Assume combustion products leaving roaster.

Difference from MWTP flowsheet is that a dedicated system that does not require particle scrubbing or acid scrubbing (before the HEPA filters).

Initial particle removal is accomplished using a baghouse to protect the HEPA filter from soot formed in the afterburner.



* Includes offgas from vents, hoods, and process units. Assumes all flows have been filtered and possibly other treatment (e.g., acid gas removal) at the offgas source.

** Final filtration uses coarse filtration for collection of carbon fines and solids carryover from scrubber. Nuclide filtration is performed by HEPA bank which is upstream of scrubber, so that it is not subject to blinding or degradation from salts and moisture from scrubber.

Fig. B.8. APC system for building ventilation air (Final Atmospheric Protection System).

BUILDING VENTILATION OFFGAS SYSTEM: DESCRIPTIONS, ASSUMPTIONS, AND DESIGN CONSIDERATIONS

1. From the feed stream information
   - Flow ≈ 15,000–18,000 acfm
   - Temperature ≈70–100°F
   - Particulate ≈ low—all inputs filtered
   - Acid gas ≈ low—some tank vents have carbon bed, most gas from dry processing in hoods
   - VOC ≈ low—carbon bed on most organic processes
   - H_2O ≈ may be low—but some concern with humidity of air from hoods on humid days

2. Product stream requirements
   - Final treatment before release to atmosphere
   - Must be low in radioactivity and particulate
   - Should provide acid gas removal, VOC removal or destruction, and particulate removal (ash)

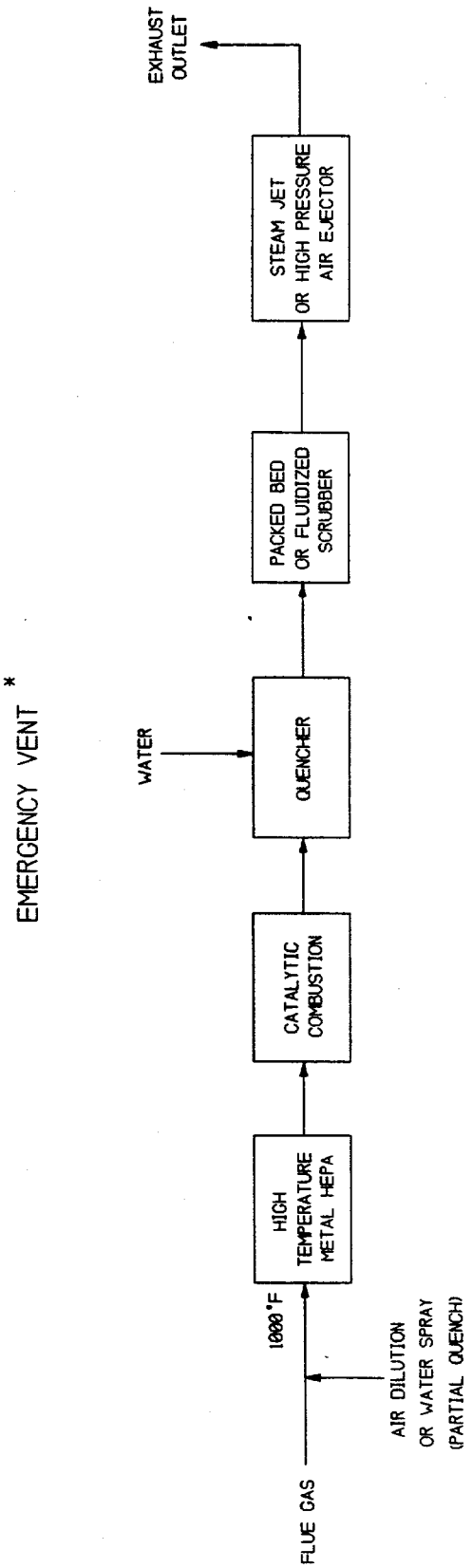
3. First functional requirement to be selected was the fine particulate removal because of product stream requirement and limited options to satisfy need (i.e., HEPA filter, sand filter, and perhaps a sintered metal filter).
   - HEPA selected because of
     — less equipment cost than sintered metal filter
     — lower space requirement than sand filter
     — lower secondary waste (HEPA replaced more often than sand bed, but one replacement of sand bed would have a major impact on processing).
   - HEPA is generally assumed to be the last unit in the train, but it could go prior to acid gas removal and VOC removal.
     — Upstream may be preferred if particulate load is very low and if acid gas is removed by aqueous scrubber due to concern of salt entrainment impact on filtration.
     — Either upstream or downstream, the acid gas removal and VOC should be selected to minimize dust loading.

4. Second functional requirement to be selected was VOC removal because of limited options—thermal incineration, catalytic incineration, and carbon bed adsorption.
   - Thermal rejected because of high energy requirement to heat a large flow to ≈2000°F range.
   - Catalytic rejected because of moderate energy requirement to heat a large flow to ≈400–600°F range.
   - Carbon bed selected because of low energy input. Carbon also has the ability to remove volatile fission products or metal vapors in addition to good VOC removal. It will generate some secondary waste (used carbon), but because of expected low concentration of VOC, replacement should be infrequent.
   - Selection of carbon bed also requires a low dust loading as criteria for acid gas removal system.

5. The acid gas removal was the last technology to be selected because a wide variety of options exist. (Wet and dry could be considered. Position acid gas removal equipment before the carbon bed to minimize acid gas adsorption onto carbon).
   - All wet and dry systems were considered.
   - Flow rate to acid gas removal would be uniform—no high turndown required.
   - Temperature of feed stream does not require cooling.
   - System design has simple operation, low maintenance, and minimal input of solids to carbon bed.
   - Dry system capable of high efficiency for particulate removal and some acid gas removal.
   - Wet system capable of high efficiency for acid gas removal and some particulate removal.
   - Four tower scrubbers were leading candidates: packed tower, tray tower, wet fluidized bed, and the froth column.
   - Froth column selected because of
     — low entrainment of salt mist
     — high particulate removal
     — ease of operation
     — aqueous provides some fire protection of carbon bed

RDT&E NEEDS

The froth column needs demonstration because it is a relatively unknown technology for mixed waste. There is a need to confirm low entrainment of salt mist and to demonstrate the method of operational control.



* Could also be handled by final atmospheric protection system

Fig. B.9. APC system for emergency ventilation.

EMERGENCY VENTILATION OFFGAS SYSTEM: DESCRIPTIONS, ASSUMPTIONS, AND DESIGN CONSIDERATIONS

1. One option that should be considered is, "Can the Final Atmospheric Protection System handle a hot gas from a thermal treatment unit for short periods of time, if the normal APC system goes down?"
   - It could handle cooling by dilution of a small hot gas flow with the large room temperature gas flow.
   - Acid gas removal, particulate removal, and VOC removal could be accommodated for a short period of time. The result of the upset condition could result in HEPA filter and carbon bed replacement.

2. Another method of providing for emergency vent processing from the thermal processing units would be a simple process consisting of cooling to about 1000°F by air dilution, a catalytic oxidizer to remove trace organics, a high-temperature HEPA filter, and a scrubber (packed or fluidized bed) for acid gas removal. A steam jet ejector is used to provide emergency flow until backup power comes on-line and restarts the induced draft fan.

RESEARCH OR DESIGN NEEDS

1. Definition of time of upset to be handled.
2. Frequency of upset anticipated.
3. High-temperature HEPA needs demonstration.
4. Definition of maximum flow that could result from emergency, upset, explosion, etc.

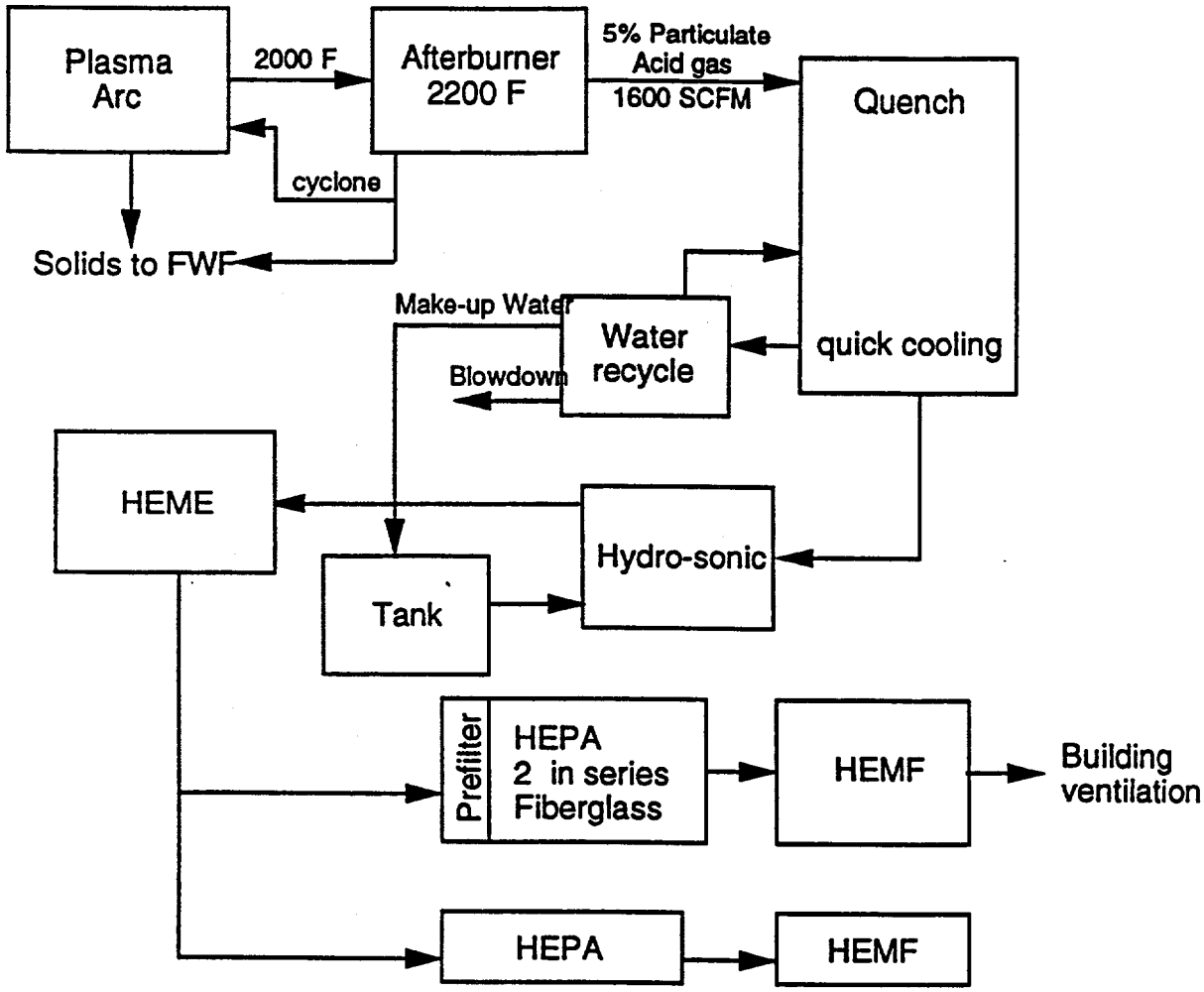


Fig. B.10.1. APC system for Plasma Hearth Furnace. Target is 50 ppm NO_x.

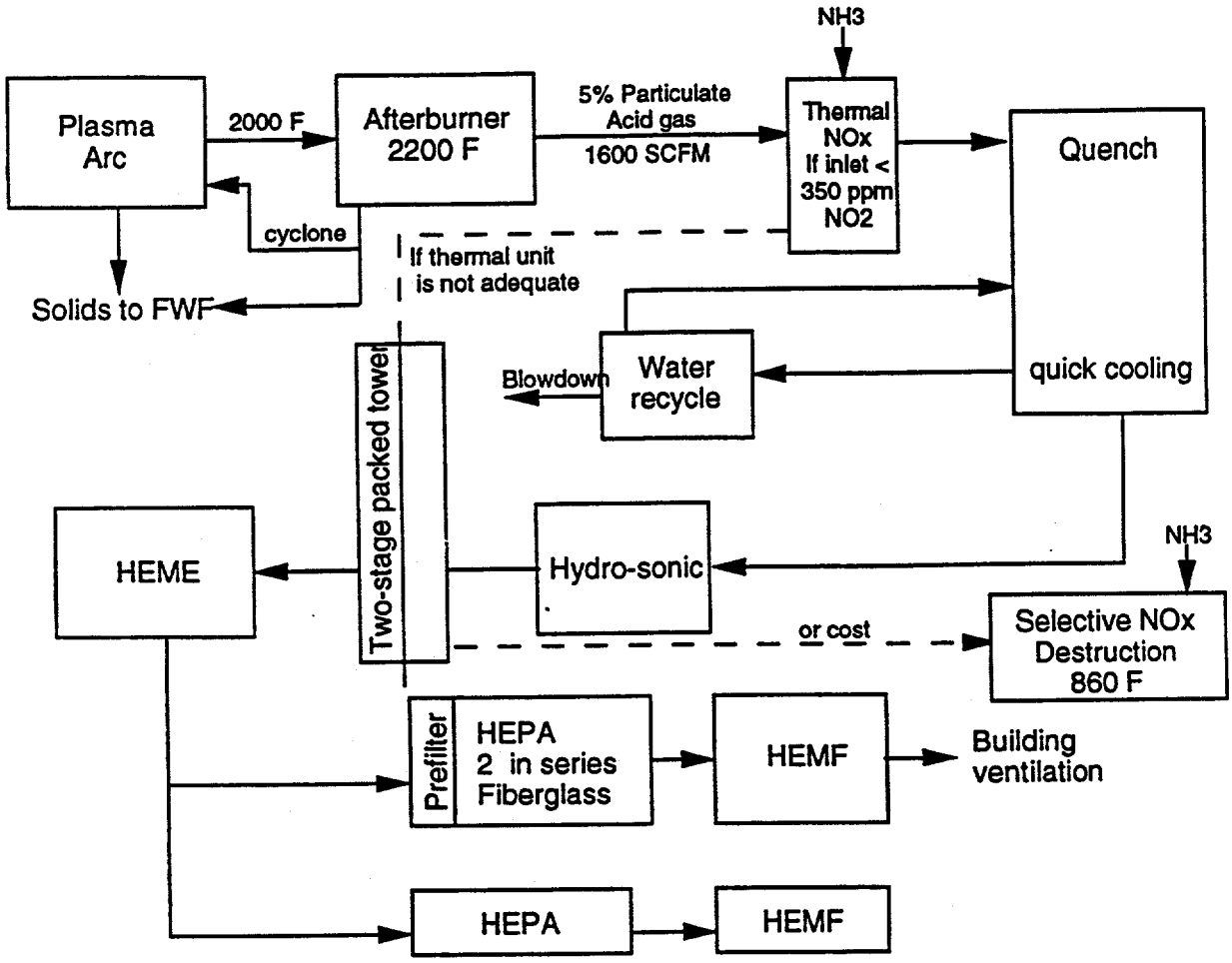


Fig. B.10.2. APC system for Plasma Hearth Furnace: prefilter with two HEPA filters in series.

PLASMA HEARTH FURNACE: DESCRIPTIONS, ASSUMPTIONS, AND DESIGN CONSIDERATIONS

Data from the centrifugal plasma arc furnace being tested in Butte indicates plutonium will stay with the ash; however, the fixed-bed plasma arc being tested at Ukiah probably has a different carryover. For the purposes of our system design, we will assume that the Ukiah plasma arc has about 5% ash carryover, compared to a rotary kiln that has ~25% carryover. Furthermore, we assume 3% carryover after the second-stage destruction unit.

The manner in which the plasma hearth primary chamber temperature is controlled will directly affect the variation in offgas flowrate as well as the chemical composition of the offgas. For example, if the temperature is controlled primarily by inlet combustion air flowrate and secondarily by waste feed rate, the fluctuation in offgas flowrate could be expected to be high. The offgas system would need to be designed for a high turn-down ratio. Other methods of controlling the plasma hearth primary chamber temperature should be investigated. One approach might be modulation of the plasma torch input power to accommodate changes in the inherent specific energy requirement (SER, kW/lb) of the waste feed resulting from changing waste composition (inert vs organic content, etc.). By this method of temperature control, at a fixed inlet air flowrate, the offgas flowrate would be expected to vary much less.

Rather than assume that high NO_x generation is always present with the high local temperatures associated with plasma processing, methods of minimizing NO_x generation should be investigated. Only the air atmosphere in and adjacent to the plasma hearth itself is a concern for NO_x generation. The use of plasma gases other than air (such as steam) should be investigated. A steam plasma might avoid local NO_x production at plasma temperature (>2000°C). The steam would pyrolyze any organics in the vicinity of the arc to CO and H_2 for subsequent combustion. Air could still be introduced into the primary chamber for combustion at the lower bulk chamber temperatures (<1300°C) away from the plasma arc. Obviously, a dry stream supply is somewhat more complex and more expensive than the currently used air supply, but the benefits of avoiding NO_x destruction technologies downstream would almost certainly offset any such disadvantages.

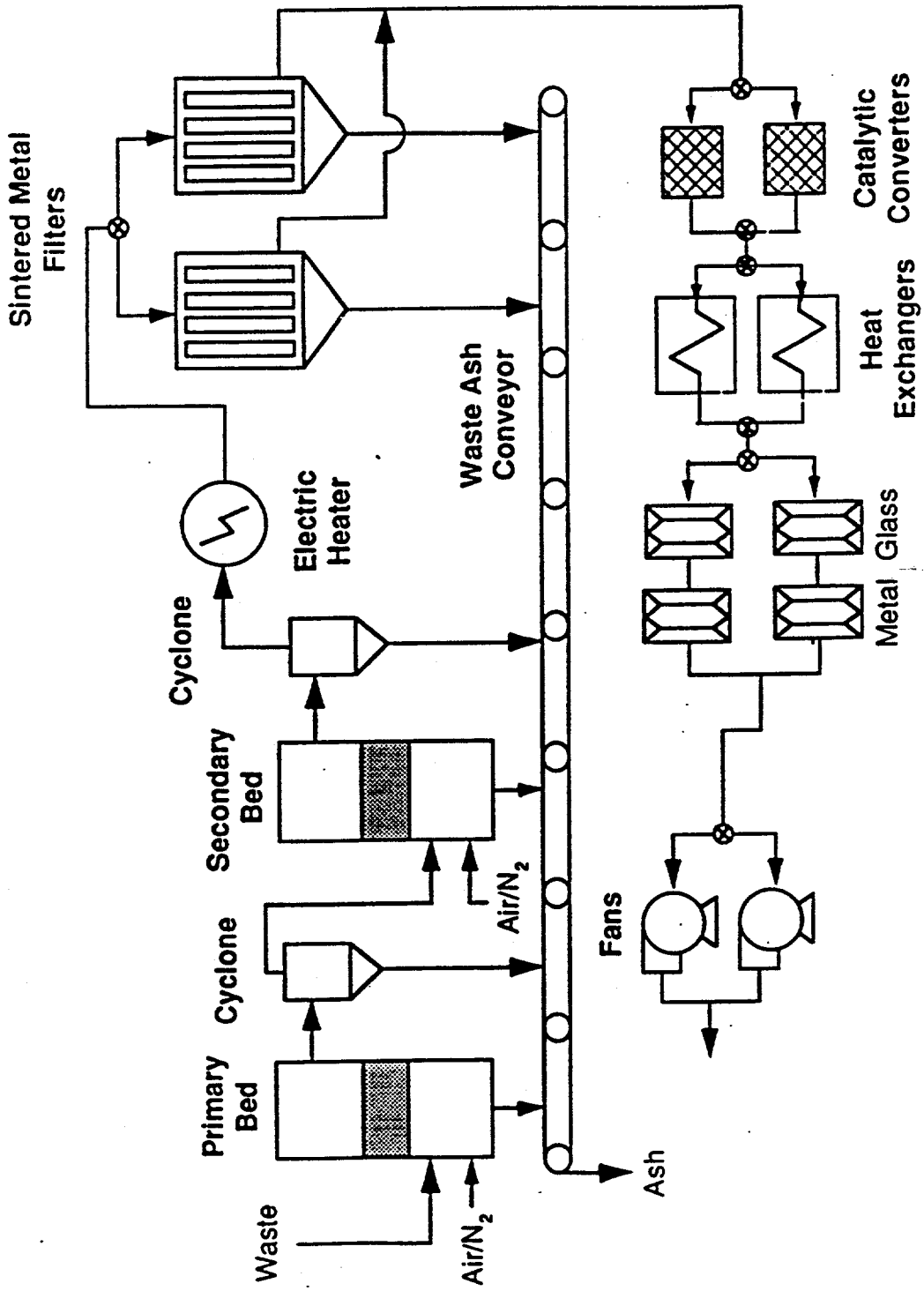


Fig. B.11. APC system for fluidized-bed incinerator at Rocky Flats.[1]

ROCKY FLATS AIR POLLUTION CONTROL SYSTEM FOR ROCKY FLATS FLUIDIZED BED INCINERATOR: DESCRIPTIONS, ASSUMPTIONS, AND DESIGN CONSIDERATIONS[1]

The process operates at a feed rate of 40 kg/h of dried sludge from aqueous waste decontamination process. The dry sludge contain about 20% nitrates. The process should result in destruction of the nitrates and some of the sulfates. The offgas from the process is about 1000 ft^3/min, composed primarily of air purged through the unit to remove the dust. Dust accumulation within the solidification equipment is a problem because it is a receptor for the microwave and could cause hot spots on the equipment walls. The Rocky Flats personnel estimated that 90–99% of the offgas flow is air purge.

The amount of nitrate fed amounts to about 17 lb/h; if all of the nitrate is decomposed, this could represent a significant NO_x offgas problem.

1993 test data from Rocky Flats should be consulted to determine the volatility of metals from sludge feed. Even though sludge is generated in an aqueous process, some organic could be present at a very low level. Volatile organics should not be a problem in the offgas.

The most important offgas treatment required will be filtration for particulate removal. Even stream cooling would not be required because of the large air dilution purged through the equipment. At this point, one might be concerned about NO_x, SO_2, volatile metal, and particulate and perhaps chloride removal. The chloride content of sludge is not high, but if this process is used with other types of feed, such as ash from the fluidized-bed incinerator, the chloride content would be very significant.

Technology options (and specifications) for each stage of APC system:

Acid gas removal:	Fluidized-bed incinerator (system choice)
Initial particle removal:	Sintered metal filter (system choice)
	Cyclone
	Ceramic filters
	Fabric filter
	ESP (wet and dry) scrubbers
	(Operate at 500 to 550°C to avoid dioxins)
Organics control:	Catalytic converter (system choice)
	Charcoal absorber
	Afterburner
Cooling to 80°C:	Heat exchanger (system choice)
	Air dilution
	Water quench
	(purpose is to ensure condensation for final particle removal)
	(Do not go below dewpoint)
Fine particle control:	Glass HEPA (system choice)
	Metal HEPA (system choice)

All moisture from combustion going up stack.
Did not consider cleanable HEPAs.
Low heat release system (1.5 M Btu/h).

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