United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Washington DC 20460

EPA-340/1-88-007
July 1988

Stationary Source Compliance Series

EPA

Municipal Waste Incinerator Field Inspection Notebook

EPA 340/1-88-007

Municipal Waste Incinerator Field Inspection Notebook

Prepared by:

Richards Engineering
Durham, North Carolina 27705

and

Entropy Environmentalists, Inc.
Research Triangle Park, North Carolina 27709

Under Contract No. 68-02-4462
Work Assignment No. 15

Prepared for:

EPA Project Officer: Aaron Martin
EPA Work Assignment Manager: Pamela Saunders

U.S. ENVIRONMENTAL PROTECTION AGENCY
Stationary Source Compliance Division
Office of Air Quality Planning and Standards
Washington, DC 20460

July 1988

DISCLAIMER

This manual was prepared by Richards Engineering and Entropy Environmentalists, Inc. for the Stationary Source Compliance Division of the U.S. Environmental Protection Agency. It has been completed in accordance with EPA Contract No. 68-02-4462, Work Assignment No. 15. The contents of this report are reproduced herein as received from the contractor. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the U.S. Environmental Protection Agency. Any mention of product names does not constitute endorsement by the U.S. Environmental Protection Agency.

The safety precautions set forth in this manual and presented at any training or orientation session, seminar, or other presentation using this manual are general in nature. The precise safety precautions required for any given situation depend upon and must be tailored to the specific circumstances. Richards Engineering and Entropy Environmentalists, Inc. expressly disclaim any liability for any personal injuries, death, property damage, or economic loss arising from any actions taken in reliance upon this manual or any training or orientation session, seminar, or other presentations based upon this manual.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

SAFETY GUIDELINES

1. DO NOT CONDUCT INTERNAL EQUIPMENT INSPECTIONS.
   Offline equipment at incinerator facilities may have a variety of significant hazards including but not limited to: inhalation, asphyxiation, thermal burn, chemical burn, eye, and falling hazards. Regulatory agency inspectors should not enter equipment even when it appears to be properly locked out and/or it is occupied by plant maintenance personnel.

2. TAKE ALL PERSONAL SAFETY EQUIPMENT.
   The minimum safety equipment for municipal incinerators consists of a half face respirator with acid gas cartridges, disposable dust/mist/fume masks, gloves, safety glasses, safety shoes, sterile eye wash bottles, and a hard hat. In some cases, more sophisticated safety equipment is necessary. If all necessary safety equipment is not available, avoid areas of potential exposure.

3. AVOID AREAS OF SUSPECTED HIGH POLLUTANT CONCENTRATIONS.
   Respirators provide only limited protection. Avoid areas such as malfunctioning combustion equipment operating at slight positive pressures, leaking expansion joints downstream of fans, fugitive emissions from positive pressure equipment, and any area with poor ventilation.

4. DO NOT DO ANYTHING WHICH APPEARS DANGEROUS.
   If you think that it may be dangerous, it probably is! Do not abdicate your safety judgement to plant personnel who may or may not be safety conscious.

5. NEVER HURRY DURING INSPECTIONS.
   This causes careless walking and climbing accidents.

6. DO NOT ASK PLANT PERSONNEL TO TAKE UNREASONABLE RISKS.
   Do not ask plant personnel to take risks to aid you compile inspection data. Limit the inspection as necessary to avoid health and safety hazards.

7. INTERRUPT THE INSPECTION IF YOU FEEL SICK.
   Interrupt the inspection immediately whenever you have any of the following symptoms: headache, nausea, dizziness, drowsiness, loss of coordination, chest pains, shortness of breath, vomiting, and eye or nose irritation. These symptoms may be caused by exposure to toxic pollutants even though there is no odor.

8. FLUSH EYES CONTACTED BY ALKALINE MATERIALS.
   It is important to flush eyes as soon as possible after alkaline materials such as calcium hydroxide or quick lime are contacted. Flush for 15 to 30 minutes. Get medical attention even if you think the exposure was minor.

9. SHOWER IMMEDIATELY IF CONTACTED BY CHEMICALS.
   In the unlikely event that you are splashed with chemicals or waste materials, remove affected clothing and shower immediately for a period of at least 15 minutes.

10. USE PROTECTIVE CLOTHING AND GLOVES.
    This equipment is needed when there is a risk of contact with incinerator bottom ash, air pollution control device solids, alkaline materials, or waste sludges and solids. Gloves are also needed for climbing abrasive and/or hot ladders. Contaminated work clothes should either be discarded or washed separately from personal clothes.

11. WEAR HEARING PROTECTION.
    Hearing protection should be used whenever required by the plant and whenever it is difficult to hear another person speaking normally from a distance of 3 feet.

12. USE GROUNDING/BONDING CABLES ON PROBES.
    This is especially important downstream of electrostatic precipitators due to the possiblities of injuries resulting from severe muscle spasms caused by contact with high static voltages.

SAFETY GUIDELINES (Continued)

13. AVOID SEVERELY VIBRATING EQUIPMENT.
    Equipment such as fans can disintegrate suddenly. Notify plant personnel immediately of the condition and leave the area.

14. PLANT PERSONNEL MUST BE PRESENT DURING THE INSPECTION.
    Never conduct plant inspections alone. Plant personnel accompanying you must be knowledgeable in plant operations, general safety procedures, and emergency procedures.

15. FOLLOW ALL PLANT AND AGENCY SAFETY REQUIREMENTS.
    Limit the inspection as necessary to ensure that you completely adhere to all plant and agency health and safety requirements.

REFERENCE SECTION

1. INSPECTION MANUAL INTRODUCTION

1.1 Background Information

Municipal waste incinerators are not a new type of air pollution source. They were included on the first emission inventories that provided the basis for the first set of comprehensive air pollution control regulations between 1971 and 1975. They were one of the first five sources for which New Source Performance Standards were promulgated. Accordingly, municipal waste incinerators have been inspected routinely for a long time. In fact, one of the first source specific inspection manuals prepared by EPA concerned municipal waste incinerators [1]. Now fifteen years later, there are numerous reasons why an updated inspection manual is needed.

The limited availability of suitable landfill space coupled with lessened public acceptance of landfills has created a very strong demand for thermal incineration alternatives. Accordingly, there has been a surge in the construction of municipal waste incinerators. As of June 1987, there were 210 individual facilities in the design or planning stages [2]. The combined capacity of these facilities is estimated at 193,400 tons of waste per day which is four times the total existing incinerator capacity. Obviously, municipal waste incineration will be an increasingly important source category as these new units come on-line between 1987 and 1993. Furthermore, it is reasonable to anticipate continued growth in the post-1993 period.

The characteristics of municipal waste incineration have changed dramatically since the 1970's. The early facilities were intended primarily for the reduction of waste volume. New facilities now recover energy in addition to reducing waste volume. Energy is generally recovered in the form of steam, however, a few larger facilities also generate electricity.

The types of combustion systems have evolved substantially to allow energy recovery, improved combustion efficiency, and reduced pollutant generation. It is not surprising that many of the innovations and refinements have come from Europe and Japan where the economics and availability of direct landfill disposal reached a critical stage long before the United States. There have been substantial improvements in mass burn technology which accounts for 59% of the planned new capacity [2]. The refuse derived fuel (hereafter termed RDF) systems that represent 20% of the new capacity were only in the research stages at the time that the previous inspection manual was prepared. There also has been substantial growth in the smaller capacity modular starved air and modular excess air type systems. Accordingly, the scope of this inspection notebook is much broader than the previous publication.

Inspection of municipal waste incinerators was previously oriented strictly toward particulate emissions and opacity. Now, there is concern over additional pollutants, especially hydrochloric acid, hydrofluoric acid, metals, nitrogen oxides, and a variety of organic pollutants such as dioxins and furans. To minimize emission of these pollutants, many States and local agencies have imposed specific permit restrictions and/or have adopted strict emission limitations. These requirements are in the form of equipment design standards, equipment performance standards, and pollutant emission limits. Generally, the particulate emission limitations are well below the NSPS requirement for municipal waste incinerators which are currently being revised. Accordingly, the on-site inspection conducted by State and local agencies must address all of these requirements that go beyond present Federal requirements.

The evolution and growth of the municipal waste incinerator industry has been matched by changes in the style and sophistication of the air pollution control systems. Dry scrubbing systems for acid gas control are now operating on a few existing sources and are expected on many units in the planning stages. This control technology did not exist in the early 1970's. Several new approaches for nitrogen oxides control are presently in use and these also will find more applications especially in areas having difficulty achieving photochemical oxidant ambient standards. Baghouses now share the particulate control duties that were previously performed mainly by electrostatic precipitators. There have been substantial component design improvements in both fabric filters and electrostatic precipitators. Continuous emission monitors for opacity, sulfur dioxide, nitrogen oxides, and hydrogen chloride are now commonly used for the early identification of combustion system and/or air pollution control system problems. All of these changes obviously affect the scope of the air pollution inspection.

There has also been refinements in air pollution source inspection techniques. The Baseline Inspection Technique [3] has been developed under the sponsorship of EPA to improve the effectiveness of on-site inspections. The inspections have been categorized in four separate levels ranging from simple surveillance activities to detailed engineering evaluations. The more advanced inspections now may include the use of agency-supplied portable instruments to provide certain important data which is not otherwise available. The major principles and practices included within the scope of air pollution source inspections have been summarized in an EPA general procedures manual titled, "Air Compliance Inspection Manual [4]."

For all of the reasons discussed above, it is necessary to revise and expand the previously published inspection guidelines for this source category.

1.2 Purpose

The primary purpose of this manual is to assist Federal, State, and local agency inspectors in conducting effective and safe Level 2 and Level 3 inspections of municipal waste incinerators. A Level 2 inspection is an on-site, walk through inspection that includes an evaluation of present operating data as indicated by plant instruments, an evaluation of operating records, and general observations of system condition and performance. A Level 3 inspection is a more comprehensive evaluation of specific conditions of concern. Portable instruments may be used in some Level 3 inspections. These two types of inspections comprise the majority of inspections conducted and are described in more detail in Reference 4.

Checklists are not provided for Level 1 inspections since these simply involve surveillance of visible emissions from off-site locations. Level 4 inspections are included but are not addressed in detail since they are conducted only by senior inspectors and agency management personnel. Furthermore, the types of activities included in the Level 4 inspection are not unique to any one source category such as municipal waste incineration. Information regarding Level 4 inspections is available in Reference 4 or in the U.S. EPA Air Pollution Training Institute course #455 manual [5].

1.3 Organization and Scope of the Notebook

1.3.1 Organization

The notebook has been organized into the three distinct parts listed below to address the differing needs of field inspectors:

Reference information
Field inspection procedures
Support information

A reference section is presented first to provide a brief overview of the numerous technical issues concerning municipal waste incineration and air pollution control. This section is needed due to the voluminious, widely scattered literature concerning these subject areas. It is also intended to help inspectors who inspect many different types of air pollution sources brush up on the characteristics of municipal waste incinerators immediately before beginning the inspection.

Inspectors who are already familiar with the types of equipment in service and the common operating problems may wish to go directly to the field inspection procedures. This material has been divided three ways to make the notebook as flexible and generally useful as possible. The three inspection procedures formats are listed below.

- Inspection overview
- Inspection checklists
- Step-by-step inspection procedure descriptions

An inspection overview summary has been presented first in each of the six inspection procedures sections to briefly summarize the fundamental approach being used to evaluate the equipment compliance status. Inspectors can apply these concepts to unique systems not explicity covered in this manual.

Checklists have been prepared in a format that can be quickly scanned during the field inspection. They have been arranged in categories of Basic Level 2, Follow-up Level 2, Level 3, and Level 4 inspections. They serve as reminders of additional checks which should be made before concluding the inspection and are also helpful when discussing the inspection scope during the preinspection meeting with the source personnel.

Detailed summaries of each inspection step are presented following the checklists. To the maximum extent possible, these provide specific information on how to compile the necessary data and observations. Inspectors should refer to one or more of the specific discussions if questions arise during the inspection.

1.3.2 Scope

The scope of the manual includes many diverse types of municipal waste combustion systems and air pollution control systems. The combustion techniques have been grouped into three categories listed below to parallel the material presented in EPA's Municipal Waste Combustion Study [6].

- Mass Burn Systems
- Refuse Derived Fuel Systems
- Modular Systems

Despite the design variability of systems included in any of these groups, the inspection steps within each category are relatively similar. The remainder of the inspection sections concern various types of air pollution control systems. All of these sections are modified and expanded versions of material previously prepared by the author and included in the "Field Inspection Notebook [7]." The format of this notebook is similar to this predecessor document.

The dry scrubbing section addresses the three separate types of systems listed below:

- o Spray dryer absorber
- o Dry injection
- o Combined spray dryer and dry injection

It should be noted that there is no generally accepted terminology for the types of dry scrubbers. Accordingly, the terms used in this notebook may not be consistent with other texts.

1.4 Limitations of This Manual

It is important to note that certain facilities have unique design and/or operating procedures. It is impossible for any reasonably sized notebook to address all of these site specific items. Also, some inspection steps included in this notebook are not relevant at certain facilities. Inspectors must tailor their work to the specific site.

General inspection safety guidelines have been included in this notebook. It is not possible to anticipate all site specific hazards or combinations of hazards. Accordingly, inspectors must exercise their judgement in regard to what is included in the inspection. Nothing should be done that endangers either the inspector or source personnel.

The information provided in this notebook will help inspectors to develop an independent and accurate assessment of the source's compliance status. Much of the information will be of value in evaluating any corrective actions proposed by the source personnel. However, inspectors should not use the inspection data and observations to demand or prescribe specific corrective actions or operating procedures. Operation and maintenance requirements of specific sources are inherently complex and a one or two day inspection is not designed to compile all of the information necessary to prepare specific procedures. Furthermore, there are numerous legal reasons why inspectors should avoid prescribing specific actions.

2. INSPECTION OF WASTE COMBUSTION SYSTEMS

The primary purpose of this section is to present background information concerning waste combustion systems and the generation of air pollutants. Later introductory sections cover the various types of air pollution control systems used on municipal waste incinerators.

The information concerning combustion equipment illustrates the purposes and limitations of the inspection steps presented in Section B of this notebook.

2.1 Background Information

2.1.1 Diversity and Variability of Municipal Waste Incineration

One of the fundamental principles of the Baseline Inspection Technique is that each plant and each operating system within a plant should be treated as unique. Shifts in site specific operating conditions are used to evaluate performance. This approach is especially important in the case of municipal waste incinerators due to the considerable diversity of the equipment presently in service and the equipment being developed.

The capacities of the waste combustion units range from very small (5 to 50 tons per day) to very large (1000 to 3000 tons per day). Factory assembled modular incinerators are generally used for the small plants. Large plants utilize either mass-burn reciprocating grate or rotary combustor incinerators, or refuse derived fuel (RDF) production facilities in conjunction with spreader stoker boilers. Combustion conditions and pollutant generation/destruction mechanisms can be quite different in these three substantially different types of combustion systems. They also differ with respect to their vulnerabilites to operating problems and their maintenance requirements.

The large majority of systems installed or planned since 1980 incorporate energy recovery. This is generally in the form of steam generation. However, some large facilities also generate and sell electrical power. To recover energy, it is necessary to install boiler tubes in the main combustion chamber and to add steam superheater sections and feedwater economizers. These heat exchangers effectively cool the gas stream down to levels manageable in air pollution control systems.

Older municipal waste incinerators without heat recovery have a water spray cooling section after the combustion chamber in order to lower gas temperatures. The presence of the heat exchange equipment in the newer systems also affects the pollutant generation/destruction mechanisms since it affects the diversity of localized gas temperatures in the furnace area and since it provides metal surface area for possible catalytic reactions.

Waste composition varies from location to location. Partially, due to this variability, it was necessary to modify combustion equipment being installed in the U.S. that was originally developed in Europe and Japan. Also, it is difficult to compare the formation and emission rates of certain pollutants in plants in the United States with the European and Japanese plants.

The variability of waste composition at a given site over time is even more of a problem than the variability of waste from site to site. Sudden changes in waste quality can upset combustion and lead to high short term pollutant emission rates. Substantial equipment damage and unscheduled outages also occur due to problems with the waste feed characteristics.

It is interesting to compare fuel variability problems of municipal waste incinerators (all types) with the operations of pulverized coal-fired boilers and stoker coal-fired boilers. General operating conditions are provided in Table 2-1. A number of comparisons are useful to establish the proper perspective. These are itemized below.

(1) Heating Value - The heating values of the fuel for municipal waste incinerators is 20 to 50% of those of bituminous coal-fired boilers. This means that the quantity of the fuel necessary to produce a pound of steam is 2 to 5 times greater than it is in the case of the coal boilers. Fuel handling is even a problem for coal-fired systems!

(2) Fuel Sizing - The variability of coal sizing is a major problem for both pulverized coal-fired and stoker coal-fired boilers. However, municipal waste has much greater fuel size variability.

(3) Maximum Fuel Size - Municipal waste includes bulky, partially noncombustible materials such as refrigerators, tires, car batteries, furniture parts, rags, and cables. Failure to remove these prior to firing leads to serious feed mechanism and/or incinerator problems. Coal-fired boilers are challenged only by small bits of scrap metal.

(4) Ash Fusion Temperature - Due primarily to the presence of glass, the temperature at which the "ash" becomes fluid is much lower for municipal waste incinerators than for coal-fired boilers. Furthermore, the variability of waste composition and the complexity of ash chemistry makes it difficult to accurately predict this temperature. Low ash fusion temperatures lead to a variety of severe operating conditions including slagging of the furnace walls, clinker formation, and pluggage of the grates. Even coal-fired boilers have ash fusion problems and they operate at the much more forgiving fusion temperatures of 2100 to 2500 °F.

Table 2-1. Fuel Differences Between Municipal Waste Incinerators and Selected Types of Coal-Fired Boilers

Heating Value (Btu/Lb as fired)	
Municipal Waste Incinerators	2,000 - 7,500
Pulverized Coal (Bituminous)	9,000 - 13,500
Stoker Coal (Bituminous)	9,000 - 13,500
Maximum Fuel Size (as fired)	
Municipal Waste Incinerators	1 ft. - 2 ft.
Pulverized Coal (Bituminous)	1/16 in.
Stoker Coal (Bituminous)	1/2 in.
Normal Fuel Sizing	
Municipal Waste Incinerators	1/32 in. - 2 ft.
Pulverized Coal (Bituminous)	95% past 200 mesh
Stoker Coal (Bituminous)	1/32 in. - 1/2 in.
Fuel Sizing Variability	
Municipal Waste Incinerators	Extreme
Pulverized Coal (Bituminous)	Minimal
Stoker Coal (Bituminous)	Moderate
Sensitivity to Fuel Sizing	
Municipal Waste Incinerators	Extreme
Pulverized Coal (Bituminous)	Moderate
Stoker Coal (Bituminous)	Extreme
Ash Fusion Temperature (°F)	
Municipal Waste Incinerators	1300 - 1600
Pulverized Coal (Bituminous)	2100 - 2500
Stoker Coal (Bituminous)	2100 - 2500

The purpose of Table 2-1 and the comparison with coal-fired boilers is to illustrate one basic point: garbage is not an especially good fuel. Occasional problems at municipal waste incinerators should be anticipated considering that even well designed and operated coal-fired boilers sometimes have serious fuel quality and fuel variability problems. Agency inspectors should exercise some patience and restraint when inspecting municipal waste incinerators because of the inherently lower fuel quality. The operating problems are often more complex than they may seem. Furthermore, there are no magic design formulas or special operating procedures that ensure 100% reliability. Burning garbage is not easy!

Inspection of municipal waste incinerators is complicated by both the diversity of the industry and the variability of equipment performance. The problem is not going to get any easier in the next several years since the municipal waste incineration industry is relatively young and growing rapidly. A relatively large number of individual equipment manufacturers are developing innovative combustion equipment and air pollution control devices to minimize operating problems and to gain a substantial share of this growing market. The diversity of the industry will increase until several dominant equipment designs are established. The variability of performance will continue until plant personnel, with the assistance of equipment manufacturers and consultants, optimize performance of these relatively new systems.

2.1.2 Pollutant Formation and Destruction Mechanism

Table 2-2 contains an extensive list of pollutants of concern during most Level 2 or Level 3 inspections of municipal waste incinerators. This is one of the unique aspects of municipal waste incinerator inspections since most other source categories involve only one or two main pollutants.

As indicated in Table 2-2, the formation rates and destruction rates of some of these are strongly influenced by combustion conditions. In other cases, the formation rates are a function primarily of the waste composition. Obviously, the focus during the inspection of the combustion equipment is on those factors that significantly affect the formation/destruction mechanisms of the pollutants of interest. Some of the important combustion equipment parameters can be monitored. Others involve very subtle and complex phenomenon which can only be evaluated by indirect means.

Table 2-2. Pollutant Formation/Destruction

Pollutant	Influenced Strongly by Combustion System Design/Operation	Influenced Strongly by Waste Composition
Particulate (total)	Yes	Yes
Particulate, metals	Yes	Yes
Hydrogen chloride	No	Yes
Hydrogen fluoride	No	Yes
Sulfur dioxide	No	Yes
Sulfuric acid	Yes	Yes
Nitrogen oxides	Yes	Yes
Organic compounds (total)	Yes	No
Dioxins and furans	Yes	Yes

2.1.2.1 Total Particulate Matter and Metals

Flyash is generated by three main mechanisms during the incineration of municipal waste: (1) suspension of noncombustible materials, (2) incomplete combustion of organic material contained within small particles entrained in the flue gas, and (3) condensation of vaporous material including both unburned organics and metals. The flyash particles leaving the combustion equipment are the chemical and physical sum of these three different generation mechanisms. The bulk of the particles is composed of the noncombustible fraction along with any partially oxidized organic particulate. The surfaces of the particles have small quantities of the condensed species. The average particle size is in the range of 1 to 5 microns which is similar to other combustion sources. Particles in this size range are invisible and as many as 50 could be lined up across the diameter of a single human hair.

The total particulate quantities leaving the combustion chamber are in the range of 2 to 10 grains per actual cubic foot of gas (gr./ACF). The particulate generation rates at any given site are a function of the three factors listed below.

- Ash content of waste feed
- Adequacy of combustion
- Fraction of material removed as bottom ash

Waste feeds to municipal waste incinerators have ash contents in the range of 5 to 25% by weight. These are high values considering the very low fuel heating values discussed in the earlier section. The ash primarily consists of glass, metal wastes (e.g. food cans and household hardware), and any sand or clay accumulated on vegetation. The ash content can be minimized by the removal of any bulky, noncombustible items such as batteries, cables, and small appliances. Shredding of the wastes will also help lower ash content slightly.

The fraction of material removed as bottom ash depends primarily on the method of introduction of the waste into the combustion chamber and the size of the waste at this point. In most mass-feed incinerators, approximately 50 to 75% of the ash is removed as bottom ash and 25 to 50% is present as flyash. There are higher fractions of flyash in spreader stoker RDF-fired boilers since the fuel is smaller and some particle burning in suspension is intended. Smaller quantities are generated in modular units, especially starved air units. Design differences of the various types of combustion equipment are discussed in a later subsection.

The adequacy of combustion determines the quantity of organic char present along with the noncombustible materials. As a general "rule-of-thumb", the flyash removed from the particulate control device hoppers should have a loss-on-ignition value in the range of 10 to 50%. The high organic char levels indicated by higher than 50% loss-on-ignition levels suggest nonideal combustion conditions.

It should be noted that there two other ash streams generated during municipal waste incineration. Relatively large particle, high loss-on-ignition ash is collected in the hopper immediately downstream of the feedwater economizer. In some plants this material is reinjected back into the furnace. The pros and cons of this practice will be discussed later. However, this is not the ash stream that inspectors should evaluate when checking the overall performance of the combustion system. Another ash stream is the siftings removed from the undergrate plenums. This very fine material seeps through the grate bars, stoker side rail seals, and stoker front and rear air seals. The siftings are a relatively insignificant ash stream and are generally vacuumed out during each major outage.

There are a variety of common metals included in the waste feed that can vaporize during combustion. These metals include lead, zinc, cadmium, mercury, and arsenic. Vapor pressure data illustrate that most of the metals will condense back into a particulate form by the time the gas stream reaches the particulate control devices.

Due to the presence of a high concentration of particles in the gas stream which can serve as condensation nuclei, the metals probably condense heterogeneously rather than homogeneously. Since the very small particles have greater surface area, the condensation occurs preferentially here. Thus, there is some enrichment of these small particles and unequal distribution of the condensed materials as a function of the particle size. This means simply that the small particles are the most toxic. Unfortunately, small particles are also the most difficult to remove in most air pollution control systems.

2.1.2.2 Dioxins and Furans

For the purposes of this inspection notebook, the terms dioxin and furan will refer collectively to the 210 isomers of these compounds. They are normally grouped into two principal categories: (1) polychlorinated dibenzo-dioxins (acronym - PCDD), and (2) polychlorinated dibenzo-furans (acronym - PCDF).

There are strong parallels between the formation rates of organic pollutants such as dioxins and furans and the formation rates of excessive particulate matter. Both are believed to be created partially by nonuniform and/or improper combustion system conditions. Furthermore, these organic compounds may condense on flyash particles once the flue gas exits the high temperature zones of the heat exchange equipment [8]. To illustrate the extent to which combustion conditions potentially influence dioxin/furan emissions, note that older plants designed simply for waste reduction have been tested at PCDD emissions as high as 4000 nanograms per normal cubic meter whereas state-of-the-art incinerators incorporating improved designs and operational controls have been tested as low as 12 nanograms per normal cubic meter [9]. It should be noted that even the high concentration indicated above is a relatively low concentration value when expressed in the conventional form of ppm. The PCDD and PCDF concentrations are in the range of 0.01 to 0.1 ppm.

There are a variety of theories concerning the method of formation of the dioxins and furans which have been detected in the outlet gas streams of municipal waste incinerators. These are summarized in Table 2-3.

Table 2-3. Proposed Dioxin/Furan Formation Mechanisms

1. Vaporization of PCDD and PCDF compounds present in waste feed to incinerator

2. Reactions between chlorinated organic precursors such as chlorophenols and PCB

3. Chlorination of polyvinyl chloride or lignin in waste feed by salt, HCl, or chlorine gas

4. Catalytic reactions between organic precursors and trace metals adsorbed on flyash particles and various chlorine compounds in the gas stream

The direct volatilization of dioxin/furan compounds contained in the waste has been suggested by studies done at several locations [10]. However, the quantities of dioxin/furan found in the gas streams was much greater than the feed quantities. Accordingly, some formation mechanisms must also be active as the flue gas passes through the boiler.

Despite the substantial chemical literature concerning dioxin and furan formation/destruction there is still considerable uncertainty regarding the chemical mechanisms involved in municipal waste combustion. This is partially due to the analytical difficulties involved with monitoring pollutants which exist in the gas stream in parts per billion concentrations. The problem is substantially complicated by the extreme sampling problems involved in gaining "representative" samples of pollutants which exist partially in the vapor state and partially in a condensed form on the surfaces of highly variable particles. Further complicating the condition is the highly heterogeneous nature of municipal waste incinerator feed composition and combustion system operation.

Since the formation mechanisms are not fully understood, there are no straight forward design procedures or operating procedures than can prevent the formation of PCDD and PCDF compounds. Instead reliance is placed on the destruction of the pollutants created in the combustion process and high efficiency collection of the dioxin/furan containing flyash. Concerning the combustion equipment, the EPA Municipal Waste Combustion Study [6] presents three basic goals for controlling the generation of dioxins/furans, namely:

- Mixing of fuel and air to minimize the existence of long-lived, fuel-rich pockets of combustion products

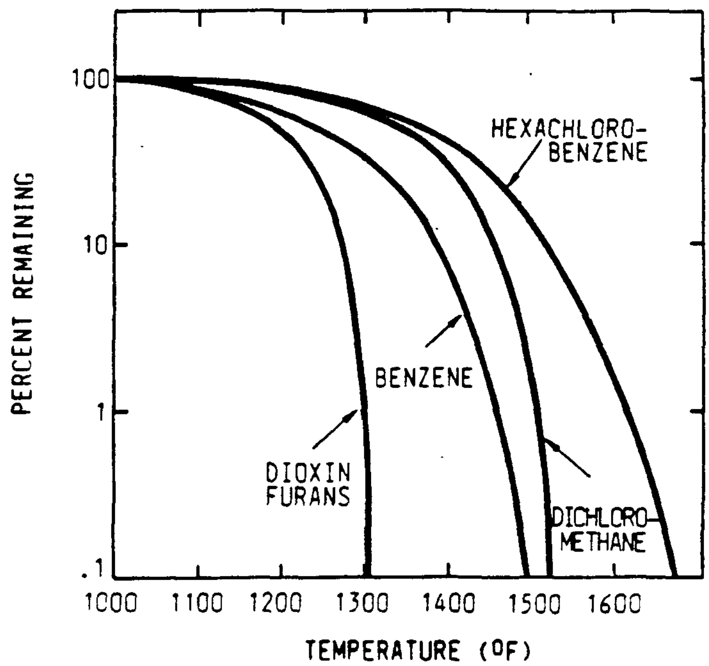
- Attainment of sufficiently high temperatures in the presence of oxygen for the destruction of hydrocarbon species

- Prevention of quench zones or low temperature pathways that will allow partially reacted fuel (solid or gaseous) from exiting the combustion chamber

(Reference 6, Page 1-5)

There are no combustion system design or operating parameters that can be related to the formation of dioxin and furans. Instead, it is necessary to use a set of indirect measurements that are logically related to conditions conducive to dioxin and furan formation/destruction.

One of the most obvious and important of these indirect parameters is the furnace temperature itself. A variety of laboratory research studies and field measurement studies have indicated that gas temperatures above 1800°F yield very low dioxin/furan concentrations [11]. In fact, the destruction efficiency-gas temperature relationship shown in Figure 2-1, suggests that these categories of organic pollutants are one of the most easily destroyed during passage through the incinerator as long as there is good vapor and oxygen mixing.



Source: Seeker et al. [6, p. 4-6]

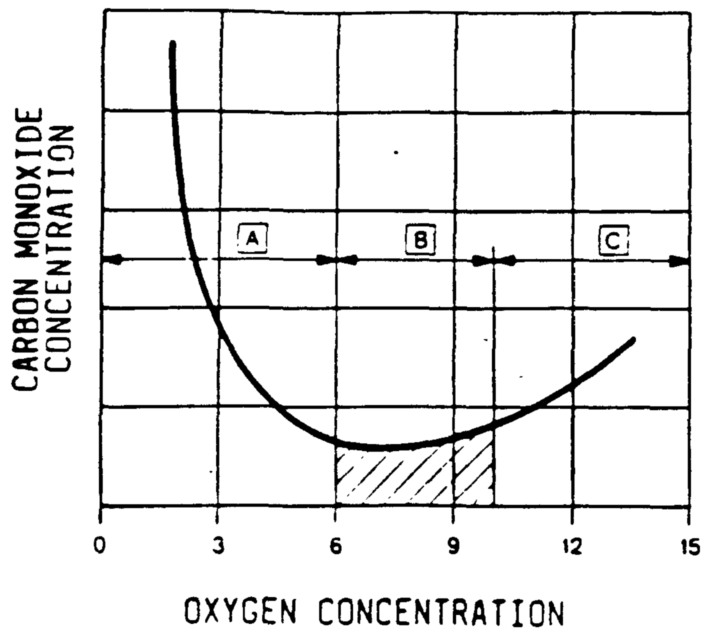
Figure 2-1. Temperature-Dioxin/Furan Destruction

The problem with the relationship illustrated in Figure 2-1 is that substantial gas temperature nonuniformities may exist as the gas stream passes up through the water tube lined furnace area and the other heat exchange areas. All portions of the gas stream may not be exposed to the same time-temperature "history." Unfortunately, it is not possible to simply look in a furnace/boiler and observe the "cold" zones.

Also it is somewhat difficult to accurately monitor the gas temperature due to the temperature nonuniformities and due to the extreme temperature levels. Generally, thermocouples with water cooled probes or pyrometers are used for temperature monitoring and neither of these are especially discriminating with respect to spatial temperature variability. Accordingly, the gas temperature provides only a gross indication of the potential for dioxin/furan survival.

The destruction temperature requirements for dioxins and furans are also a function of the oxygen concentrations throughout the furnace volume. The average flue gas furnace temperatures necessary for adequate dioxin and furan destruction are lower when the oxygen levels increase [6]. Therefore, inspectors should attempt to evaluate the temperature data in conjunction with the oxygen analyzer.

Carbon monoxide monitoring data provides a useful back-up check for evaluating potential dioxin/furan emissions [12]. As in the case with furnace temperature, this is an indirect indicator and it is not possible to relate a certain concentration of CO to dioxin/furan concentrations. However, increases in the CO levels are indicative of combustion problems which in turn could conceivably lead to increased pollutant emission rates. The generally acceptable CO concentration curve is presented in Figure 2-2. This indicates that CO decreases rapidly as the average oxygen concentration increases to 6 to 9% (volume basis, dry). At these levels there is sufficient excess air to overcome major nonuniformities in fuel-air mixing and the complex set of combustion reactions is relatively complete. The addition of more air than necessary results in some cooling of the furnace area since all of the oxygen, nitrogen, and water vapor included in the air must be heated up to the exhaust gas temperatures. This cooling action quenches the reactions responsible for oxidation of carbon monoxide to carbon dioxide. Presumably, this also quenches the reactions necessary to complete the thermal destruction of the highly undesirable dioxins and furans.



A - Insufficient Air
B - Appropriate Operating Region
C - "Cold Burning"

Source: Seeker et al. [6, p.3-13]

Figure 2-2. Carbon Monoxide - Oxygen Profile

As a general "rule-of-thumb" the carbon monoxide concentrations should be maintained at levels below 100 ppm [12]. Excursions to levels in the range of 300 to 500 ppm certainly suggest possible combustion problems and increased organic pollutant emissions. Inspectors should ask plant personnel how they intend to respond to increases in the monitored CO levels above 100 ppm. Furthermore, CO records since the last inspection should be reviewed to determine if chronic combustion related problems exist.

2.1.2.3 Acid Gases

The sulfur dioxide emission rates from municipal waste incinerators are directly related to the sulfur content of the waste feed. The waste feed sulfur contents of 0.05% to 0.25% are well below the levels of coal-fired and No. 6 oil-fired boilers. Also, as much as 50% of the feed sulfur is probably tied up in the bottom ash [13]. Accordingly, sulfur dioxide concentrations are typically in the range of 20 to 200 ppm with an average value near 80 ppm [13].

The other acid gases of concern include hydrochloric acid, hydrofluoric acid, and sulfuric acid. Hydrocloric acid formation is directly related to the concentration of chlorine containing wastes being fed. These could include polyvinyl chloride (PVC), other chlorinated plastics, and sodium chloride. The fraction of chlorine that is ultimately converted to hydrogen chloride is not known. The tested concentrations (uncorrected) of hydrogen chloride have ranged from 70 to more than 1000 ppm [13].

Hydrogen fluoride is also derived from the various fluorinated wastes present in the feed. Tested concentrations are in the range of 3 to 20 ppm (uncorrected) which is well below the levels of hydrogen chloride [13].

2.1.2.4 Nitrogen Oxides

Nitrogen oxides measurements at various existing plants have indicated highly variable emission rates. These have ranged from a low of 0.05 pounds per million Btu to a high of almost 1.0 pound per million Btu [14]. Most of the measurements are in the range of 0.23 to

0.63 pounds per million Btu [15]. There has not been any consistent relationship between the type of incinerator and the emission rates.

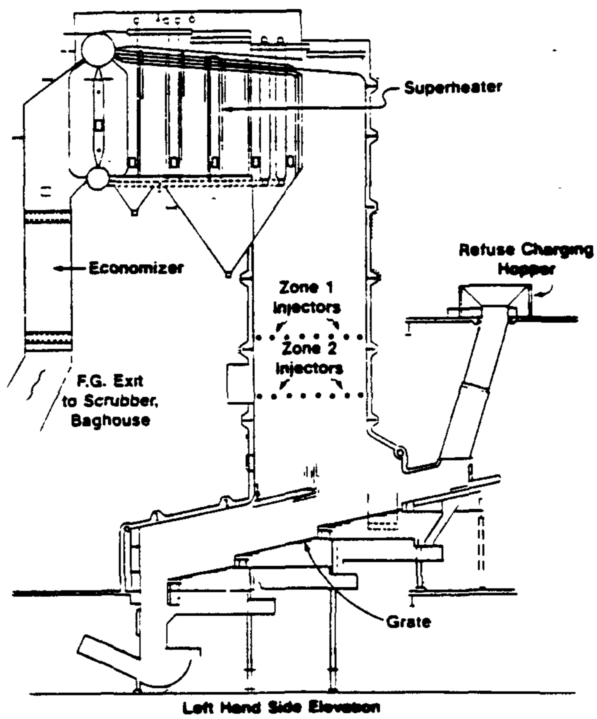
The formation mechanisms are probably similar to those involved in nitrogen oxides formation in coal-fired boilers. These include thermal formation and fuel nitrogen conversion [13]. In fact, the importance of fuel nitrogen may be one of the reasons that it has been difficult to develop correlations of nitrogen oxides emissions and incinerator styles.

The thermal formation mechanism is highly dependent on the furnace temperatures and oxygen concentrations. The conditions which favor dioxin and furan destruction are essentially identical to those that favor nitrogen oxides formation. Accordingly, modern plants designed to minimize the survival of the chlorinated organics may suffer higher nitrogen oxides emissions than the existing municipal waste incinerators.

The possible control options for reducing nitrogen oxides emissions include (1) flue gas recirculation, (2) Thermal DeNox (ammonia injection), (3) selective catalytic reduction, and (4) reburning with natural gas.

Flue gas recirculation has been used successfully on a variety of coal-fired boilers for nitrogen oxides control. However, the potential nitrogen oxides reductions are only in the range of 20 to 50%. All of the other control options have the capability of reducing nitrogen oxides 50 to 70%.

The Thermal DeNox process was also developed for coal-fired boilers. This process simply uses reactions between ammonia and nitrogen oxides at high gas temperatures to yield molecular nitrogen. The ammonia is injected through a series of nozzles immediately above the furnace area of the incinerator as indicated in Figure 2-3.



Source: Hurst and White [15, p.122]

Figure 2-3. Ammonia Injection Nozzle Locations for the Thermal DeNox Process

In the Thermal DeNox process, the ammonia is injected at an area of the furnace/boiler which is at approximately 1800 °F. This temperature range is critical. If the gas temperatures at the injection location exceed 2200 °F, the ammonia is oxidized and the resulting nitrogen oxides emissions are actually increased rather than being controlled. If the gas temperatures at the injection location are lower than 1600 °F, unreacted ammonia is emitted from the system [15].

There are also some lingering concerns about the possible formation of various ammonia compounds such as ammonium sulfate, ammonium bisulfate, and ammonium chloride. The main concerns are plume formation and fouling of the heat exchange surfaces.

The selective catalytic technique is similar to the Thermal DeNox process. A catalyst is added to allow operation at much lower temperatures, to decrease the potential for ammonia emissions from the system and to increase the possible nitrogen oxides removal efficiency [15]. The ammonia used for chemical reduction of the nitrogen oxide is injected downstream from the economizer where the temperature is in the range of 300 to 400°C (572 to 750°F). However, the catalyst is vulnerable to poisoning due to the variety of metal and acid compounds present in municipal waste that could either poison or suppress the catalyst activity. Due to the development work necessary for this process, inspectors will not need to evaluate selective catalytic systems in the immediate future.

Reburning techniques are also at a very early stage of development and these also will be used on a commercial scale for some time. Accordingly, it is not discussed any further.

2.2 General Incinerator Plant Components

A complete municipal incinerator facility consists of the following basic components:

- Waste storage and handling
- Energy conversion and utilization
- Residual disposal
- Waste combustion and air pollution control

2.2.1 Waste Storage and Handling

The waste storage and handling area generally consists of a tipping floor or tipping pit for receiving the waste from the trucks. This receiving and temporary storage area is generally sized for several days processing rates to allow for short term plant outages. To the extent possible, the stored material should be mixed to minimize fuel heating value and size variability [16]. As discussed in Section 2.1.1, fuel variability can cause significant incinerator firing problems that in turn lead to excessive particulate and organic pollutant emissions. Therefore, the as-charged characteristics of the fuel are the primary issue during the inspection of this part of the facility. It is also necessary to confirm that the operators are in fact attempting to remove any bulky, noncombustible items which would adversely affect the fuel-air ratios in the incinerator. These bulky items could include large appliances, small appliances, tires, automotive parts, and furniture.

Odor problems should also be noted while completing the brief inspection of the waste storage area. Generally the receiving area and incinerator charging area are enclosed to prevent odors and to avoid wind problems in the unloading area.

2.2.2 Energy Conversion and Utilization

The energy conversion and utilization consists primarily of the heat exchange surfaces within the boiler and, in a few cases, it also includes turbine generators. The inspection of this part of the system is generally limited to an evaluation of the steam generation rate and the feed water rates. These two important operating conditions are always monitored on a continuous basis. They provide a clear indication of the average incinerator loads and the variability of the incinerator loads. This is a major issue with incinerators since it is difficult to operate at low loads without risking increased dioxin/furan and particulate emissions due to the low furnace gas temperatures. The reason for looking at both feedwater and steam rates is to ensure that accurate data is obtained. Either one of the monitors could fail or provide inaccurate readings. Since the two values should be approximately equivalent at any given time, it is possible to check the plant instruments.

2.2.3 Residual Disposal

It is necessary to confirm that the incinerator bottom ash and air pollution control device wastes are disposed without creating fugitive particulate emissions. Another issue is the possible classification as a hazardous waste under RCRA regulations. If the waste material has any one (or more) of the four characteristics listed below, the material is labeled as hazardous.

- Ignitability,
- Reactivity,
- Corrosivity,
- EP Toxicity

The EP Toxicity test is simply an extraction type test to determine if there are leachable components (such as metals) in the ash which are considered toxic (40 CFR 261.24). In the future, this test may be replaced by the Toxicity Characteristic Leaching Procedure [References 16 and 51 FR 21685, June 13, 1986].

Generally the bottom ash is nonhazardous. However, the flyash can sometimes have sufficiently high concentrations of one or more metallic compounds to be labeled as hazardous. This is partially due to the volatilization of the metals in the furnace area and subsequent condensation on flyash particles as the cooled flue gases leave the heat exchange areas of the boiler (See earlier discussion in section 2.2.1.). Since the generated flyash is much lower in quantity than the combustion system bottom ash [20], there is the possibility that mixing of the bottom ash and flyash will result in a mixture that overall could be classified as nonhazardous. This raises regulatory policy questions that are beyond the scope of this notebook. Nevertheless, agency inspectors should fully understand their agency's position regarding mixing of bottom ash and fly ash.

If the bottom ash and/or flyash is hazardous waste in accordance with the RCRA regulations, it must be sent to a Subtitle C facility. These are specially designed and operated landfills which can accept hazardous wastes. The disposal costs are considerably higher than those at conventional sanitary landfills.

2.2.4 Waste Combustion and Air Pollution Control

The waste combustion equipment and its associated air pollution control equipment obviously demand most of the attention during the on-site inspection. Due to the diversity of the various types of incinerator systems, each of these must be discussed separately.

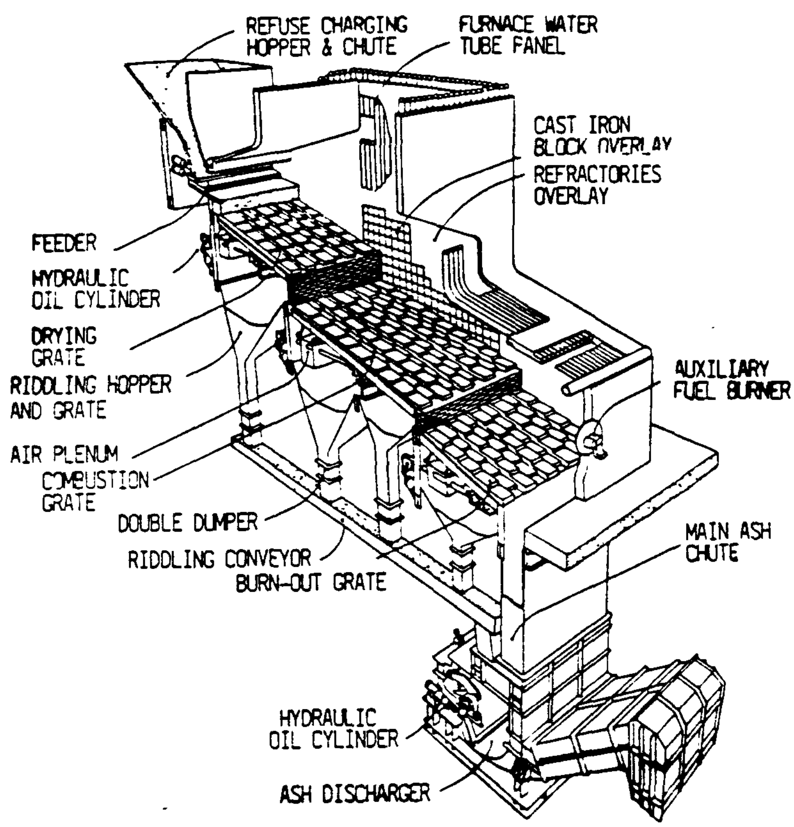
2.2.4.1 Mass Burn Systems

The waste feed materials receive very little pre-treatment prior to charging to mass burn incinerators. Obviously oversized material such as refrigerators are often set aside. Also, any material which is potentially explosive, including gas cylinders and paint cans, is also removed if noticed by plant personnel. All other materials are charged as received. The design of the charge pit, the cranes, and entrance to the furnace must be free of any obstacles which could be easily blocked by oversized material being introduced to the furnace. Furthermore, the ash pit entrance must be sufficiently sized in the event that bulky noncombustible material is inadvertently carried into the furnace.

There are two main styles of mass burn incinerators: (1) the sloped, reciprocating grate design, and (2) the rotary combustor design. The sloped, reciprocating grate design is illustrated in Figure 2-4 and the rotary combustor is illustrated in Figure 2-5.

The large reciprocating grate units have an arch positioned over the waste feed entering the furnace. This radiates heat to the fuel to dry and ignite the material. This is analogous to the refractory arches used in overfeed stokers designed for coal combustion.

The waste is rotated during passage through the furnace to ensure that some waste is not partially insulated from combustion. The rotating action created by the grate bar movement also helps maintain a relatively uniform fuel bed which is essential for proper localized fuel-air ratios.



Source: Seeker et al. [6, p.5-39]

Figure 2-4. Cross Sectional Sketch of a Mass Burn Incinerator

The normal variations in the fuel properties must be handled by changes in the grate speed, the feed rate, and the undergrate and overfire air supplies. Accordingly, careful operator attention is necessary since waste feed characteristics can change rapidly.

It is normally necessary to have at least two undergrate plenums in the active burning area for distribution of air up through the grates. This is partially because the air flow through the waste fuel-ash layer decreases as the combustion reactions reach completion. The undergrate air pressures in the second plenum are generally slightly lower since flow resistance is lower and since there is now less combustible material. Also, separate undergrate plenums are needed in the initial drying zone and the ash zone burnout areas. The pressures in these grates must be set in accordance with the fuel characteristics and the ash quantities.

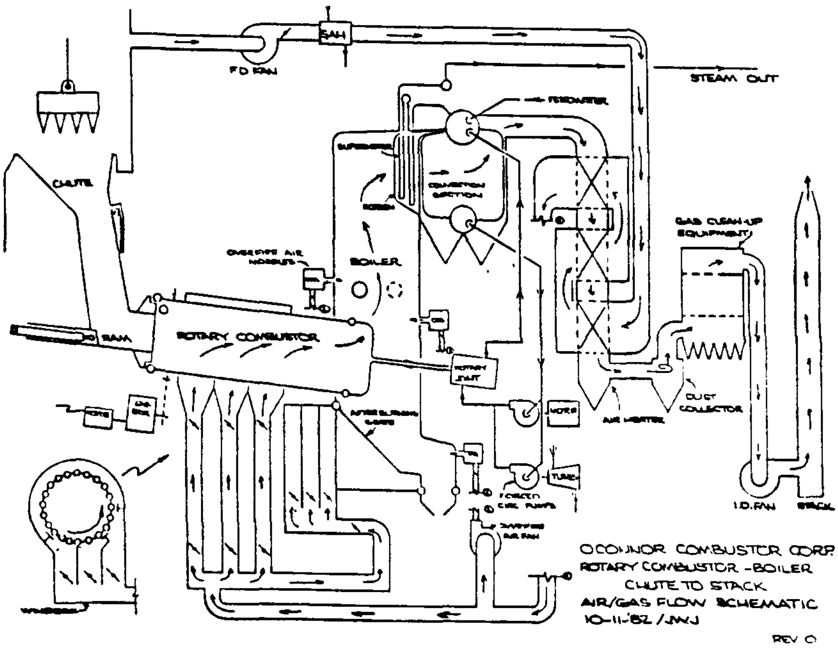
The undergrate and overfire air pressures can generally be evaluated by inspectors, even during Level 2 inspections. The undergrate air pressures are almost always monitored by means of on-site static pressure gauges. Conventional pneumatic gauges have given way to more modern differential pressure sensors/transmitters which provide an electrical signal in the control room. This data, along with the firing rate data and steam rate data, should be routinely recorded on the furnace/boiler operating log. Shifts in operating conditions from baseline site specific levels should be evaluated. Also, the data can be compared against the normal operating conditions for each style of unit.

Due to differences in reciprocating grate design philosophies among the various manufacturers, there are substantial differences in the fuel-ash depths, the grate air flow resistances, and the furnace configurations. This obviously affects the normal operating ranges of the underfire air pressures, the overfire air pressures, and the fraction of total combustion air used for overfire air. A summary of the manufacturer specific operating conditions is provided in Reference 6 for inspectors who wish to compare plant values against "typical" values for that specific style of incinerator. However, it should be recognized that most plants have made slight adjustments to these values to achieve optimum operating conditions with their waste fuel characteristics. Also, manufacturers may modify their equipment slightly as additional experience is gained with on-line systems. For these reasons, comparisons with "typical" values are generally not as meaningful as shifts in baseline site specific conditions.

The uniformity of air-fuel ratios is primarily dependent on the uniformity of the fuel-ash layers on the grates and the adequacy of the undergrate air flows for the fuel-ash beds. Inspectors can qualitatively evaluate the fuel-ash beds by using observation hatches on the sides of the furnace. However, extreme caution is necessary since shrapnel from exploding aerosol cans can cause severe injuries while looking into the hatches. Eye protection is mandatory. Also, the line of sight should be selected to avoid the probable trajectories of high velocity objects. Additional information regarding the use of observation hatches is included in Section 2.3.

The operating feedrate for a mass feed system is based on an average design fuel heating value that is often 4500 to 5000 Btu per pound. The stoker must be sized for the expected variations in this heating value. Very high heating value wastes could lead to excessive Btu per square foot of grate area and this leads to excessive furnace temperatures which damage the grates and can lead to slagging. Plants which use preheated undergrate air are especially prone to these problems. Excessively low heating values can tax the capability of the drying zone of the stoker to adequately prepare the wastes for combustion.

A sketch of a rotary combustor is provided in Figure 2-5. The waste feed techique is similar to that of the reciprocating grate units with the exception of the ram used for rotary combustor charging. There is a series of undergrate air plenums in the rotary combustor and in the afterburning grate. The air pressures and flows in each of these plenums is set by a series of dampers. A single forced draft fan supplies all of the undergrate air. More turbulent mixing of the waste with the combustion air is possible due to the rotation. The Level 2 and Level 3 inspection is similar to the sloped, reciprocating grates with the exception that there is no attempt to maintain uniform fuel beds on the grates in a rotary combustor.



Source: O'Connell, C.
1984 National Waste Processing
Conference, pp. 305-317

Figure 2-5. Rotary Combustor Type Mass Burn System

2.2.4.2 Refuse Derived Fuel Incinerator Systems

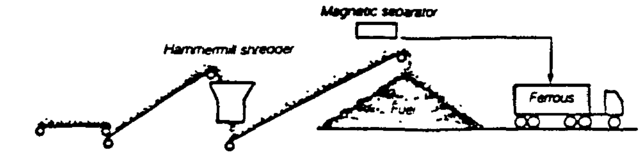
Processing of waste materials provides one means to overcome the heterogeneous characteristics and low heating value quality of the waste. Once prepared in a more useable form, it can be fired either alone or in combination with coal, wood chips, or other conventional fuels having higher heating values.

One style of refuse preparation is the relatively simple "shred-and-burn." At this type of plant, the waste is deposited on the tipping floor and moved onto conveyors by means of front-end loaders. As the unprocessed waste moves toward the shredders, the solid waste is examined visually by plant personnel for any dangerous items that could cause explosions or other problems [18]. The risk of explosions is very real. Accordingly, regulatory agency inspectors should minimize their time in this area and adhere to all facility safety requirements. This will include staying behind any personnel protective barriers and avoiding areas adjacent to explosion vents.

Following the shredding operation, magnetic separators are used to remove any tramp ferrous metals that are included in the waste feed stream. This material could damage the RDF fuel distribution equipment and the stoker parts.

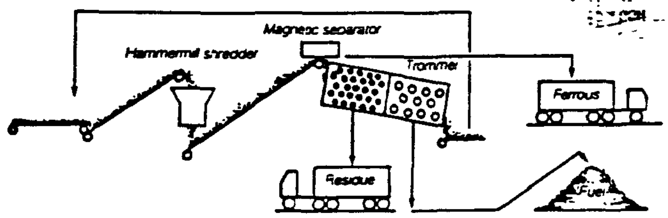
There are a variety of other RDF fuel preparation techniques. These are summarized in a series of sketches provided in Figure 2-6. The "shred-and-burn" arrangement is shown in the top figure. In the next arrangement a Trommel screen is added for the removal of some of the small sized noncombustible material such as sand and shattered glass. The oversized material from the Trommel screen is recycled back to the hammermill for additional size reduction.

The main problem with the arrangements shown in Figures 2-6a and 2-6b is that the shredder is the first unit to process the as-received wastes. Any undetected containers of flammable liquids or compressed gases could cause an explosion. RDF preparation tech-niques shown in Figures 2-6c and 2-6d have been used to minimize the very common and very serious explosion problems. The flail shredder is a low energy unit designed simply to rip open garbage bags and other containers so that the waste can be screened. Small diameter noncombustible material is separated prior to the hammermill. The fourth arrangement, shown in Figure 2-6d includes a screen after the hammermill and the magnetic separator to further remove any improperly sized materials which could damage the fuel transport equipment, the fuel distribution equipment, or the stoker grates.



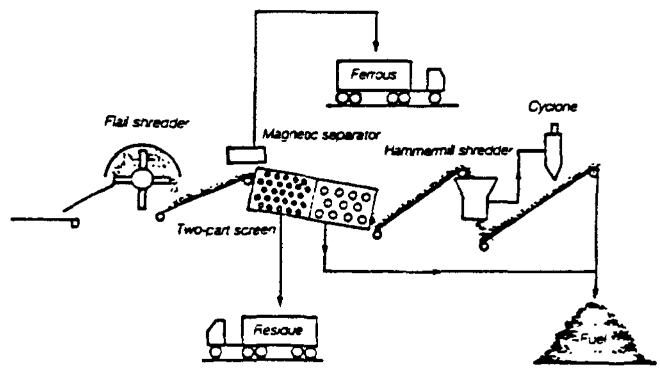
4. Simplest RDF preparation is shred and ferrous removal. Method is least expensive, but causes boiler slagging problems from glass content, plus high shredder wear

Figure 2-6a.



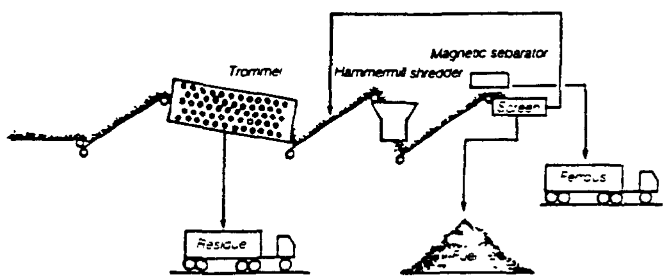
5. Addition of a trommel prevents many noncombustibles and glass from entering boiler, but all material must pass through shredder leading to heavy wear

Figure 2-6b.



6. Flail shredder before trommel eases materials separation. Two-part screen ensures **less** loss of combustible material to residue

Figure 2-6c.



7. Trommel placed before shredder saves wear on the shredder and reduces the explosion potential by screening out cans of volatile liquids, etc

Figure 2-6d.

Source: Reason, J. [20, p.19]

Figure 2-6. Refuse Derived Fuel Preparation

In all four cases, the RDF fuel is processed to yield a fuel with a limited size distribution and without any oversized material. The glass content is reduced in some systems, thereby reducing the ash fusion problems. Furthermore, there is some reduction in the overall metals content of the waste feed. This has a beneficial impact on the overall emissions of trace metals from the combustion system. Basically, the various RDF processing techniques produce a fuel which is less variable and more desirable than those used in mass burn plants.

Unfortunately, the operating problems at RDF facilities are not limited to simply producing the RDF fuel. One of the major problems with RDF systems is the reliability and uniformity of the feed to the stoker equipment [19]. The RDF materials are very erosive due partially to the fuel size and due partially to the metals content. Some of the problems include erosion of the fuel transport lines and erosion of the fuel distributors. The latter problem can lead to very nonuniform fuel deposits on the grate which in turn lead to nonuniform localized fuel-air ratios and high pollutant generation rates.

Nonuniform fuel distribution on the grates can generally be observed by looking in the front access hatches of the spreader stoker unit (immediately above the location of the person shown in Figure 2-7). It is also possible to look at the back end of the grate using the various side observation hatches (not shown on Figure 2-7). The fuel-ash layers should appear to be uniform from side-to-side and from front-to-back. A partial list of the possible problems leading to nonuniform distribution is provided below.

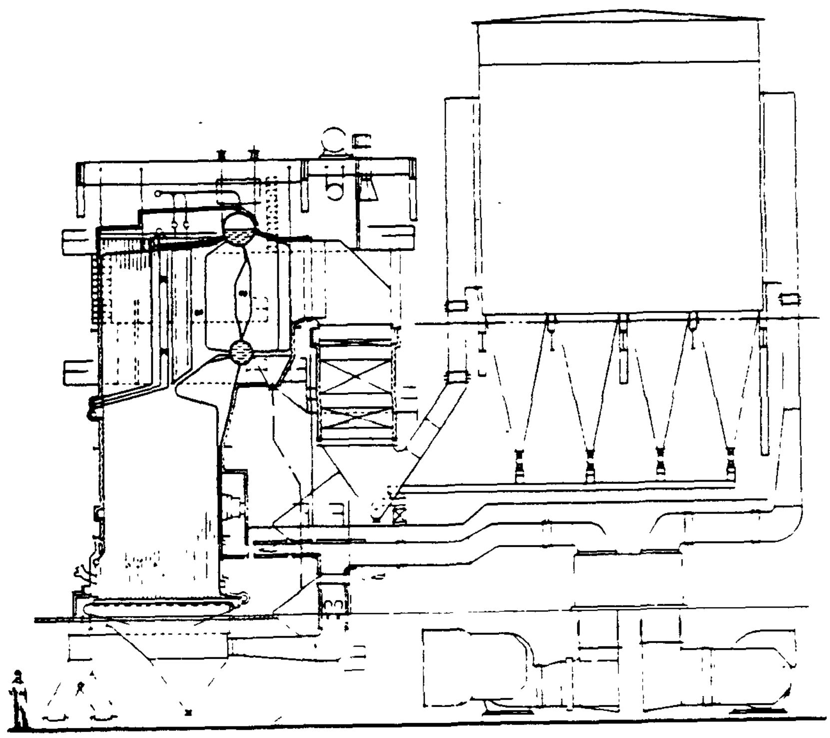
Poor front-to-back distribution

- Worn distributor plates
- Change in RDF particle sizing
- Improper matching of rotor blades in coal feeders (if coal used)
- Frequent RDF fuel interruptions

Poor side-to-side distribution

- Unbalanced RDF flows to each distributor
- Improper refractory angles near feeders
- Segregation of RDF fuels fed to each distributor

Spreader stoker type RDF-fired boilers have only one undergrate plenum as indicated in Figure 2-7. Non-uniform fuel-ash layers on portions of the grate can lead to serious thin spots as the high velocity combustion air channels through the areas of minimum flow resistance. The areas with high fuel-ash deposits have insufficient air flow and operate fuel-rich.



Source: Daniel, P.L., Barna, J.L. & Blue, J.D. 1986 National Waste Processing Conference, pp. 221-228

Figure 2-7. Spreader Stoker Boiler

The thin spots also expose the grate parts and support rails to the radiant heat of the combustion chamber. This can lead to grate damage and clinkering. The presence of the air preheater in Figure 2-7 renders this unit even more vulnerable to this condition. The importance of uniform fuel-ash deposits on the grates of spreader stoker units should not be underestimated.

The undergrate air pressures and overfire air pressures are as important for RDF-fired spreader stokers as they are for the various types of mass burn incinerators. The monitoring techniques are also similar. The large majority of plants monitor these pressures continuously using differential pressure transducers and transmitters. This data should be available in the boiler control room and should be recorded on a routine basis on the daily operating logs for the boiler. There should also be a series of 1/4" ports in the undergrate supply duct and in the various overfire air manifolds for manually checking these pressures.

The overfire air pressures are especially important since the the furnace areas often have a greater cross sectional area than the mass burn units. It is more difficult for the overfire air to penetrate across this area since the manifolds stretch across the front and back walls. Therefore, each bank of nozzle must penetrate approximately one-half the length of the furnace chamber. In the case of coal-fired boilers, there has been a gradual trend from low overfire air pressures in the range of 5 to 15 inches of water toward higher overfire air pressures in the range of 25 to 40 inches of water. A similar trend may occur in the case of RDF-fired units.

Refractory linings over the lower boiler tubes (not shown in Figure 2-7) have often been installed to increase the furnace temperatures and thereby reduce the formation of organic pollutants. In most plants, the refractory has been effective. However, in certain cases, slagging problems have occurred since the localized temperatures have exceeded the ash fusion temperatures of the particular waste being handled. Slagging is an intolerable operating situation which leads directly to serious stoker equipment damage and excessive pollutant (fly ash and organic pollutant) emissions. In these cases, it has been necessary to remove the refractory to avoid this severe problem.

Other problems with RDF feed systems include fires, bridging, and jamming. Waste materials which are especially troublesome include rags, wires, cables, chains, and hose. All of these interrupt the flow of RDF to the stoker.

Inspectors should avoid immediate contact with RDF since it contains potentially irritating and toxic chemicals in a finely divided form. It is the policy of some plants that all personnel must cover all exposed skin and wear respirators [18].

2.2.4.3 Modular Systems

Individual modular incinerator units typically have a capacity of 5 to 100 tons per day [15]. Larger modular facilities consist of multiple parallel systems to allow flexibility of operation. These factory-assembled units are often less expensive for small communities to build and operate [16]. Energy recovery in modular incinerators is less effective than for larger, field erected mass burn systems and RDF systems. One of the advantages of the modular units is that they reduce the various problems involved in shipping wastes long distances to a large centralized facility [20].

Modular systems consist of two combustion chambers arranged in series. The waste material is feed in a charging pit using a front end loader. A hydraulic ram is used to move the material into the initial combustion chamber which is called the primary chamber. The waste is moved through the primary chamber by two additional hydraulic rams which operate at the bottom of the primary chamber. The average waste residence time in the primary chamber is 6 to 12 hours (21), and this helps to dampen out the normal variations in waste fuel characteristics.

The primary chamber is designed to gasify the volatile fraction of the waste. Combustion of the vaporous material is completed in the secondary chamber. The operating temperatures are typically 1000 to 1200°F in the primary chamber and 1600 to 2000°F in the secondary chamber. Auxiliary burners are used in the secondary chamber when necessary to maintain desired outlet gas temperatures.

There are two basic types of modular units: (1) the excess air incinerators, and (2) the starved air (sometimes termed controlled air) incinerators. In the excess air units, the quantity of air supplied to the primary combustion chamber is roughly equivalent to the stoichiometric requirements. In other words, enough air is provided to complete combustion. For these types of systems, the secondary chamber simply provides a polishing step to eliminate any uncombusted vapors escaping the primary chamber.

In starved air units, the quantity of air supplied to the primary chamber is reduced to approximately 40% of the stoichiometric requirements. This reduces the gas velocities in this chamber and thereby reduces the quantities of particulate matter suspended in the flue gas passing to the secondary chamber. The air necessary to complete combustion is added to the secondary chamber that normally operates at temperatures in the range of 1600 F to 2000°F. An auxiliary burner is present in the secondary chamber to ensure proper exit gas temperatures.

Warping of dampers and charging doors in starved air systems has been reported as a frequent problem. This can lead to excessive combustion in the primary chamber and is probably caused originally by excessive operating temperatures.

2.3 Safety Considerations

2.3.1 Walking Hazards in Waste Receiving/Handling Areas

There are a variety of walking and overhead equipment hazards in the waste receiving area. Inspectors should carefully select positions to observe waste mixing operations, waste processing operations, and general fugitive emissions.

2.3.2 Contact with Wastes and RDF Fuel

Direct skin contact with the wastes and RDF fuels should be avoided. Gloves and protective clothing are required when there is any possibility of contact.

2.3.3 Eye Hazards Involved in Observing Combustion Conditions

The majority of municipal waste combustion systems include a set of observation hatches to allow the operators to periodically evaluate the distribution of waste feed on the grates, the adequacy of undergrate air flow, and the condition of overfire air nozzles. Use of these hatches during the inspection involves several hazards which include:

- Shrapnel from disintegrating aerosol cans and paint cans
- Sudden high temperature puffs during combustor pressure fluctuations
- Radiation from intense combustion

On units subject to pressure fluctuations, the observation hatches should not be used since exposure to the high temperature puffs (often flames 1 to 5 feet in length which occur in fractions of a second) could result in blindness, serious burns, and significant pollutant inhalation hazards. Pressure fluctuations are especially prevalent on the modular type incinerators. Regardless of the type of unit, variations in the combustion chamber static pressure should be reviewed before using an observation hatch.

To minimize shrapnel hazards, inspectors should avoid looking directly into the furnace area. The observation hatch should be used as a partial shield while looking into the unit on an angle. Obviously, this practice inhibits the inspector's view of the combustion conditions. This is a necessary limitation since aerosol can and paint can disintegration is a relatively common occurrence and since the shrapnel can cause blindness.

Proper eye protection must be used to shield the eyes from the intense radiation generated during waste combustion. Plant personnel can generally provide a sight glass or full face shield for this purpose. It should also be noted that observation hatches should only be opened and closed by plant personnel. Regulatory agency personnel should not touch any process equipment during an inspection.

2.3.4 Internal Inspections Prohibited

Agency inspectors should not participate in internal inspections of the combustion equipment under any circumstances. Sufficient time and safety equipment is not available to ensure safety.

3. INSPECTION OF DRY SCRUBBERS

Dry scrubbers utilize absorption and adsorption for the removal of sulfur dioxide, hydrogen chloride, hydrogen fluoride, and other acid gases. Some adsorption of vapor state organic compounds and metallic compounds also occurs in some dry scrubber applications. This relatively new control technology is presently in use on pulverized coal-fired boilers and municipal waste incinerators. Much of the presently available information applicable to municipal waste incinerators has been drawn from European installations operating for the last 3 to 5 years and U.S. installations operating for the last 1 to 2 years. Changes and refinements in municipal waste incinerator dry scrubbers should be anticipated as more experience is gained.

3.1 Components and Operating Principles of Dry Scrubbers

There is considerable diversity in the variety of processes which are collectively termed "dry scrubbing." This is partially because the technology is relatively new and is still evolving. The diversity also exists because of the differing control requirements. For purposes of this field inspection notebook, the various dry scrubbing techniques have been grouped into three major categories: (1) spray dryer absorbers, (2) dry injection adsorption systems, and (3) combination spray dryer and dry injection systems. Specific types of dry scrubbing processes within each group are listed below. Alternative terms for these categories used in some publications are shown in parentheses.

Spray Dryer Absorption (Semi-wet)
- Rotary atomizer spray dryer systems
- Air atomizing nozzle spray dryer systems

Dry Injection Adsorption (Dry)
- Dry injection without recycle
- Dry injection with recycle

Combination Spray Dryer - Dry Injection (Semi-wet/dry)

Simplified block diagrams of the three major types of dry scrubbing systems are presented is Figures 3-1, 3-2 and 3-3. The main differences between the various systems are the physical form of the alkaline reagent and the design of the vessel used for contacting the acid gas laden stream with the reagent. The alkaline feed requirements are much higher for the dry injection adsoption than the other two categories. Conversely, the spray dryer absorption and combination systems are much more complicated.

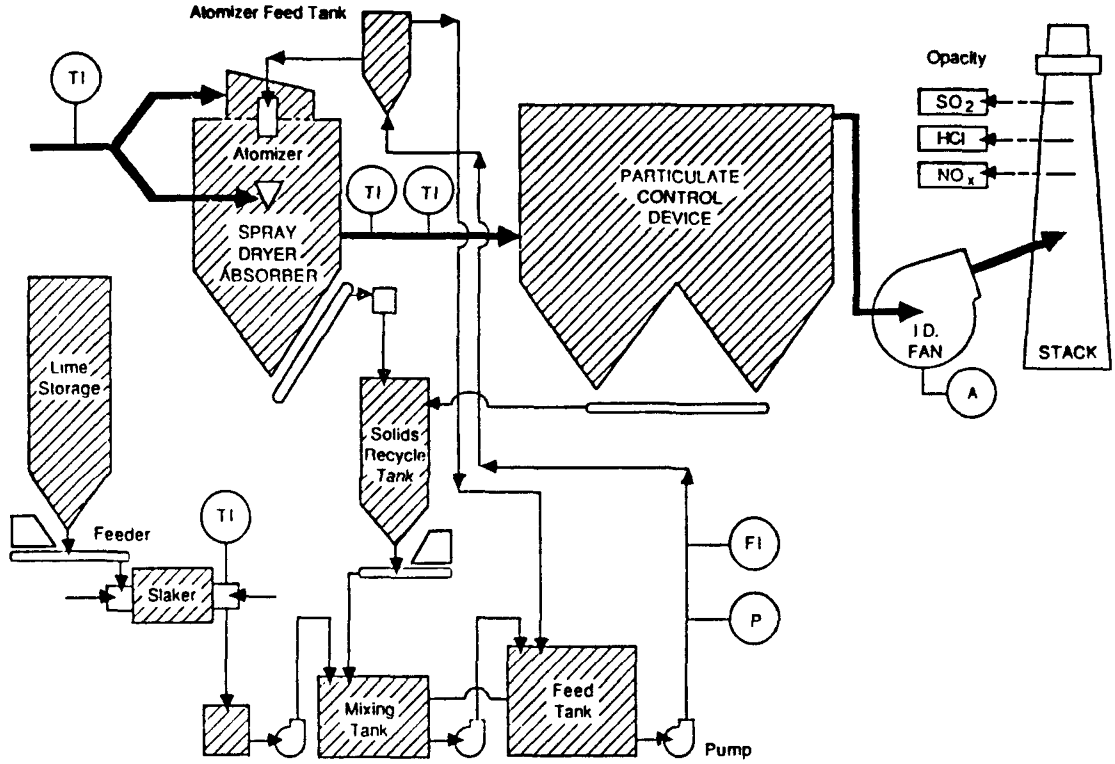
The pollutant removal efficiencies for all three categories of dry scrubbing systems appear to be very high. In most cases, outlet gas stream continuous emission monitors provide a direct indication of the system performance. Agency inspections of all three types of dry scrubbing systems are similar with respect to the importance of reviewing the adequacy of these continuous monitors and of reviewing data for selected time periods since the last inspection. Subsequent inspection steps vary substantially for the three types of dry scrubbers due to different components and operating principles.

It should be noted that the particulate control devices shown on the right hand side of the flowcharts are generally fabric filters or electrostatic precipitators. It is also possible that one and two stage wet scrubbing systems will be used in certain cases. However, the later discussions will primarily focus on fabric filters and precipitators since these dominate present and planned applications.

3.1.1 Spray Dryer Absorbers

In this type of dry scrubbing system, the alkaline reagent is prepared as a slurry containing 5 to 20% by weight solids [22,23,24]. This slurry is atomized in a large absorber vessel having a residence time of 6 to 20 seconds [22,23].

There are two main ways of atomization: (1) rotary atomizers, and (2) air atomizing nozzles. There is generally only one rotary atomizer. However, a few applications have as many as three rotary atomizers.



Note: A - Motor current gauge
P - Pressure gauge
FI - Flow indicating gauge
TI - Temperature gauge

Figure 3-1. Components of a Spray Dryer Absorber System (Semi-wet Process)

The shape of the scrubber vessel must be different to take into account the differences in the slurry spray pattern and the time required for droplet evaporation. The length-to-diameter ratio for rotary atomizers is much smaller than that for absorber vessels using air atomizing nozzles.

It is important that all of the slurry droplets evaporate to dryness prior to approaching the absorber vessel side walls and prior to exiting the absorber with the gas stream. Accumulations of material on the side walls or at the bottom of the absorber would necessitate an outage since these deposits would further impede drying. Proper drying of the slurry is achieved by the generation of small slurry droplets, by proper flue gas contact, and by use of moderately hot flue gases.

Drying that is too rapid can reduce pollutant collection efficiency since the primary removal mechanism is absorption into the droplets. There must be sufficient contact time for the absorption. For this reason, spray dryer absorbers are operated with exit gas temperatures 90 to 180 °F above the saturation temperature [22,25,26]. The absorber exit gas temperatures are monitored to ensure proper "approach-to-saturation" and therefore these values are an important inspection point. It is simply the difference between the wet bulb and dry bulb temperature monitors at the outlet of the absorber vessel.

In rotary atomizers, a thin film of slurry is fed to the top of the atomizer disk as it rotates at speeds of 10,000 to 17,000 rpm. These atomizers generate very small slurry droplets having diameters in the range of 100 microns. The spray pattern is inherently broad due to the geometry of the disk.

High pressure air is used to provide the physical energy required for droplet formation in nozzle type atomizers. The typical air pressures are 70 to 90 psig. Slurry droplets in the range of 70 to 200 microns are generated. This type of atomizer can generally operate over wider variations of the gas flow rate than can be used in a rotary atomizer. However, the nozzle atomizer does not have the slurry feed turndown capability of the rotary atomizer.

The alkaline material generally purchased for use in a spray dryer absorber is pebble lime. This material must be slaked in order to prepare a reactive slurry for absorption of acid gases. Slaking is the addition of water to convert calcium oxide to calcium hydroxide. Proper slaking conditions are important to ensure that the resulting calcium hydroxide slurry has the proper particle size distribution and that no coating of the particles has occurred due to the precipitation of contaminants in the slaking water.

Some of the important operating parameters of the lime slaker are the quality of the slaking water, the feed rate of lime, and the slurry exit temperature. However, it is difficult to relate present operating conditions or shifts from baseline operating conditions to possible changes in the absorption characteristics of the dry scrubber system. A variety of subtle changes in the slaker can affect the reactivity of the liquor produced.

One of the problems which has been reported for spray dryer absorber type systems is the pluggage of the slurry feed line to the atomizer. Scaling of the line can be severe due to the very high pH of this liquor. The flow rate of the liquor to the atomizer is usually monitored by a magnetic flow meter. However, this instrument is also vulnerable to scaling since the flow sensing elements are on the inside surface of the pipe. To minimize the pluggage problems, the lines must be well sloped and include the capability for flushing of the lines immediately after outages. Also, there should not be abrupt line changes, sharp bends, or adjacent high temperature equipment. During the inspection, it is essentially impossible to identify emerging slurry line problems.

Recycle of the solids collected in the absorber vessel is important in most systems. It increases the solids content of the slurry fed to the atomizer and thereby improves the drying of the droplets. Recycle also maximizes reagent utilization. The rate of solids recycle is monitored on a continuous basis. The rest of the spent absorbent is sent to a landfill.

3.1.2 Dry Injection Adsorption Systems

This type of dry scrubber uses finely divided calcium hydroxide for the adsorption of acid gases. The reagent feed has particle sizes which are 90% by weight through 325 mesh screens [26]. This is approximately the consistency of talcum powder. This size is important to ensure that there is adequate calcium hydroxide surface area for high efficiency pollutant removal.

Proper particle sizes are maintained by transporting the lime to the dry scrubber system by means of a positive pressure pneumatic conveyor. This provides the initial fluidization necessary to break up any clumps of reagent which have formed during storage. The air flow rate in the pneumatic conveyor is kept at a constant level regardless of system load in order to ensure proper particle sizes.

Fluidization is completed when the calcium hydroxide is injected countercurrently into the gas stream. A venturi section is used for the contactor due to the turbulent action available for mixing the gas stream and reagent. The gas stream containing the entrained calcium hydroxide particles and fly ash is then treated in a fabric filter.

Adsorption of acid gases and organic compounds (if present) occurs primarily while the gas stream passes through the dust cake composed of calcium hydroxide and fly ash. Pollutant removal efficiency is dependent on the reagent particle size range, on the adequacy of dust cake formation, and on the quantity of reagent injected.

The calcium hydroxide feed rate for dry injection systems is 3 to 4 times the stoichiometric quantities needed [25,26]. This is much higher than the spray dryer absorber type systems and it makes this approach unattractive for very large systems.

In one version of the dry injection system, solids are recycled from the particulate control device back into the flue gas contactor (sometimes termed "reactor"). The primary purpose of the recycle stream is to increase reagent utilization and thereby reduce overall calcium hydroxide costs.

3.1.3 Combination Spray Dryer and Dry Injection Systems

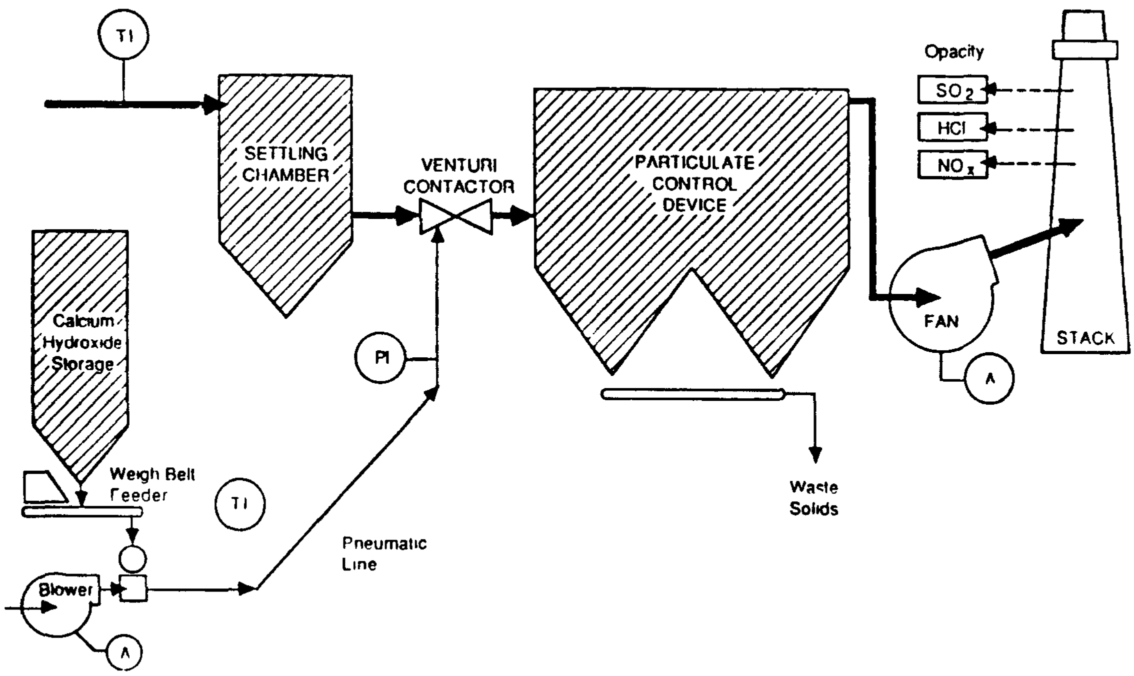
A flowchart for this system is shown in Figure 3-3. The acid gas laden flue gas is first treated in an upflow type spray dryer absorber. A series of calcium hydroxide sprays near the bottom of the absorber vessel are used for droplet generation.

After the upflow chamber, the partially treated flue gas then passes through a venturi contactor section where it is exposed to a calcium silicate and lime suspension. The purpose of the second reagent material is to improve the dust cake characteristics in the downstream baghouse and to optimize acid gas removal in this dust cake. The calcium silicate reportedly improves dust cake porosity and serves as an adsorbant for the acid gases.

Solids collected in the baghouse may be recycled to the venturi contactor. This improves reagent utilization and facilitates additional pollutant removal.

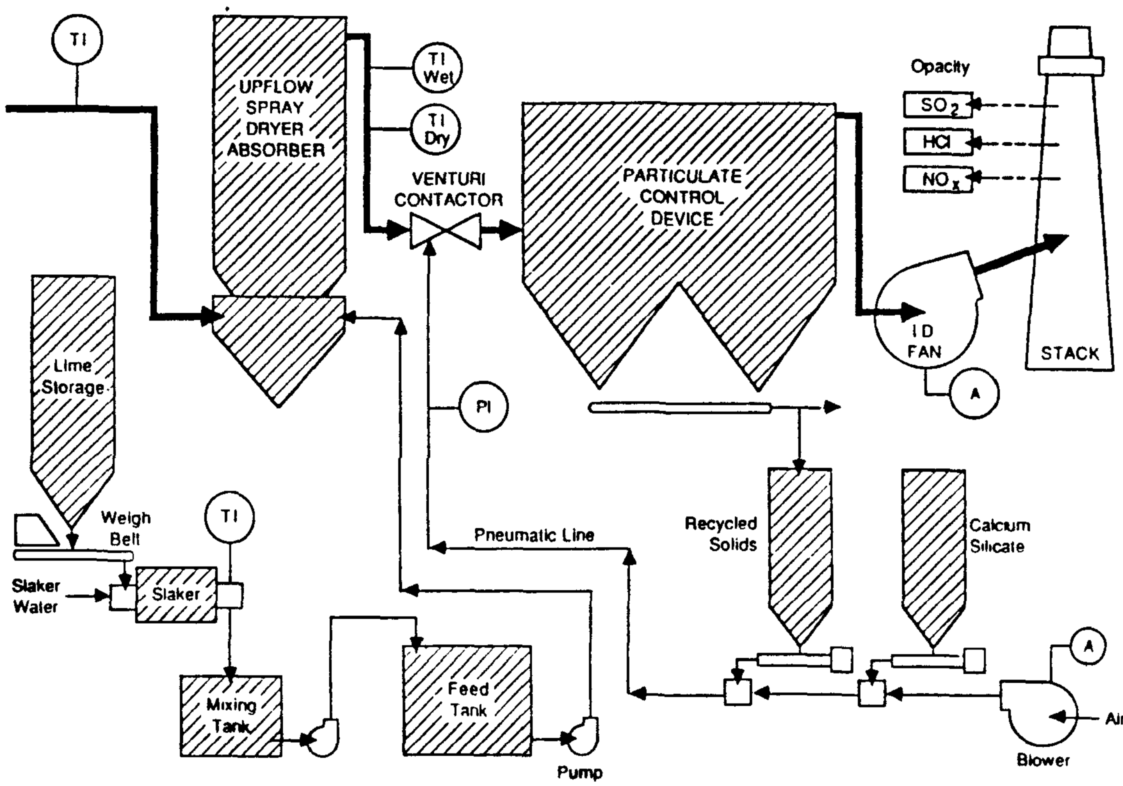
3.2 General Comments

Corrosion can present major problems for all types of dry scrubbers used on applications with high hydrogen chloride concentrations such as municipal waste incinerators. The calcium chloride reaction product formed in dry scrubbers and any uncollected hydrogen chloride are both very corrosive and cause damage in any areas of the absorber vessel or particulate control device where cooling and water vapor condensation can occur. Two common reasons for low localized gas temperatures include air infiltration and improper insulation around support beams. Due to the potential problems related to corrosion, the inspections should include checks for air infiltration and a visible evaluation of common corrosion sites.



Note: A - Motor current gauge
PI - Pressure gauge
TI - Temperature gauge

Figure 3-2. Components of a Dry Injection Adsorption System (Dry Process)



Note: A - Motor current gauge
PI - Pressure gauge
TI (wet) - Wet bulb temperature gauge
TI (dry) - Dry Bulb temperature gauge

Figure 3-3. Components of a Combination Spray Dryer and Dry Injection Adsorption System (Semi-wet/Dry Process)

3.3 Safety Considerations

3.3.1 Inhalation Hazards Around Positive Pressure System Components

Poorly ventilated areas in the vicinity of positive pressure dry scrubber absorbers, particulate control systems, and/or ductwork should be avoided. There are a variety of inhalation hazards associated with municipal waste incinerators, including but not limited to the following:

- hydrogen chloride
- hydrogen fluoride
- sulfuric acid mist
- sulfur dioxide
- dioxins/furans
- carbon monoxide
- heavy metal enriched flyash.

Concentrations of these pollutants can conceivably exceed the maximum allowable use levels of air-purifying respirators. Furthermore, there is no single type of air-purifying respirator which is appropriate for the wide range of pollutant chemicals which are emitted from municipal waste incinerators. Inspectors must be able to recognize and avoid areas of potentially significant exposure to fugitive emissions from the combustion and dry scrubbing systems. A simple flowchart which indicates the locations of all fans is a useful starting point in identifying portions of the system which operate at positive pressure.

3.3.2 Chemical Burns and Eye Hazards Around the Pebble Lime and/or Calcium Hydroxide Preparation Area

The strong alkalis used in dry scrubbing have the potential to cause severe eye damage. While the probability of eye contact and skin contact is relatively small for agency inspectors, it is nevertheless important to keep in mind the general first aid procedures. These are briefly summarized below.

- After eye contact, flushing should be started immediately.
- Eyes should be flushed for 15 to 30 minutes.
- After skin contact, all affected clothing should be removed and showering should be done for a minimum of 15 minutes.
- Medical attention should be obtained in all situations.

During the routine inspection, agency personnel should note the locations of all eye wash stations and showers. These are generally located in the immediate vicinities of chemical handling areas. After the first aid procedures are completed, it is especially important to get qualified medical attention regardless of the presumed seriousness of the exposure. All inspectors should have full first aid and safety training before conducting field inspections of municipal waste incinerators or any other type of air pollution source.

3.3.3 Internal Inspections Prohibited

Inspectors should not enter dry scrubber absorber vessels or air pollution control devices under any circumstances. All of the necessary inspection steps can be accomplished without internal inspections. Proper isolation, lockout, and testing of confined areas requires substantial time and safety equipment, neither of which is available to the agency inspector. Furthermore, serious accidents can and have happened to agency inspectors while inside equipment with plant personnel.

4. INSPECTION OF ELECTROSTATIC PRECIPITATORS

Electrostatic precipitation is one of the main particulate control techniques being used on municipal waste incinerators installed during the last fifteen years. Continued use of electrostatic precipitators is expected both as a stand alone control device and as part of dry scrubbing systems. The inspection of municipal waste incinerator precipitators is relatively similar to the inspection of electrostatic precipitators serving coal-fired boilers, cement kilns, and kraft pulp mills.

4.1 Components of Electrostatic Precipitators

An electrostatic precipitator consists of a large number of discharge electrodes and collection plates arranged in parallel rows along the direction of gas flow. The collection plates are grounded along with the hoppers and shell of the precipitator. The discharge electrodes are energized to negative voltages ranging between 15,000 volts and 50,000 volts.

The gas velocity through the numerous parallel passages of the precipitator ranges from 3 to 6 feet per second. This represents an order of magnitude decrease in the velocity that exists in the ductwork leading to the precipitator. The deceleration is accomplished in an inlet chamber at the front of the precipitator. There are normally one or more perforated plates in the inlet chamber to achieve as uniform gas distribution as possible. The high voltage for the discharge electrodes is provided by a transformer-rectifier set (hereafter termed T-R set). It converts alternating current from a 480 volt supply to direct current at very high voltages. Each T-R set energizes an independent portion of the electrostatic precipitator called a field. The T-R sets are always mounted on the roof of the precipitator since it is difficult to run the high voltage lines for long distances.

In municipal waste applications there are normally 2 to 4 fields in series along the direction of gas flow. Each field in series removes from 60 to 85% of the incoming particulate matter to that field.

Some very large precipitators are also divided into parallel chambers. Solid partitions between the chambers prevents gas from passing from one chamber to the other while passing through the precipitator. Each of the chambers is evaluated separately during the inspection.

Each of the T-R sets is connected to a control cabinet. This controls the 480 volt alternating current power supply to the T-R set. It contains all of the electrical meters used to evaluate the operating conditions inside each of the precipitator fields. A major part of the inspection involves the interpretation of this electrical data. One of the first steps in the evaluation of the electrical data is to determine how the T-R sets are laid out on the precipitator so that the various control cabinets can be matched up with the T-R sets they control. This is important since the field-by-field trends in a chamber are used to evaluate potential operating problems.

The types of meters present on the control cabinet are listed below along with the usual range of the gauge.

Primary voltage, 0 to 500 volts A.C.
Primary current, 0 to 200 amps A.C.
Secondary current, 0 to 2 amps D.C.
Secondary voltage, 0 to 50 kilovolts, D.C.
Spark Rate, 0 to 200 sparks/minute

The primary voltage and current data concerns the 480 volt alternating current power supply to the T-R set. The secondary voltage is the voltage leaving the T-R set and on the discharge electrodes within the precipitator. The secondary current is the direct current flow from the T-R set that passes through the field. The spark rate is the number of short term arcs that jump between the discharge electrodes and collection plates in the field.

Electrical conditions can be evaluated using either the primary meters or the secondary meters. Whenever they are available, the secondary meters are generally used since these provide information on the electrical conditions within the precipitator fields. However, many older precipitators were not equipped with secondary voltage meters. For these units, the primary meters can be used.

4.2 Operating Principles

Under normal operating conditions, the values of the primary and secondary meters in each field can not be set intentionally by the operators. Instead, the electrical operating conditions are determined by the characteristics of the particles passing through the precipitator field and by the ability of the power supply to respond to sparks within the field. Some of the most important properties of the dust include the total quantity of dust, the particle size distribution of the dust, and the particle resistivity distribution.

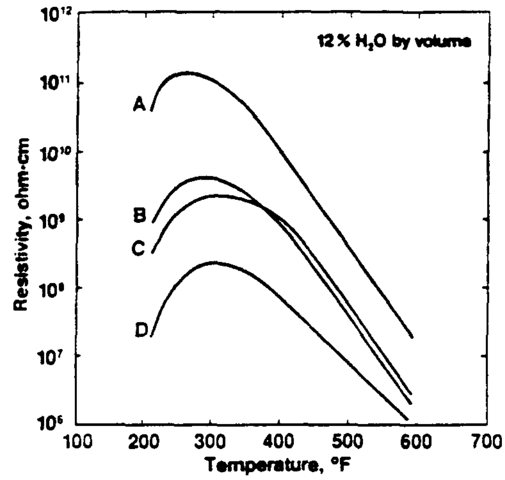
The dust resistivity is a measure of the ability of the electrons on the surface of the dust particles to pass the grounded collection plate. If the electrons can flow easily, the dust resistivity is low.

The electrons can flow around the outside surfaces of particles that comprise the dust layer on the collection plate or they can pass directly through the dust particles. Below 350 °F, compounds such as sulfuric acid and water condense on the particle surfaces to facilitate electron flow around the outer surfaces. Also, carbonaceous material due to incomplete combustion in the incinerator can contribute to charge dissipation. For these reasons, the ash resistivity drops rapidly as the gas temperature drops below 350 °F. When the particle temperature is above 500 °F, the constitutents within the dust particles (other than uncombusted material) generally provide a conductive path. Therefore, the resistivity tends to decrease as the gas temperatures increase above 500 °F. This type of charge dissipation is termed bulk conductivity. Due to the strong temperature dependence of these two separate parts of charge dissipation, the particle resistivity exhibits a peak when the temperature is in the range of 350 °F as illustrated in Figure 4-1.

Electrostatic precipitators serving municipal incinerators generally have inlet gas temperatures between 350 °F and 450 °F which means that they operate in the range having the least temperature sensitivity. Precipitators operating on other types of sources with gas temperatures in the range of 280 to 350 °F can have significantly more difficulty with resistivity variations caused by extreme gas temperature sensitivity. Of course, municipal waste incinerator precipitators can have similar problems if the gas temperature decreases from 350 °F.

As indicated in Figure 4-1, ash resistivities in municipal waste incinerator precipitators are generally in the moderate range of 1×10^9 ohm-cm to 5×10^{11} ohm-cm. This is range in which precipitators work best. However, ash resistivities can become undesirably low if the combustibles content of the ash increases or if the gas temperature becomes very low in localized parts of the precipitator.

Under low resistivity conditions, the precipitator currents can be very high while the spark rates are negligible. The operating voltages are low because the power supplies reach the current limits at relatively low voltages. In these areas, the dust layer on the collection plates is not strongly bonded and even light rapping can result in the reentrainment of the material that had been collected. Conversely, the high resistivity zones in the precipitator generally have low currents, low voltages, and high spark rates. Due to the poor electrical operating conditions, overall particle collection can be quite low. Neither high or low resistivity is desirable.



Source: Petersen, H.H.
1984 National Waste Processing Conference
pp. 377-384

Figure 4-1. Typical Resistivity Versus Temperature Relationship

The electrical operating conditions of an electrostatic precipitator can be summarized using graphs, and power input totals. Figure 4-2 illustrates graphs of the secondary voltage, secondary currents, and spark rate for a one chamber, four field precipitator. Baseline data for each parameter is provided in the graphs to help identify shifts in these electrical conditions. When all of the fields in a given chamber shift in unison (there may be a time lag of several hours for the outlet fields), there has normally been a change in the dust characteristics due to process operating changes or fuel changes. When only one of the fields shifts, there is normally an internal mechanical problem.

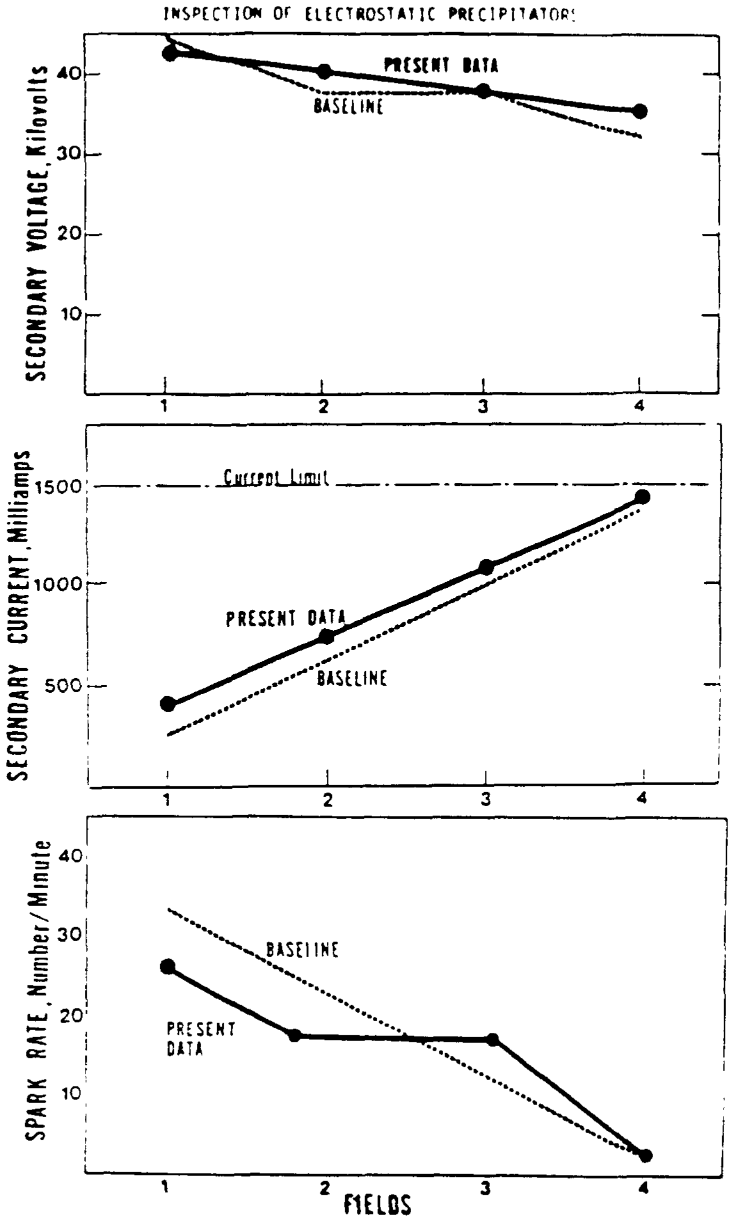


Figure 4-3. Trends in the Voltages, Currents and Spark Rates in a Precipitator Chamber

The advantage of the graphs is that they allow for rapid interpretation of the large quantity of data obtained while observing the T-R set control cabinets.

Another way to summarize the electrical data is to calculate the overall power input for a precipitator chamber. This can be done using either the primary meters using Equation 4-1 or the secondary meters using Equation 4-2.

Primary Meters:

(Volts, A.C.) x (Amps A.C.) x 0.75 = (Watts)

Equation 4-1

Secondary Meters:

(Kilovolts, D.C.) x (Milliamps, D.C.) = (Watts)

Equation 4-2

The power input in watts for each field in the chamber is then added to calculate the total power input. If the actual gas flow rate is known, the power input is often presented as total watts per thousand actual cubic feet per minute of gas flow.

It should be noted, however, that the power input is usually calculated only for precipitators that consistently operate in either the moderate or high resistivity range. In these ranges, an increase in the power input generally corresponds with a decrease in the particulate emission rate. In the low resistivity range, there is no typical relationship between power input and particulate emission rates.

The alignment between the parallel sets of collection plates and discharge electrodes is very important. For units with high resistivity zones, the spacing tolerances must be maintained within plus or minus a quarter inch throughout the unit. Even for units with moderate-to-low resistivity, the alignment must be within plus or minus a half inch throughout the unit. Considering that there are a large number of collection plates and discharge electrodes, maintaining proper alignment is not simple.

Large quantities of dust are often handled by electrostatic precipitators. The types of solids discharge valves and solids handling systems are generally selected based on the overall quantity of material to be transported and on the characteristics of these solids. The most common types of solids discharge systems used on municipal waste incinerators include: (1) rotary valves and screw conveyors, and (2) pneumatic systems.

The fan can be either located before or after the electrostatic precipitator. When it is after the precipitator (the normal location for MWCs), the gas stream is "pulled" through and the static pressure is less than atmospheric pressure (termed "negative pressure"). As with other types of control devices, negative pressure electrostatic precipitators are vulnerable to air infiltration. This can lead to a number of significant operating problems considering the highly corrosive nature of municipal waste incinerator exhaust gas components.

When the fan is before the precipitator, the gas stream is "pushed" through. This creates static pressures inside the precipitator which are greater than atmospheric pressure (termed "positive pressure"). Special care is warranted whenever inspecting these units, since fugitive emissions from the unit can result in very high levels of toxic pollutants in the vicinity of the precipitator.

4.3 General Safety Considerations

4.3.1 Inhalation Hazards

Fugitive emissions from municipal waste incineration systems can accumulate in poorly ventilated areas around the precipitator such as the roof and hopper weather enclosures, annular stack monitoring locations, and areas adjacent to cracked breeching expansion joints. The inhalation hazards can include chemical asphyxiants, physical asphyxiants, toxic gases/vapors, and toxic particulate.

4.3.2 Use of Portable Instruments

Portable instruments should not be used on electrostatic precipitator systems. Very high static voltages can accumulate on probes downstream of precipitators due to the impaction of charged particles. Touching improperly grounded and bonded probes can result in involuntary muscle action that can result in a fall. Furthermore, in some units, the probes could inadvertently approach the electrified zone of the precipitator that operates at 15 to 50 kilovolts.

4.3.3 Internal Inspections Prohibited

Inspectors should not enter an electrostatic precipitator under any circumstances. All of the necessary inspection steps can be accomplished without internal inspections. Furthermore, the side access hatches and penthouse/roof access hatches should not be opened under any circumstances. The internal components can be at high voltages even though the unit is out-of-service. Also, the hopper hatches should not be opened during the inspection since hot, free flowing dust can be released and since the inrushing air can cause hopper fires in some cases.

5. INSPECTION OF FABRIC FILTERS

Pulse jet and reverse air fabric filters are addressed in this section since these are the two most common types of systems used on municipal waste incinerators. The fabric filters are generally used as part of the dry scrubbing system. However, they can also serve as stand-alone particulate control devices.

5.1 Components and Operating Principles of Pulse Jet Fabric Filters

Pulse jet fabric filters utilize compressed air for routine bag cleaning. They are sometimes referred to as "Reverse Jet" fabric filters.

The presence of a row of diaphragm valves along the top of the baghouse indicates that the baghouse is a pulse jet unit. These valves control the compressed air flow into each row of bags which is used to routinely clean the dust from the bags. On a few units, the diaphragm valves can not be seen since they are in an enclosed compartment on the top of the unit. In these cases, the pulse jet baghouse can be recognized by the distinctive, regularly occurring sound of the operating diaphragm valves.

There are two major types of pulse jet baghouses: (1) top access, and (2) side access. Figure 5-1 illustrates the top access design which includes a number of large hatches across the top of the baghouse for bag replacement and maintenance. Another major type has one large hatch on the side for access to the bags. The side access units often have a single small hatch on the top of the shell for routine inspection of the baghouse.

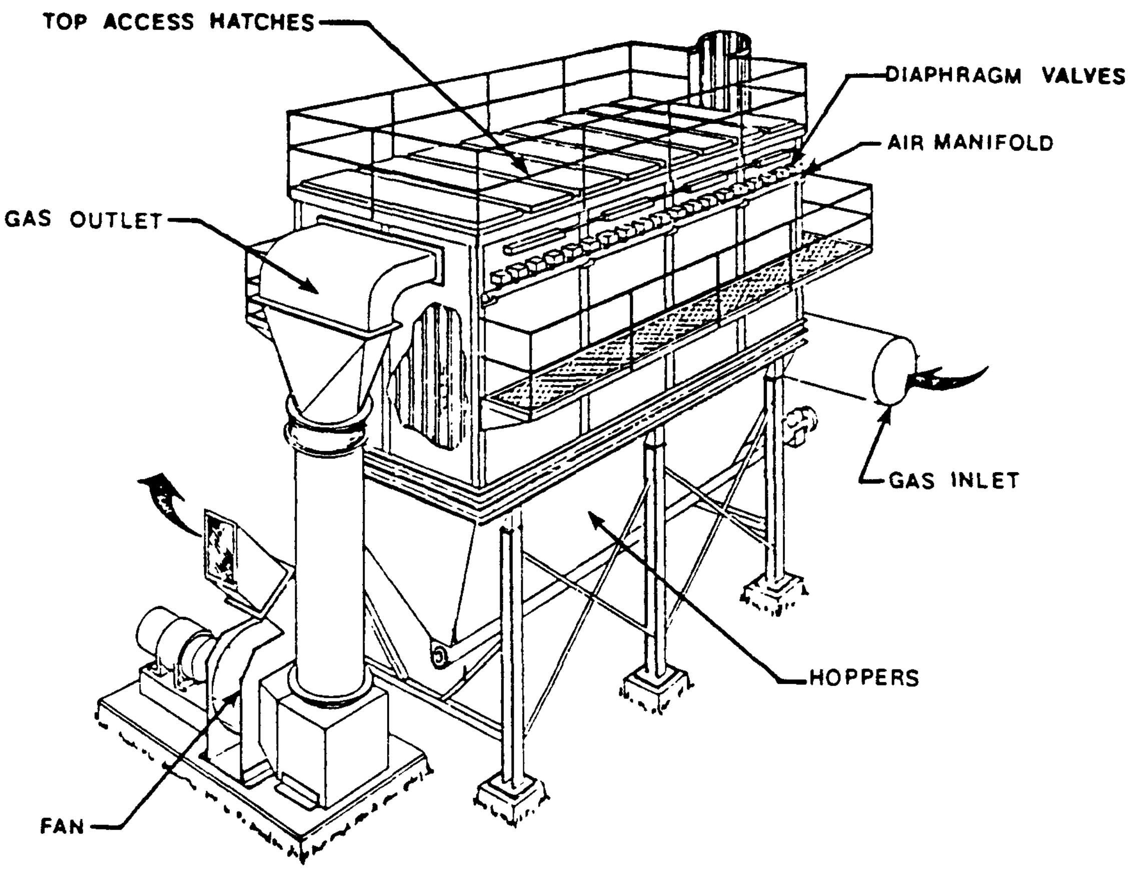


Figure 5-1. Top Access Pulse Jet Fabric Filter

Like most small units, the pulse jet collector depicted in Figure 5-1 is not divided into compartments. These are not needed on small units that operate intermittantly since bags are cleaned row-by-row as the unit continues to operate. A few of the large units are divided into separate compartments so that it is possible to perform maintenance work on part of the unit while the other part continues to operate.

Another distinguishing characteristics of pulse jet units is the use of a support cage for the bags. The cage fits inside the cylindrical bags and prevents the bags from collapsing during filtering. Bags and cages are usually sold separately.

The fan shown in Figure 5-1 is after the baghouse. This means that the particulate laden gas stream is "pulled" through the baghouse and that the static pressures throughout the unit are less than atmospheric pressure. Outside air will leak into the baghouse if the hatches are not secure, if the shell is corroded, or if the hopper is not properly sealed. Air infiltration can result in a number of significant baghouse maintenance problems.

Pulse jet units operate equally well when the fan is ahead of the baghouse and the gas stream is "pushed" through. In these units, the static pressures are greater than atmospheric pressure and there are potential safety problems with leakage of pollutant laden gas out into the areas surrounding the baghouse.

A cross sectional drawing of a pulse jet fabric filter is shown in Figure 5-2 on the next page. Refer to this drawing while reading the following section concerning the basic operating characteristics of pulse jet baghouses.

The baghouse is divided into a "clean" side and a "dirty" side by the tube sheet mounted near the top of the unit. The dust laden gas stream enters below this tube sheet and the filtered gas collects in a plenum above the tube sheet. There are holes in the tube sheet for each of the bags which are normally arranged in rows.

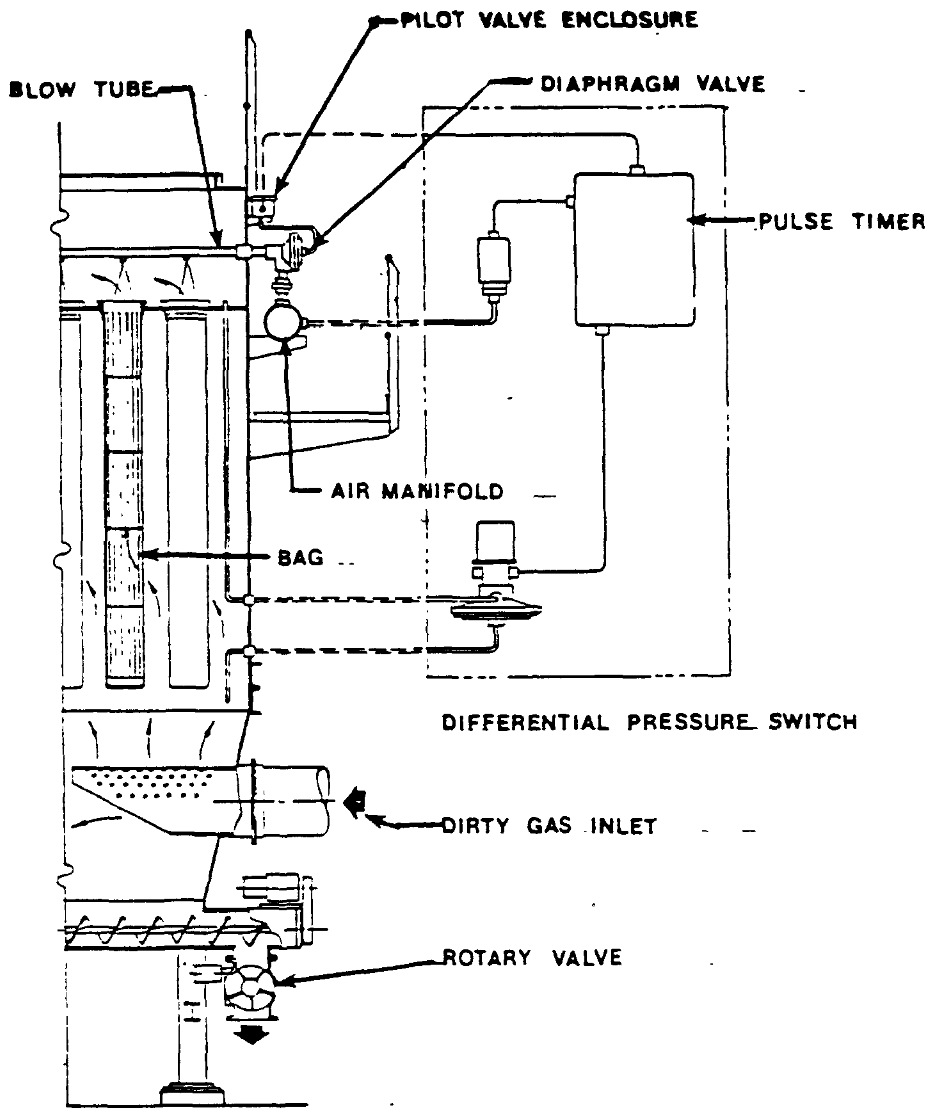


Figure 5-2. Cross Sectional Sketch of Pulse Jet Fabric Filter

The bags and cages hang from the tube sheet. The dust laden inlet gas stream flows around the outside of each bag and the dust gradually accumulates on the outside surfaces of the bags during filtering. The cleaned gas passes up the inside of the bag and out into the "clean" gas plenum.

A pulse jet fabric filter uses bags which are supported on cages. The cages hang from the tube sheet near the top of the baghouse. Dust accumulates on the outer surfaces of the bags as the gas stream passes through the bags and into the center of the bags. The filtered gas is collected in a plenum at the top of the baghouse.

The dust must occasionaly be removed from the bags in order to avoid excessively high gas flow resistances. The bags are cleaned by introducing a high pressure pulse of compressed air at the top of the bag. The sudden pulse of compressed air generates a pressure wave which travels down inside of the bag. The pressure wave also induces some filtered gas to flow downward into the bag. Due to the combined action of the pressure wave and the reverse gas flow, the bags are briefly deflected outward. This cracks the dust cake on the outside of the bags and causes the dust to fall into the hopper. Cleaning is normally done on a row-by-row basis while the baghouse is operating.

The compressed air at pressures from 60 to 100 psig is generated by an air compressor and stored temporarily in the compressed air manifold. When the pilot valve (a standard solenoid valve) is opened by the controller, the diaphragm valve suddenly opens to let compressed air into the delivery tube which serves a row of bags. There are holes in the delivery tube above each bag for injection of the compressed air into the top of each bag. The cleaning system controller can either operate on the basis of a differential pressure sensor as shown in Figure 5-2, or it can simply operate as a timer. In either case, bags are usually cleaned on a relatively frequent basis with each row being cleaned from once every five minutes to once every hour. Cleaning is usually done by starting with the first row of bags and proceeding through the remaining rows in the order that they are mounted.

Bags used in pulse jet collectors are generally less than 6 inches in diameter and range in length from 6 to 14 feet. Felted fabric is the most common type of material.

One of the basic design parameters of a pulse jet fabric filter is the gas-to-cloth ratio (sometimes called the air-to-cloth ratio) which is simply the number of cubic feet of gas at actual conditions passing through the average square foot of cloth per unit of time. The normal units are $ft^3/min/ft$ which can be reduced to ft/min. Most new commercial pulse jet units are designed for an average gas-to-cloth ratio between 3 and 8 depending on the characteristics of the fabric selected, the particle size of the dust to be collected, and the installation and operation costs. Some older pulse jet units were designed for gas-to-cloth ratios up to 15 ft/min.

Pulse jet units do not necessarily operate at the design average gas-to-cloth ratio. When incinerator operating rates are low, the prevailing average gas-to-cloth ratio could be substantially below the design value. Conversely, the average gas-to-cloth ratio could be well above the design value if some of the bags are inadequately cleaned or if sticky or wet material blocks part of the fabric surface. Very high gas-to-cloth ratio conditions can lead to high gas flow resistance which in turn can result in both seepage of dust through the bags and fugitive emissions from the process equipment.

The difference between the gas stream pressures before and after the baghouse is called the static pressure drop. The actual static pressure drop depends on the actual average gas-to-cloth ratio, the physical characteristics of the dust, the type of fabric used in the bags, and the adequacy of cleaning. A pulse jet baghouse with new bags that have not yet been exposed to dust would normally have a static pressure drop of 0.5 to 1.5 inches of water. During normal operation, the pulse jet baghouses generally have a static pressure drop between 3 and 8 inches of water. The difference between the static pressure drop across a clean, new unit and one in normal service is due to the gas flow resistance through the dust layer on each of the bags. The dust layer (sometimes called the dust cake) is important since it is responsible for much of the particle filtering. Very low static pressure drops can often indicate inadequate dust layers for proper filtering. Very high static pressure drops often mean that a substantial fraction of the available cloth area has been inadequately cleaned or has been blocked by wet and/or sticky material. High particulate emissions also occur when the static pressure drop is very high. The optimum overall efficiency of a pulse jet baghouse system is generally in the moderate static pressure drop range.

5.2 Components and Operating Principles of Reverse Air Fabric Filters

In reverse air systems, the bags are suspended from the top and are attached to a tube sheet which is immediately above the hoppers. As shown in Figure 5-3, the inlet gas enters from the hoppers and passes upward into each of the bags. The dust cake builds up on the inside surface of the bags and filtered gas passes into the chamber surrounding the bags.

These baghouses are usually divided into 2 or more compartments. The bags are cleaned by isolating the compartment from the inlet gas stream. Filtered gas is moved backward through the compartment to break up the dust cake and discharge it to the hoppers below. The cleaning gas from the compartment being cleaned is recycled to the inlet gas duct. A set of dampers (poppet valves in Figure 5-3) and activators are used.

Due to the relatively large size of many commercial bags, a significant gas flow exists at the entrance to the bags. The average gas velocity at this point can be between 300 and 500 feet per minute, depending of the actual gas-to-cloth ratio and the bag size. It is important that the particulate laden air enter the bag in as straight a direction as possible in order to minimize fabric abrasion. The inlet gas stream can also cause fabric damage if the bags are slightly slack and some of the fabric is folded over the bag inlet. Because of these and other possible problems, the large majority of the bag failures occur near the bottom of the bags.

Bags used in reverse air baghouses generally range in length from 10 to 30 feet. Reverse air bags utilize a set of anti-collapse rings sewn around the bags at a number of locations on the bag to prevent complete closure of the bag during reverse air cleaning. Woven fabrics are generally used. The bags are usually attached to the tube sheet by using a thimble and clamp. Firm bag attachments are important to prevent the flow of unfiltered gas through any gaps.

Large quantities of dust are often handled by reverse air and shaker baghouses. The types of solids discharge valves and solids handling systems are generally selected based on the overall quantity of material to be transported and on the characteristics of these solids. The most common types of solids discharge systems include (1) rotary valves and screw conveyors, (2) pneumatic systems, and (3) pressurized systems.

An isometric drawing of a reverse air baghouse is shown in Figure 5-4. This unit has the main fan downstream of the baghouse. This means that the particulate laden gas stream is "pulled" through the baghouse and that the static pressures throughout the unit are less than atmospheric pressure (termed "negative pressure"). With this type of arrangement, outside air can leak into the baghouse if the hatches are not secure, if the shell is corroded, or if the hopper is not properly sealed. Air infiltration can result in a number of significant baghouse maintenance problems.

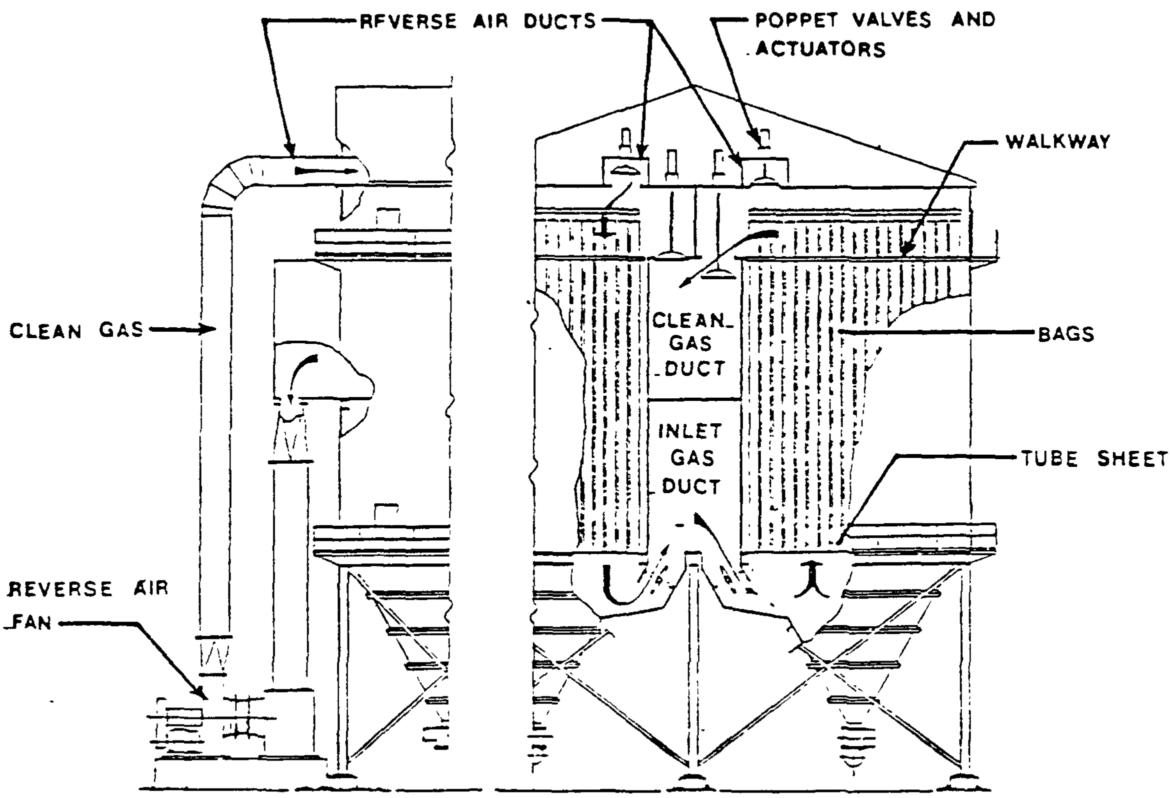


Figure 5-3. Cross Section of a Reverse Air Fabric Filter

Reverse air and shaker units operate equally well when the fan is ahead of the baghouse and the gas stream is "pushed" through. In these units, the static pressures are greater than atmospheric pressure (termed "positive pressure") and there can be potential safety problems with leakage of pollutant laden gas out into the areas surrounding the baghouse. In most positive pressure units, the filtered gas from each compartment is released to the atmosphere through a large roof monitor or through a set of short stacks.

One of the basic design parameters of reverse air and shaker fabric filters is the gas-to-cloth ratio (sometimes called the air-to-cloth ratio) which is simply the number of cubic feet of gas at actual conditions passing through the average square foot of cloth per unit of time. The normal units are $ft^3/min/ft$ which can be reduced to ft/min. Most new commercial reverse air and shaker units are designed for an average gas-to-cloth ratio between 1 and 3 ft/min depending on the characteristics of the fabric selected, the particle size of the dust to be collected, and the necessary installation and operation costs.

Reverse air and shaker units do not necessarily operate at the design average gas-to-cloth ratio. When production rates are low, the prevailing average gas-to-cloth ratio could be substantially below the design value. Conversely, the prevailing average gas-to-cloth ratio could be well above the design value if some of the bags are inadequately cleaned or if sticky or wet material blocks part of the fabric surface. Very high gas-to-cloth ratio conditions can lead to high gas flow resistance which in turn can result in both the seepage of dust through the bags and fugitive emissions from the process equipment served by the baghouse.

The difference between the gas stream pressures before and after the baghouse is called the static pressure drop. The actual static pressure drop depends on the actual average gas-to-cloth ratio, the physical characteristics of the dust, the type of fabric used in the bags, and the adequacy of cleaning. A reverse air or shaker baghouse with new bags which have not yet

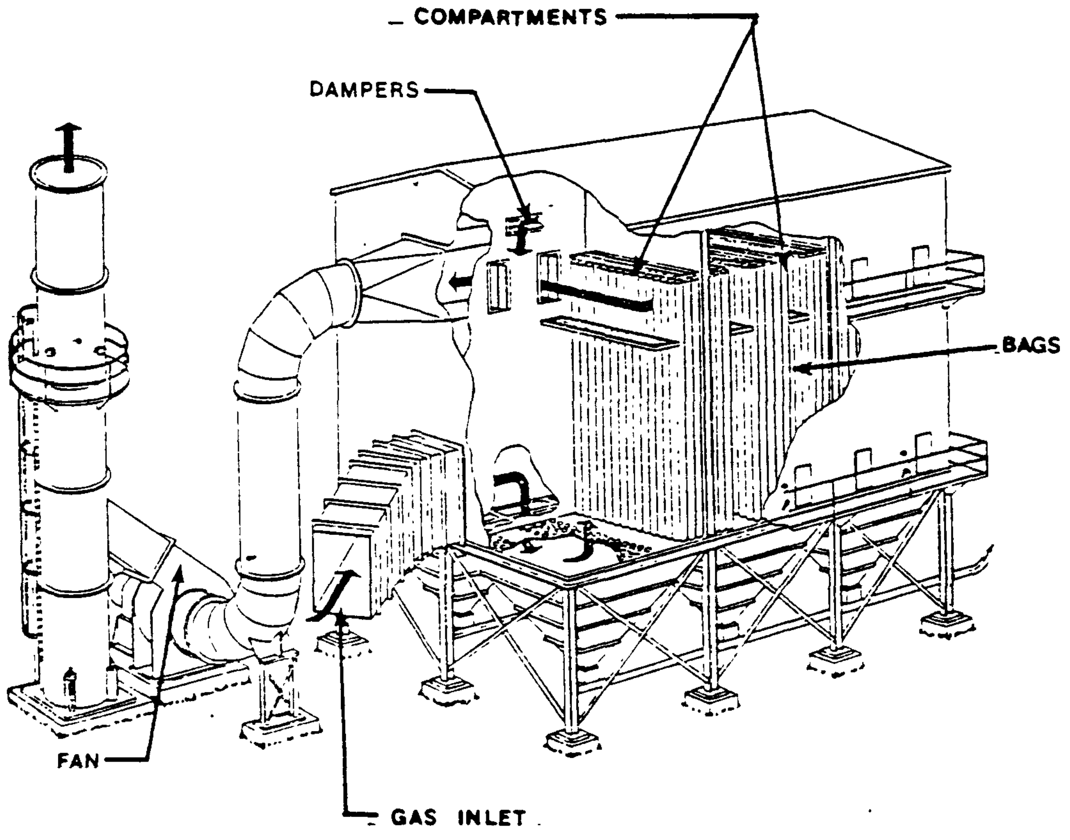


Figure 5-4. Isometric View of a Reverse Air Fabric Filter

been exposed to dust would normally have a static pressure drop of 0.5 to 1.5 inches of water. During normal operation, the baghouses generally have a static pressure drop between 3 and 8 inches of water. The difference between the static pressure drop across a clean, new unit and one in normal service is due to the gas flow resistance through the dust layer on each of the bags. The dust layer (sometimes called the dust cake) is important since it is responsible for most of the particle filtering. Very low static pressure drops can often indicate inadequate dust layers for proper filtering. Very high static pressure drops often mean that a substantial fraction of the available cloth area has been inadequately cleaned or has been blocked by wet and/or sticky material. High particulate emissions also occur when the static pressure drops are very high. The optimum overall efficiency of a reverse air or shaker baghouse system is generally in the moderate static pressure drop range.

5.3 General Safety Considerations

5.3.1 Hot Surfaces

Pulse jet fabric filters serving municipal waste incinerators operate at relatively high gas temperatures of 250 to 350°F. Uninsulated baghouse roofs can be a serious burn hazard. Unfortunately, it is important to inspect this area due to the possible air infiltration problems and due to the presence of the diaphragm values and compressed air pressure gauge.

5.3.2 Inhalation Hazards

Fugitive emissions from positive pressure fabric filter systems can accumulate in poorly ventilated areas around the baghouse such as the walks between the rows of compartments. The inhalation hazards can include chemical asphyxiants, physical asphyxiants, toxic gases/vapors, and toxic particulate.

5.3.3 Internal Inspections Prohibited

Inspectors should not enter a fabric filter under any circumstances. All of the necessary inspection steps can be accomplished without internal inspections. However, in some cases, it is helpful to open one or more of the baghouse top and/or side access hatches in order to observe internal conditions. In these situations, inspectors should request that plant personnel open the hatches. The hopper hatches should not be opened during the inspection since hot, free flowing dust can be released.

6. INSPECTION OF WET SCRUBBERS

The most common types of wet scrubber systems used on municipal waste incinerators are addressed in this inspection notebook. These include the following:

- Spray tower
- Packed beds
- Venturi

Inspectors should modify these procedures as necessary for types of scrubbers not specifically discussed in this notebook. It should be noted that the wet scrubbers presently in service are on relatively old units. Most new incinerators use dry scrubbers or electrostatic precipitators.

6.1 Components and Types of Wet Scrubbers

A scrubber is not an isolated piece of equipment. It is a system composed of a large number of individual components. A partial list of the major components of commercial systems is provided below.

- Scrubber vessel
- Gas cooler and humidifier
- Liquor treatment equipment
- Gas stream demister
- Liquor recirculation tanks, pumps, and piping
- Alkaline addition equipment
- Fans, dampers, and bypass stacks

One of the first steps in the inspection of any wet scrubber system is to prepare a flowchart which includes the components listed directly above. This will be invaluable in evaluating the on-site instrumentation and in identifying system problems.

6.1.1 Spray Tower Scrubbers

The gas stream enters near the bottom of the scrubber and enters upward at velocities between 2 and 10 feet per second. The liquor enters at the top of the unit through one or more spray headers. Nozzles are oriented on the headers so that all of the gas stream is exposed to the sprayed liquor. Careful scrubber design is necessary to achieve proper liquor distribution since this is a function of the type of nozzles used, the spray angle of the nozzles, the nozzle placement, and the liquor pressure. It is also important to design the headers so that solid deposits do not accumulate.

A spray tower scrubber has a limited particulate removal capability. For municipal waste incinerators, it is used primarily for acid gas removal. A high efficiency particulate control device must be upstream of the scrubber to meet the particulate emission limitations. Alkaline reagents are necessary to maintain liquor pH during the absorption of hydrogen chloride, hydrogen fluoride, and sulfur oxides.

6.1.2 Packed Bed Scrubbers

This type of scrubber is used strictly for acid gas removal. The large liquor surface area created as the liquor gradually passes over the packing material favors gas diffusion and absorption. Packed bed scrubbers are not effective for collection of small particulate matter since the gas velocity through the bed(s) is relatively slow.

Packed beds can be either vertical or horizontal. Regardless of the orientation of the bed, the liquor is sprayed from the top and flows downward across the bed. Proper liquor distribution is important for efficient removal of gases. This is one of the few types of scrubbers in which the static pressure drop is not very important.

One of the major problems with these scrubbers is the accumulation of solids at the entry to the bed and within the bed. The dissolved and suspended solids levels in the liquor must be monitored carefully.

6.1.3 Venturi Scrubbers

A conventional venturi scrubber is illustrated in Figure 6-1. The gas stream enters the converging section and is accelerated by approximately a factor of ten. The liquor is injected just above the throat. Droplets form due to the shearing action of the high velocity gas. Impaction of particles occurs on the droplets which are initially moving slower than the gas stream. The high liquor surface area also allows for gas absorption.

The gas stream is decelerated in the diverging section. After the venturi section, the gas stream turns 90° and passes into the demister chamber. The venturi scrubbers are usually part of a large and relatively complex scrubber system.

There are a large number of variations to the standard venturi configuration. Figure 6-2 illustrates one common throat design which incorporates internal dampers to vary the gas velocity. These can be opened or closed to maintain a constant static pressure drop when the gas flow varies. The dampers can also be used to adjust the static pressure drop when the inlet particle size distribution varies.

6.2 Wet Scrubber Operating Principles

Impaction is the primary means for collection of particles in wet scrubbers. The effectiveness of impaction is related to the square of the particle diameter and the difference in velocities of the liquor droplets and the particles.

The importance of particle size is emphasized in Figure 6-3. For particles greater than 1 to 2 microns in diameter, impaction is so effective that penetration (emissions) are quite low. However, penetration of smaller particles, such as the particles in the 0.1 to 0.5 micron range is very high. Unfortunately, municipal waste incinerators can generate substantial quantities of particulate matter in this submicron range due to the condensation of partially combusted organic compounds and the condensation of metallic vapors.

For constant particle size distribution, the overall particulate collection efficiency in a wet scrubber system generally increases as the static pressure drop increases. The static pressure drop is a measure of the total amount of energy used in the scrubber to accelerate the gas stream, to atomize the liquor droplets, and to overcome friction. At high static pressure drops, the difference in droplet and particles velocities is high and a large number of small diameter droplets are formed. Both of these conditions favor particle impaction into water droplets.

Another important variable is the liquor surface tension. If this is too high, some small particles which impact on the water droplet will "bounce" off and not be captured. High surface tension also has an adverse impact on droplet formation.

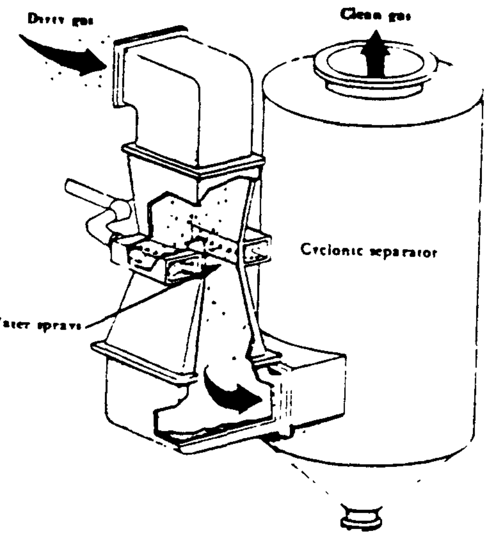


Figure 6-1. Conventional Venturi Scrubber

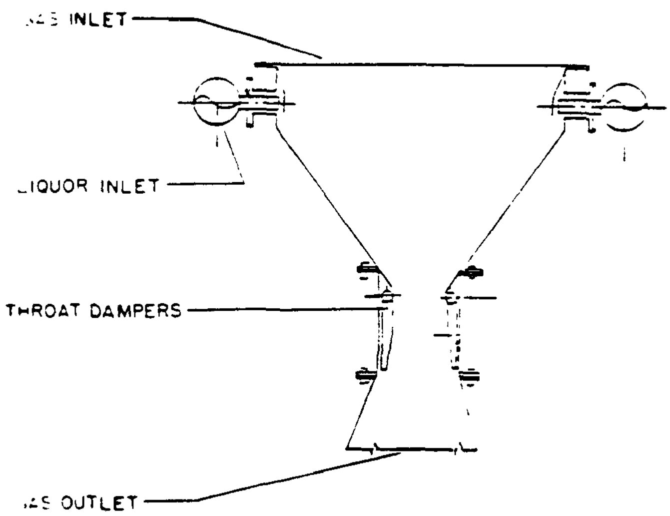


Figure 6-2. Venturi Throat Dampers

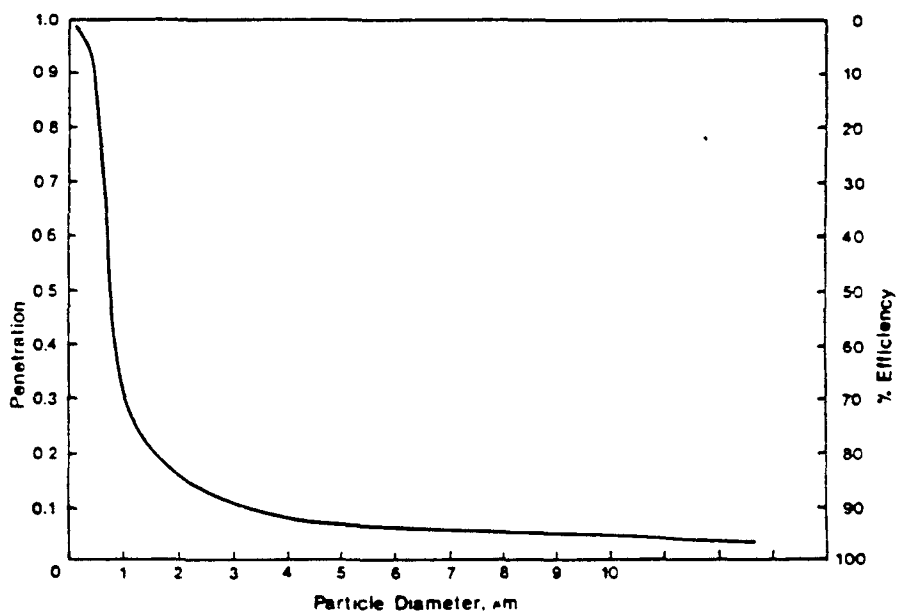


Figure 6-3. Relationship Between Particle Penetration (Emissions) and Particle size

Unfortunately, the scrubber liquors having surface tensions which provide optimum particle impaction may have poor solids settling properties. Surfactants can be added to reduce surface tension. Conversely, flocculants and anti-foaming agents generally increase the surface tension.

6.3 General Safety Considerations

Venturi scrubbers may operate at much higher positive static pressures than other types of air pollution control systems. Furthermore, there is a significant potential for corrosion and erosion of the scrubber vessel and ductwork. For these reasons, fugitive leaks are a common problem. The inhalation hazards can include chemical asphyxiants, physical asphyxiants, toxic gases, and toxic particulate. Inspectors should avoid all areas with obvious leaks and any areas with poor ventilation. During Level 3 and Level 4 inspections, only small diameter ports should be used.

Extreme care is often necessary when walking around the scrubber and when climbing access ladders. Slip hazards can be created by the water droplets reentrained in the exhaust gas, by the liquor draining from the pumps, and by the liquor seeping from pipes and tanks. These slip hazards are not always obvious. Furthermore, freezing can occur in cold weather.

A few systems are subjected to fan imbalance conditions due to the build-up of sludge on the fan blades, due to the corrosion of the fan blades, due to the erosion of the fan blades, and a variety of other factors. The inspection should be terminated immediately whenever an inspector observes a severely vibrating fan. A responsible plant representative should be notified once the inspector reaches a safe location. Severely vibrating fans can rapidly disintegrate.

All liquor samples necessary for Level 3 or Level 4 inspections should be taken by the plant personnel, not the inspector. Furthermore, inspectors should only ask responsible and experienced plant personnel to take the samples. Eye injuries and chemical burns (in some cases) are possible if the samples are taken incorrectly.

Inspectors should not, under any circumstances, enter a wet scrubber vessel or any tank or confined area in the system. All of the necessary inspection steps can be accomplished without internal inspections. Access hatches or viewing ports should not be opened during the inspection due to the risk of eye injuries.

REFERENCES

1. Hopper, T., "Municipal Incinerator Enforcement Manual," U.S. Environmental Protection Agency Publication No. 340/1-76-013, January 1977.

2. Radian Corporation, "Municipal Waste Combustion Study: Characterization of the Municipal Waste Combustion Industry," U.S. Environmental Protection Agency Publication No. 530-SW-87-021b, June 1987.

3. Richards, J.R., and Segall, R.R., "Baseline Source Inspection Techniques," U.S. Environmental Protection Agency Publication No. 340/1-85-022a, June 1985.

4. U.S. EPA Stationary Source Compliance Division, "Air Compliance Inspection Manual," U.S. Environmental Protection Agency Publication No. 340/1-85-020, September 1985.

5. Richards, J.; "Advanced Inspection Techniques for Senior Inspectors and Managers, Instructor's Guide," U.S. Environmental Protection Agency, Air Pollution Training Institute Course #455 Manual, November 1987.

6. Seeker, W.R., Lanier, W.S., and Heap, M.P., "Municipal Waste Combustion Study: Combustion Control of MSW Combustors to Minimize Emission of Trace Organics," U.S. Environmental Protection Agency Publication No. 530-SW-87-021c, June 1987.

7. Richards, J., "Air Pollution Source Field Inspection Notebook," U.S. Environmental Protection Agency Publication No. 340-1-88-001, 1988.

8. Seeker, W.R., Lanier, W.S., and Heap, M.P.; "Municipal Waste Combustion Study: Combustion Control of MSW Combustors to Minimize Emission of Trace Organics," U.S. Environmental Protection Agency Publication No. 530-SW-87-C, June 1987, page 4-6.

9. Seeker, W.R., Lanier, W.S., and Heap, M.P.; "Municipal Waste Combustion Study: Combustion Control of MSW Combustors to Minimize Emission of Trace Organics," U.S. Environmental Protection Agency Publication No. 530-SW-87-C, June 1987, page 2-4.

10. Ozvacic, V., Wong, G., Tosine, H., Clement, R.E., and Osborne, J.; "Emissions of Chlorinated Organics from Two Municipal Incinerators in Ontario," J. of the Air Pollution Control Association, Volume 35, No. 8, pages 849-855, August 1985.

11. Fred C. Hart Associates, Inc., "Conclusions of New York's Study of Dioxins and MSW Incineration," Waste Age, pages 25-30, November 1984.

12. Hasselriis, F., "Minimizing Trace Organic Emissions From Combustion of Municipal Solid Waste by the Use of Carbon Monoxide Monitors," 1986 National Waste Processing Conference, pages 129-144, June 1986.

13. O'Connell, W.L., Stotler, G.C., and Clark, R., "Emissions and Emission Control in Modern Municipal Incinerators," 1982 National Waste Processing Conference, pages 285-297, May 1982.

14. Seeker, W.R., Lanier, W.S., and Heap, M.P.; "Municipal Waste Combustion Study: Combustion Control of MSW Combustors to Minimize Emission of Trace Organics," U.S. Environmental Protection Agency Publication No. 530-SW-87-C, June 1987, page 4-8.

15. Hurst, B.E., and White, C.M., "Thermal DeNOx: A Commercial Selective Noncatalytic NOx REduction Process for Waste-to-Energy Applications," 1986 National Waste Processing Conference, pages 119-127, June 1986.

16. Cross, F., O'Leary, P., and Walsh, P.; "Waste-to-Energy Systems: The Menu," Waste Age, pages 52-60, February 1987.

17. Walsh, P., O'Leary P., and Cross, F., "Residue Disposal from Waste-to-Energy Facilities," Waste Age, pages 57-62, May 1987.

18. Nollet, A.R., and Greeley, R.H., "New Concepts for Explosion Alleviation in Shred-First Solid Waste Plants," 1982 National Waste Processing Conference, pages 271-276, May 1982.

19. Barberis, J.L. and Lilly, R., "Shakedown Trials: New York State RDF Steam Generating Plant - Albany, New York," 1982 National Waste Processing Conference, pages 277-283, May 1982.

20. Reason, J., "Next step for Waste-to-Energy: Better Availability, Efficiency," Power, pages 17-24, July 1986.

21. Seeker, W.R., Lanier, W.S., and Heap, M.P.; "Municipal Waste Combustion Study: Combustion Control of MSW Combustors to Minimize Emission of Trace Organics," U.S. Environmental Protection Agency Publication No. 530-SW-87-C, June 1987, page 3-17.

22. Donnelly, J.R., Quach, M.T., and Moller, J.T., "Design Considerations for Resource Recovery Spray Dryer Absorption Systems," Presented at the 79th Annual Meeting of the Air Pollution Control Association, Minneapolis Minnesota, June, 1986.

23. Ferguson, W.B. Jr., Borio, D.C., and Bump, D.L., "Equipment Design Considerations for the Control of Emissions From Waste-to-Energy Facilities," Presented at the 79th Annual Meeting of the Air Pollution Control Association, Minneapolis Minnesota, June 1986.

24. Sedman, C.B., and Brna, T.G., "Municipal Waste Combustion Study Flue Gas Cleaning Technology, U.S. Environmental Protection Agency Publication No. 530-SW-87-021d, June 1987.

25. Moller, J.T. and Christiansen, O.B.; "Dry Scrubbing of MSW Incinerator Flue Gas by Spray Dryer Absorption: New Developments in Europe," Presented at the 78th Annual Meeting of the Air Pollution Control Association, Detroit, Michigan, June, 1985.

26. Foster, J.T., Hochhauser, M.L., Petti, V.J., Sandell, M.A., and Porter, T.J., "Design and Start-up of a Dry Scrubbing System for Solid Particulate and Acid Gas Control on a Municipal Refuse-Fired Incinerator," Presented at the Air Pollution Control Association Specialty Conference on Thermal Treatment of Municipal, Industrial and Hospital Wastes, Pittsburgh, Pa., November 4-6, 1987.

FIELD INSPECTION PROCEDURES

1. INSPECTION PROCEDURES

1.1 Inspection Purpose and Scope

General Objectives	Complete an independent, technically defensible evaluation of the compliance status.
	Determine if stack tests or other procedures are necessary to complete the evaluation of compliance status.
	Compile sufficient technically defensible and legally sound data to support any enforcement necessary.
	Help plant personnel understand regulatory requirements.
	Do whatever possible within the inspection authority to help sources and agencies avoid costly and time consuming litigation.
Specific Objectives	Determine if there are any significant baseline shifts in system operation that are indirect indicators of non-compliance with emission limitations.
	Review continuous emission monitors for direct indications of noncompliance since the last inspection.
	Review system operating logs for indirect indications of occasional noncompliance since the last inspection.
	Evaluate equipment operating practices to qualitatively determine the potential for near term equipment failures and excess emission problems.

1.1 Inspection Purpose and Scope (Continued)

Inspection Limitations	Do not prescribe or demand specific operating practices, start-up and shutdown practices, system operating rate limits, or equipment modifications.
	Do not do anything which endangers you or the plant personnel.
	Do not enter equipment under any circumstances.
	Obey all agency and plant safety policies.
	Respect all company-union agreements.
	Do not conduct the inspection alone. An authorized plant representative must be present at all times.
	Do not attempt to reach conclusions of law regarding the compliance status. An inspection is limited to gathering technical data.

1.2 Levels of Inspection

Level 1	Visible emissions observations and odor surveys made from outside the plant boundaries (not discussed in this inspection notebook)
Basic Level 2	Walkthrough evaluation of the municipal waste incinerator, the waste preparation and handling equipment, the residue disposal equipment, and the air pollution control system All data provided by on-site gauges and records The minimum inspection steps necessary to determine compliance status and to evaluate potential for violations
Follow-up Level 2	More comprehensive Level 2 inspection made when there are indications of noncompliance since the last inspection or of emerging problems which could cause noncompliance in the immediate future
Level 3	Comprehensive inspections made when there is a need to negotiate compliance programs with plant personnel or to prepare enforcement cases Certain data is obtained by inspector supplied instruments
Level 4	Initial inspection made by senior inspector or agency managers to acquire baseline data, to identify potential inspection safety problems, and to tailor the inspection checklists to the specific plant

2. INSPECTION OF COMBUSTION EQUIPMENT

2.1 Inspection Summaries

2.1.1 Combustion Equipment Inspection Overview

Incinerator

Evaluate adequacy of fuel-air ratios since this can affect the emissions of particulate, organic pollutants, and dioxin/furans.

Evaluate adequacy of exit gas temperatures since this is an indirect indicator of dioxin/furan survival. Gas temperature also affects nitrogen oxides generation by thermal mechanisms.

Evaluate flue gas oxygen concentrations since this affects particulate emissions, dioxin/furan survival, and nitrogen oxides formation. These also indicate possible air infiltration.

Evaluate temporal variations in the waste fuel quality and the methods used at the plant to adjust combustion conditions.

Evaluate physical condition of incinerator shell and waste feed delivery equipment. Check for audible air infiltration into incinerator and for audible air losses from undergrate plenums and forced draft supply ducts.

Review combustion equipment operating load variations. These systems have limited turndown capability and operation at low loads can possibly lead to high dioxin/furan emissions.

Review start-up, shutdown frequencies and procedures since these can cause short term emission problems and can lead to rapid equipment deterioration.

2.1.1 Combustion Equipment Inspection Overview

Waste Receiving, Storage, and Handling	Evaluate efforts to mix wastes to minimize the heterogeneous characteristics and stabilize combustion. Check for obvious changes in the types of wastes being fired and/or in the size range of the waste being fired. Such changes could increase emissions and/or require substantial operational adjustments in the incinerator. Evaluate efforts to remove bulky items and explosive items which could damage incinerator equipment. Check for fugitive particulate emissions and for windblown waste from trucks and receiving area. Check for odor emissions.
Steam and Electricity Generation	Review steam and/or electrical power generation rates as one indicator of load and the variability of load. Rapid load swings and operation at low loads can lead to high pollutant emissions. However, note that energy generation is also a function of fuel heating value.
Residue Handling and Disposal	Check records concerning incinerator bottom ash composition since this could indicate combustion problems. Observe bottom ash to determine obvious combustion problems. Check for RCRA Subtitle C compliance and for fugitive emissions.

2.1.2 Inspection Checklists

2.1.2.1 Basic Level 2 Inspection Checklist

Mass Burn, RDF-Fired, and Modular Systems	o Uniformity of ash beds on the grates in the burnout zone o Undergrate air pressures o Overfire air pressures o Incinerator draft o Firing rates, last 8 hours o Exit gas temperatures, last 8 hours o Exit gas oxygen levels, last 8 hours o Exit gas carbon monoxide concentrations, last 8 hours o Ultimate disposal of ash o Fugitive emissions from waste receiving and ash disposal operations o Flowchart of system if not already available
RDF-Fired Systems Only	o Quantities of coal, wood, or other supplemental fuels fired, last 8 hours
Modular Incinerators Only	o Primary and secondary chamber exit gas temperatures, last 8 hours o Incinerator shell corrosion o Frequency of dump stack operation

2.1.2.2 Follow-up Level 2 Inspection Checklist

Mass Burn, RDF-Fired, and Modular Systems	o All elements of Basic Level 2 inspection o Variability of wastes being charged o General types and sizes of wastes fired o Forced draft air leaks in undergrate plenums and supply ducts o Incinerator shell audible air infiltration o Audible air infiltration through charging area o Physical appearance of overfire air nozzles (to the extent observable) o Economizer ash reinjection (yes or no) o Bottom ash appearance o Exit gas temperature records, last 12 months o Exit gas oxygen level records, last 12 months o Exit gas carbon monoxide concentration records, last 12 months o Forced draft and induced draft fan currents o Operating times of the auxiliary burner
RDF-Fired Systems Only	o Physical appearance of RDF distributor equipment (to the extent observable)
Modular Incinerators Only	o Quantities of waste placed in charge pit for each charge

2.1.2.3 Combustion Equipment Level 3 Inspection Checklist

Mass Burn, RDF-Fired, and Modular Systems	o All elements of Basic and Follow-up o Level 2 inspections o Measured exit gas oxygen concentration o Measured exit gas carbon monoxide concentration o Measured undergrate and overfire air pressures (Mass Burn and RDF-Fired) o Bottom ash samples o Start-up and shutdown procedures

2.1.2.4 Combustion Equipment Level 4 Inspection Checklist

Mass Burn, RDF-Fired, and Modular Systems	o All elements of Level 2 follow-up inspections and Level 3 inspections o Flowchart of system o Possible locations for additional measurement ports and stack sampling ports o Possible locations for ash sampling o Potential safety problems and necessary inspector safety equipment o Types of waste composition records and incinerator operating records o Necessary modifications to inspection checklists due to site specific conditions

2.2 Level 2 Inspection Procedures

2.2.1 Basic Level 2 Inspection Procedures

Uniformity of ash bed on the grates in the burnout zone (MASS BURN UNITS)

Nonuniform fuel-ash layers on the grates leads to unequal fuel-air ratios and increased emissions of particulate matter and partially combusted organic compounds. The fuel-ash bed provides some of the air flow resistance necessary to ensure uniform air velocities upward through the grates. One reasonably convenient location to observe the ash layer is the burnout area since there is much lower flame brightness. Also, the risk of shrapnel from exploding cans and other waste is lower in this area. Nevertheless, extreme caution is warranted whenever attempting to look inside the incinerator. Eye and face protection is mandatory and it is necessary to choose a viewing angle that is protected from the trajectories of flying debris.

Perfectly even fuel distribution at the inlet of the unit is never possible, therefore, some slight variations in the ash layer at the burnout zone will generally exist. However, there should be no substantial side-to-side variations or variations along the line of grate movement in the burnout zone. There should be no extreme ash layer thin spots or exposed grate bars since these indicate entrainment of partially combusted ash due to the high localized undergrate velocities. Also, there should be no very bulky noncombustible waste in the ash deposits since this potentially damages the ash handling equipment and since the items contribute to nonuniform fuel distribution.

Uniformity of fuel beds on the grate (RDF-FIRED UNITS)

Nonuniform fuel-ash layers on the grates leads to unequal fuel-air ratios and increased emissions of particulate matter and partially combusted organic compounds. The fuel-ash bed provides some of the air flow resistance necessary to ensure uniform air velocities upward through

Uniformity of fuel beds on the grate (RDF-FIRED UNITS)
the grates. The most convenient locations for observing the fuel-ash beds are the front access hatches located below the feeders on spreader stoker boilers. At this location, the combustion is essentially completed and only burned out ash and char remain. Therefore, the flame luminosity is not a problem as long as you look downward through the hatch rather than attempting to look straight inwards. Eye and face protection is mandatory due to the chance that small aerosol cans will explode or the chance that there will be sudden incinerator static pressure excursions. Neither of these problems is especially common with this type of incinerator.

From the front access hatches it is possible to evaluate the adequacy of side-to-side variations in the ash bed. Significant differences generally indicate a feeder problem (Generally there are from two to four separate feeders.), or fuel size segregation in the fuel delivery equipment.

Uniformity of fuel beds on the grate (MODULAR UNITS)
This inspection step is not applicable to Modular Incinerators. Do not attempt to look through the hatches of this type of system.

Undergrate air pressures (MASS BURN UNITS)
Most modern mass burn incinerators have at least four undergrate plenums at least two for the combustion zone, one for initial drying of the waste feed, and one for the burnout zone. The static pressures in each zone are set by adjustable dampers located in the supply lines to each plenum. The static pressures are monitored in the main control room and most operators record these pressures on a frequent basis.

The typical static pressure values depend primarily on the grate design characteristics and there is considerable variation among incinerator manufacturers. Values are often between 1 to 5 inches of water and are relatively stable during the inspection.

Undergrate air pressures (MASS BURN UNITS)

Actual undergrate air pressures depend on the fuel bed depths being used, on the extent of pluggage of the grates, and on the incinerator operating rate. Some variations from baseline levels are normal. Extremely low values could indicate thin spots in the fuel-ash bed and possible incomplete burnout of the waste. High values could indicate partial grate pluggage and non-uniform air-fuel ratios on the grate.

Undergrate air pressure (RDF-FIRED UNITS)

Spreader stoker type incinerators have only one undergrate plenum. The static pressure in this plenum is generally controlled by the forced draft fan dampers. The static pressure is monitored in the main control room and most operators record this pressure on a frequent basis.

The typical static pressure values depend primarily on the grate design characterisitics and there are moderate variations among stoker manufacturers. Values are often in the range of 1 to 3 inches of water. The indicated values should be relatively stable over the time frame of the inspection.

Actual undergrate air pressure depend on the fuel bed depths being used, the ash content of the waste, the extent of pluggage of the grates, and the incinerator operating rate. Some variations from baseline levels are normal. Extremely low values could indicate thin spots in the fuel-ash bed and possibly incomplete burnout of the waste. High values could indicate partial grate pluggage and nonuniform air-fuel ratios on the grate.

Undergrate air pressure (MODULAR UNITS)

This inspection step is not applicable to Modular Units.

Overfire air pressures (MASS BURN UNITS)

Most mass burn units have from two to four overfire air headers. Each of these headers supply an array of nozzles within the incinerator. The air pressures in each of the headers is controllable by means of dampers. The pressures can be monitored either in the control room or by static pressure gauges on the headers themselves (gauges not present in some older units). Typical values are in the range of 15 to 50 inches of water. These values should be relatively stable over the time frame of the inspection.

Some variations from baseline levels are common since these are changed slightly to optimize combustion and since these are sometimes varied as a function of the incinerator load. However,major shifts from the baseline levels are very uncommon and should be questioned. Very low overfire air pressures suggest poor mixing in the upper zones of the combustion chamber and this could lead to poor combustion of volatile compounds released from the grate and poor destruction of dioxin/ furan compounds. Much higher than baseline values indicate either than plant personnel have installed smaller diameter nozzles in the incinerator or that a greater fraction of the total combustion air is now being supplied by the overfire nozzles rather than the undergrate plenums.

Overfire air pressures (RDF-FIRED UNITS)

Most RDF-fired spreader stokers have between two and four separate overfire air headers. Generally there are two parallel headers on the front wall, one directly below the feeders and a second several feet above the feeders. There is usually at least one header across the back furnace wall, several feet above the grates. The air pressures in each of the headers is controllable by means of dampers. The pressures are normally monitored either in the control room or by static pressure gauges on the headers themselves. Typical values are between 15 to 50 inches of water and they are relatively stable during the inspection.

Overfire air pressures (RDF-FIRED UNITS)

Some variations from baseline levels are common since these are changed slightly to optimize combustion and since these are sometimes varied as a function of the incinerator load. However, major shifts from the baseline levels are very uncommon and should be questioned. Very low overfire air pressures suggest poor mixing in the upper zones of the combustion chamber and this could lead to poor combustion of volatile compounds released from the grate and poor destruction of dioxin/furan compounds. Much higher than baseline values indicate either that plant personnel have installed smaller diameter nozzles in the incinerator or that a greater fraction of the total combustion air is now being supplied by the overfire nozzles rather than the undergrate plenums.

Overfire Air Pressure (MODULAR UNITS)

This inspection step is not applicable to Modular Incinerators.

Incinerator draft (ALL TYPES OF INCINERATORS)

The static pressure of the incinerator in the main combustion zone is typically a negative 0.05 to a negative 0.15 inches of water regardless of equipment manufacturer. This static pressure is monitored continuously by an instrument located in the main control room. The present value should be in this range and it should be relatively stable. Incinerator drafts less than negative 0.15 inches of water indicate problems with the forced draft air supply and suggest severe air infiltration. Both of these lead to less than ideal combustion conditions. Incinerator drafts that are 0.0 inches of water or higher demonstrate that the incinerator has gone positive pressure. This is a severe combustion problem and a severe personnel exposure problem. Under no circumstances should the incinerator operate with positive pressures. This indicates an induced draft fan problem or a gas flow resistance problem either in the incinerator or the air pollution system.

Exit gas temperatures for last 8 hours (All INCINERATORS)

The incinerator gas temperatures are generally kept above 1800 °F to ensure maximum destruction of dioxin/furan compounds to complete oxidation of carbon monoxide to carbon dioxide. This value is checked to confirm that the plant has been able to maintain this minimum temperature.

This temperature is monitored in the incinerator control room along with other gas temperatures throughout the system. In most plants, the temperature is either recorded on a multi-pen chart recorder or monitored by a data acquisition system. In either case, it is possible to scan the temperature data for the last 8 hours to determine the stability of this value. Some variations in the exit gas temperature are normal since it is a function of the incinerator load and the waste fuel heating value. It can be depressed by wet fuel such as leaves and it can be incresed when substantial quantities of plastics and other high caloric value wastes are added (Mass Burn and Modular Units). The auxiliary burner (if present) should be operated if the gas temperature falls substantially below 1800 °F.

Exit gas oxygen levels for last 8 hours (ALL INCINERATORS)

There is usually a continuous oxygen analyzer located downstream of the feedwater economizer (Mass Burn or RDF-Fired) or the waste heat boiler (Modular). As indicated in the reference section of this notebook, the typical oxygen concentrations are generally in the range of 6 to 12%. Values lower than 6% generally indicate inadequate excess air rates and incomplete combustion of volatile compounds. Values higher than 12% generally indicate severe air infiltration through the charging area, the incinerator shell, or the ash pit. The cold air infiltrating the unit could quench the oxidation reactions and cause high concentrations of partially combusted material to escape the incinerator. These emissions could include dioxins and furans.

Exit gas carbon monoxide levels for last 8 hours (All TYPES OF INCINERATORS

Carbon monoxide is used as one of the indirect indicators of the adequacy of combustion. Typical concentrations are in the range of 25 to 100 ppm (uncorrected). Average values above 200 ppm suggest significant combustion problems. Inspectors should check the frequency and severity of short term CO terms. Plant personnel should be asked about possible corrective actions to improve combustion. Also, the instrument calibration and routine maintenance records should be briefly reviewed.

Flowchart of the system (ALL TYPES OF INCINERATORS)

A simple flowchart of the incinerator system components and material streams should be prepared to aid in the evaluation of the plant instruments and the incinerator operating conditions. The flowchart should include a block diagram of (1) the waste receiving, storage, and handling operations, (2) the incinerator chamber(s), the overfire air manifolds, the undergrate plenums, the ash pits, the auxiliary burners, the economizer ash reinjection lines, (3) the air pollution control system and solids handling equipment, and (4) the stack and any effluent gas continuous emission monitors. The main instruments used in the inspection should be identified on this simple sketch.

Fugitive emissions (ALL TYPES OF INCINERATORS)

Visible emission observations should be performed whenever there are apparent fugitive emissions from the waste receiving area, the RDF processing equipment, or the bottom ash handling equipment. There should not be any uncovered outside storage of bottom ash or control device ash. Furthermore, good plant housekeeping is necessary to minimize fugitive emissions. Care is necessary to avoid any skin contact with the waste feed, the RDF fuel, or the ash. It is also necessary to avoid overhead equipment and other moving equipment in these areas.

Quantities of supplemental fuels for last 8 hours (RDF-FIRED UNITS)

The combustion conditions are significantly dependent on the mix of fuels being fired. The quantities of coal or wood being fired can be determined approximately by recording the scale readings. This information is generally recorded on the daily operating logs. However, it should be noted that fuel scale readings require frequent calibration and these are often incorrect by as much as 50% despite the best efforts of qualified maintenance personnel. Therefore, this data provides only a very rough indication of the supplemental fuel feeding rates.

Primary and secondary chamber temperatures for last 8 hours (MODULAR UNITS)

The primary and secondary chamber exit gas temperatures are monitored by thermocouples in the outlet ducts. This data can be obtained from the main incinerator control panels. However, in some of the especially small units, this is not recorded on a continuous basis. In these cases, the temperature history over the last 8 hours should be obtained from the hour-by-hour entries in the daily operating log sheets.

The primary chamber outlet temperatures are generally in the range of 1000 to 1200 °F. For starved air units, higher temperatures may indicate air infiltration into the primary chamber and premature oxidation of the volatile material released during waste combustion. For excess air units, higher temperatures generally indicate the charging of wastes with high caloric values Low temperatures in the primary chamber indicate low waste feed rates or low waste caloric value. Some slight increases and decreases in the primary chamber temperature are normal during the ram charging of fresh wastes.

The secondary chamber outlet gas temperatures are normally between 1800 and 2000 °F. The secondary chamber burner should on when necessary to maintain 1800 °F.

Incinerator shell corrosion (MODULAR INCINERATORS)

Evaluate the exterior of both the primary and secondary chambers for signs of corrosion. This can be caused by the infiltration of cold air that in turn results in the absorption of highly corrosive hydrogen chloride into water droplets on the metal surfaces. The air infiltration condition worsens as the corrosion continues. This can lead to "cold" zones in the affected chamber and thereby contribute to increased emissions of partially combusted organic compounds.

Frequency of dump stack operation (MODULAR INCINERATORS)

There is generally a direct discharge dump stack on the back of the secondary chamber. In some plants, this is used when there is no need for the steam that would be generated in the waste heat boiler or when the waste heat boiler is down. For modular incinerators requiring air pollution control equipment, the operation of the dump stack results in the bypassing of this device. The status of the dump stack can be determined by observing the position of the stack seal (on the top of stack) or by noting the dump stack status light on the control panel.

2.2.2 Follow-up Level 2 Inspection Procedures

Variability of wastes being charged (All INCINERATORS)

From a safe vantage point, observe the variability of the wastes being charged to the incinerator (Mass Burn and Modular Incinerators). The operator should be attempting to mix wastes with much different heating values. Sudden shifts in the moisture content, density, and heating value of the wastes being charged can upset combustion within the incinerator and lead to excess pollutant emissions.

The bulky, noncombustible items and the potentially dangerous items should be removed prior to charging (Mass Burn and Modular Incinerators) or prior to shredding (RDF-Fired Incinerators). A partial list of inappropriate materials for incineration is provided below.

- Red bag (infectious) wastes
- Paint and solvent cans
- Live ammunition boxes
- Metal furniture parts
- Automotive and bicycle parts
- Bagged asbestos waste
- Tree stumps
- Gas cylinders
- Large appliances
- Small appliances
- Mattresses
- Cables
- Chemical drums

Variability of RDF fuel (RDF-FIRED UNITS)

If there are indications of occasional combustion system problems identified during the routine Level 2 inspection, the variability of the RDF fuel should be briefly reviewed. RDF fuel proximate and ultimate analyses provide one measure of the extent of variability. Fuel samples must be sent to a testing laboratory for the determination of proximate and ultimate analyses. The reports consist of a single page. As part of these analyses, it is also helpful to determine the ash fusion temperature data.

Variability of RDF fuel (RDF-FIRED UNITS)

Low ash fusion values create possible slagging problems and partial pluggage of the stoker grates. These problems disrupt the fuel-air ratios in the boiler and increase pollutant emissions. They also create major maintenance problems for the plant.

Another very important fuel property is the size distribution. This data is obtained by a relatively simple gravimetric test using a set of screens. This test can be conducted on-site. A relatively consistent fuel size gradation is necessary to ensure proper fuel-air ratios in the boiler. Excessive levels of very fine material can result in large piles of fuel at the front of the stoker immediately below the distributors. Excessive quantities of large diameter material will lead to fuel piles at the back end of the stoker.

Forced draft air leaks in undergrate plenums and supply ducts (MASS BURN AND RDF-FIRED UNITS)

Possible leaks of forced draft air should be investigated if the undergrate air pressures are significantly higher or significantly lower than the baseline levels for a given incinerator load. While these leaks are rarely the main reason for the change in undergrate pressures, they can be serious problems since they reduce the total quantity of undergrate air used for combustion. The most likely leak sites, which can be found during a Level 2 inspection, include the side walls between the incinerator and the undergrate plenums and any forced draft duct expansion joints.

Incinerator shell audible air infiltration (ALL TYPES OF INCINERATORS)

This leads to cold zones within the incinerator and increased emissions of partially combusted or reacted organic compounds. Most of these leaks occur in the refractory in inaccessible locations. However, they are sometime noticeable around the charging area and near the overfire air headers on both the front and back of the incinerator.

Economizer ash reinjection (MASS BURN AND RDF-FIRED UNITS)

If the unit has a chronic problem with excess particulate emissons, inspectors should determine if the plant is continuing to reinject economizer ash back into the incinerator. In some cases, reinjection simply recycles ash through the system until it is small enough to escape both the economizer and the air pollution control device. In other plants, reinjection can allow very modest thermal efficiency improvements without severe equipment wear and emission problems. The use of reinjection can be visually determined by using the site ports generally installed on the relatively short pipes leading from the economizer hopper to the back of the incinerator. In some cases, operators can also safely obtain samples of the economizer ash. However, this is rarely necessary.

Bottom ash appearance (ALL TYPES OF INCINERATORS)

The presence of substantial carbonaceous material in the incinerator ash is a clear indication of combustion problems. The ash characteristics can be observed through observation hatches around the burnout zone of the incinerator. In some cases, plant personnel may be able to provide a small sample of ash which is being sent to the landfill for disposal. However, inspectors should not under any circumstances ask plant personnel to take any personal risks to get a sample of the ash. The sample should be sealed and handled properly since it may contain hazardous materials.

Exit gas temperature records for last 12 months (ALL TYPES OF INCINERATORS)

The gas temperature records since the last inspection should be reviewed to identify any problems in maintaining a reasonable minimum exit gas temperature. The generally accepted value is 1800 °F. The auxiliary burner (if present) is used to maintain minimum temperature during periods of waste feed interruption or during periods when excessive quantities of wet or noncombustible waste has been charged. For modern units, the

Exit gas temperature records for last 12 months (ALL TYPES OF INCINERATORS)
gas temperature records and the status of the auxiliary burner can be determined by scanning the daily operating logs of the incinerator, by scanning some of the temperature recorder strip charts, or by checking the output reports from the data acquisition system.

Exit gas oxygen levels for last 12 months (ALL TYPES OF INCINERATORS)

For modern units, the continuous oxygen analyzer data for the past year should be scanned to determine if the oxygen concentrations have remained in the normal range. In most plants, this range is 6 to 12%. Values higher or lower than this range can often indicate combustion problems. This data is available on the daily incinerator operating logs, on the analyzer strip charts, or on the data sheets generated by the data acquisition system.

Exit gas carbon monoxide levels for last 12 months (ALL TYPES OF INCINERATORS)

Carbon monoxide concentration provides one indication of the adequacy of combustion (CO is not monitored on all units). Values should generally be below 100 ppm (uncorrected) except during periods of start-up and shutdown. This data is available on the daily incinerator operating logs, on the analyzer strip charts, or on the data sheets generated by the data acquisition system.

Forced draft and induced draft fan motor currents (ALL TYPES OF INCINERATORS)

These values are used as one indicator of the overall operating rate of the incinerator system. The steam generation rate data are not sufficient, due to the variability of the waste feed characteristics and the high potential moisture and noncombustibles levels in this feed. These values should be compared against baseline data sets as one means to confirm that the system is operating at full load. It should be noted that this data is not available in some facilities.

Ultimate disposal of ash and material removed prior to charging (ALL TYPES OF INCINERATORS)

Waste handling and disposal practices should be determined to confirm compliance with labeling, transport, and disposal requirements of RCRA.

Forced draft air leaks in undergrate plenum and supply duct (MASS BURN AND RDF-FIRED UNITS)

Possible leaks of forced draft air should be investigated if undergrate air pressure is significantly higher or significantly lower than the baseline level for a given boiler load. While these leaks are rarely the main reason for the change in undergrate pressure, they can be serious problems since they reduce the total quantity of undergrate air used for combustion. The most likely leak sites, which can be found during a Level 2 inspection, include the side walls between the incinerator and the undergrate plenum and any forced draft duct expansion joints.

Physical condition of overfire air nozzles, (MASS BURN AND RDF-FIRED UNITS)

On some units, side observation ports can be used to see the upper rows of overfire air nozzles across the front wall and back walls of the boiler. These should not be plugged or slagged over. Eye and face protection is mandatory when looking into the boiler.

Steam rates and feed water rates for last 12 months, ALL TYPES OF INCINERATORS)

The variability of incinerator load can be evaluated using steam rate and feedwater rate data available from the daily logs or the strip chart recorders. Periods of high opacity, high carbon monoxide concentration, low exit gas temperatures, and/or unusual oxygen levels should be compared with the incinerator load data.

Audible air infiltration into incinerator shell and charging door (MODULAR UNITS)

Air infiltration through warped charging doors or corroded areas of the shell can lead to localized "cold" zones in the primary chamber. They can also cause some undesirable particle reentrainment and carry-over into the secondary chamber. Care must be exercised in attempting to find audible leaks, since there is moving equipment around the charge pit and since there can be fugitive pollutant emissions accumulating in the poorly ventilated areas around the primary chambers.

2.3 Level 3 Inspection Procedures

Economizer/waste heat boiler exit gas temperature (ALL TYPES OF INCINERATORS)

The economizer or waste heat boiler exit gas temperature should be used as an indirect measurement of the average gas temperature entering the superheater section of the boiler/incinerator. Direct measurement of the gas temperature entering the superheater or waste heat boiler is very difficult using portable instruments since the gas temperature is very hot (>1800°F hopefully) and since relatively long probes are necessary to reach representative measurement locations. Also, most systems do not have safe and convenient measurement ports in this area of the incinerator.

The measured economizer or waste heat boiler exit gas temperature can be compared against baseline values for similar boiler load conditions. It can also be compared against the economizer exit gas temperature monitored continuously by the on-site instruments. Lower gas temperature observed at this location suggest low gas temperature readings from the on-site temperature monitors located upstream of the superheater.

Exit gas oxygen concentration (ALL TYPES OF INCINERATORS)

The exit gas oxygen concentration should be measured when there are indications of combustion related emission problems and when the on-site oxygen analyzer is either inoperative or nonexistent. The types of instruments available include multi-gas combustion gas analyzers, ORSATs, and manual single-gas absorbers.

Sampling locations having extreme high gas temperatures should be avoided since this will destroy the probe and create a safety problem. In the case of mass burn units and RDF-fired boilers, the measurements should be taken downstream of the feedwater economizer.

The oxygen concentration should be measured at several locations along the duct diameter. Stratification of the gas stream can result in nonuniform oxygen concentrations across the duct diameter. Also, the measurements should be repeated several times over a reasonable time span to account for short term fluctuations in the oxygen levels. This is especially important for the modular units since ram charging and dump stack operation create frequent short term oxygen concentration changes.

The oxygen measurements should be checked using carbon dioxide measurements (if carbon dioxide data is also provided by the instrument being used). The sum of the oxygen and carbon dioxide measurements should be in the range of 18 and 22%, e.g. 10% oxygen plus 9% carbon dioxide equals 19%.

Carbon monoxide concentrations (ALL INCINERATORS)

This measurement should be made when there are indications of combustion problems and there is no carbon monoxide analyzer. Values greater than 200 ppm (uncorrected for CO_2 concentration) suggest nonideal conditions and the emission of partially combusted organic compounds. To ensure representative results, the measurements should be made at several locations in the duct and should be made several times over a reasonable time span.

Undergrate and overfire pressures (MASS BURN AND RDF-FIRED UNITS)

These pressures should be measured if there are indications of significant combustion problems and the on-site instruments are either unreliable or inoperative. Manometers or diaphragm gauges having measurement ranges of 0 to 10 inches of water and 0 to 40 inches of water are usually sufficient.

Undergrate and overfire air pressures (MASS BURN AND RDF-FIRED UNITS)

It should be noted that some systems do not have measurement ports in the undergrate and overfire air plenums. If these are not available, the measurements cannot be performed during the present inspection. Ports should be requested for future inspections. Although the undergrate supply ducts and overfire air headers are relatively safe, plant personnel should never be asked to install measurement ports on operating systems.

Start-up and shutdown procedures (ALL TYPES OF INCINERATORS)

If the facility has frequent start-ups, the start-up and shutdown procedures should be evaluated. The emphasis should be on techniques used to maintain minimum furnace exit gas temperatures and on the criteria for beginning waste charging to the unit. Continuous monitoring data for carbon monoxide and oxygen should be checked to determine the duration of nonideal combustion conditions after waste charging has begun (data not available on all units).

Also, the efforts to minimize the number of start-up/shut-down cycles should be discussed since this is generally the best means of minimizing both equipment deterioration and pollutant emissions. The equipment damage is primarily due to the thermal expansion and contraction. Corrosion due to condensation of acid vapors that are incompletely purged from the furnace area is also a significant problem.

System flowchart (ALL TYPES OF INCINERATORS)

A relatively simple flowchart is very helpful in conducting a complete and effective Level 2/Level 3 inspection. This should be prepared by agency management personnel or senior inspectors during a Level 4 inspection. It should consist of a simple diagram that includes the following elements:

- Incinerator chamber(s), undergrate plenums, and overfire air header locations
- Location(s) of forced draft fans for undergrate air and overfire air. Location of induced draft fan for effluent gas movement.
- Charging pits, chutes, and rams
- Locations of major instruments and monitoring locations on the equipment (static pressure gauges, temperature monitors, oxygen analyzers, and carbon monoxide analyzers)
- Waste receiving, storage, and processing
- Ash handling and storage

Locations for measurement ports (ALL TYPES OF INCINERATORS)

Many existing incinerators do not have convenient and safe ports that can be used for static pressure, gas temperature, oxygen, and carbon monoxide measurements. One purpose of the Level 4 inspection is to select (with the assistance of plant personnel) locations for ports to be installed at a later date to facilitate Level 3 inspections. Ports may be necessary in the overfire air headers, the undergrate plenum supply ducts, and the economizer gas outlet duct. Information regarding possible sample port locations is provided in the U.S. EPA Publication titled, " Preferred Measurement Ports for Air Pollution Control Systems," EPA 340/1-86-034.

Potential safety problems (ALL TYPES OF INCINERATORS)

Agency management personnel and/or senior inspectors should identify potential safety problems involved in standard Level 2/Level 3 inspections at this site. To the extent possible, the system owner/operators should eliminate these hazards. For those hazards which cannot be eliminated, agency personnel should prepare notes on how future inspections should be limited and should prepare a list of the necessary personnel safety equipment. A partial list of common health and safety hazards include the following:

- Eye injuries while observing combustion conditions through observation hatches
- Skin contact with RDF fuels
- Thermal burns
- Moving equipment hazards

Records (ALL TYPES OF INCINERATORS)

A summary of the normal operating records and routine laboratory analyses should be compiled. If possible, example photocopies of these forms should be included in the inspection file so that new personnel assigned inspection responsibilities will know what data and information is available on these forms.

Inspection checklists

Senior inspectors and/or agency management personnel should modify the checklists presented in this notebook to match the specific conditions at the facility being inspected. Inspection points which are irrelevant and unnecessarily time consuming should be omitted to reduce the inspection time requirements and lessen the disruption of the plant personnel's schedule. Also, any inspection steps which involve unreasonable risks to the inspector, the plant personnel, or the equipment should be deleted. In some cases, it may be necessary to add other inspection points not discussed in this notebook. The modified checklist should be included in the inspection file.

3. INSPECTION OF DRY SCRUBBERS

3.1 Inspection Summaries

3.1.1 Dry Scrubber System Inspection Overview

Stack	Evaluate average opacities and puffing conditions as direct indications of particulate device operating problems. The presence of a secondary plume is an direct indication of severe combustion problems or dry scrubber problems.
Continuous Emission Monitors	Evaluate frequency and severity of excess emissions of particulate matter, hydrogen chloride, sulfur dioxide, and nitrogen oxides.
Particulate Control Device (see also Sections 4-6)	Evaluate inlet and outlet gas temperatures as one indication of air infiltration. Listen for obvious infiltration around the hoppers, access hatches and expansion joints. Evaluate adequacy of routine cleaning system operation. Evaluate operating parameters that are indirectly related to particulate collection efficiency (e.g. ESPs - power data, wet scrubbers - pressure drop). Compare present operating levels to baseline values. Evaluate corrosion problems. Check for fugitive emissions from the hopper solids handling equipment. Evaluate operating logs and maintenance records with respect to attempts to prevent repeat failures of the same components.

3.1.1 Dry Scrubber System Inspection Overview

Dry Scrubber Vessel	Evaluate operating conditions which are indirectly related to the acid gas removal efficiency. One of the most important of these is the outlet dry bulb and wet bulb temperatures. Compare the present operating levels with baseline values.
	Evaluate inlet gas temperatures at present and variations of this value since the last inspection. Low inlet temperatures could lead to solids build-up problems in spray dryer type systems.
	Determine if solids recycle from the absorber vessel and/or the particulate control device is being used.
	Review records to evaluate frequency and severity of deviations from normal operating conditions.
	Evaluate corrosion problems which could lead to future excess emission problems.
Alkaline Reagent Preparation	Review maintenance records to evaluate efforts to maintain slurry feed and density instruments.
	Evaluate slaker (if present) liquor outlet temperature as an indirect indication of the adequacy of calcium hydroxide slurry preparation.
	Evaluate procedures used to adjust dry scrubber operation to various incinerator loads and inlet pollutant concentrations.

3.1.2 Level 2 Inspection Checklists

3.1.2.1 Basic Level 2 Inspection Points

Stack
- Visible emissions for 6 to 30 minutes for each stack or discharge vent
- Presence of condensing plume

Continuous Monitors for Opacity, Sulfur Dioxide, Hydrogen Chloride, and Nitrogen Oxides
- Double pass transmissometer condition
- Double pass transmissometer opacity data for at least the last 8 hours
- Sulfur dioxide, hydrogen chloride, and nitrogen oxides emissions for at least the last 8 hours

Dry Scrubber - General
- System flowchart
- General physical condition

Dry Scrubber - Spray Dryer Absorbers and Combination Systems
- Absorber vessel approach-to-saturation for for at least the last 8 hours
- Make-up reagent feed rates and absorber recycle rates for at least the last 8 hours
- Nozzle air and slurry pressures (if present)

Dry Scrubber - Dry Injection System and Combination Systems
- Calcium hydroxide feed rate for at least the last 8 hours
- Calcium silicate/calcium hydroxide feed rates for at least the last 8 hours (if calcium silicate used)
- Solids recycle rates (if recycle used)

Dry Scrubber - Fabric Filters, Electrostatic Precipitators, and Wet Scrubbers
See Sections 4, 5, and 6

3.1.2.2 Follow-up Level 2 Inspections

Stack

- All elements of a Basic Level 2 inspection
- Sulfur dioxide and hydrogen chloride continuous monitoring data for previous 12 months

Dry Scrubber - Spray Dryer Absorber and Combination Systems

- Absorber vessel approach-to-saturation values during past previous 12 months
- Reagent feed rates during last 12 months
- Absorber vessel inlet gas temperatures during past 12 months
- Slaker slurry outlet temperatures during past 12 months (if slaker present)
- Slurry density monitor data and slurry flow monitor maintenance information during past 12 months
- Absorber gas flow rates (if monitored)

Dry Scrubber - Dry Injection System and Combination Systems

- Reagent feed rates during past 12 months
- Calcium silicate/calcium hydroxide feed rates during past 12 months
- Solids recycle rates during past 12 months (if recycle used)

Dry Scrubber - Fabric Filters, Electrostatic Precipitators, and Wet Scrubbers

See Sections 4, 5, and 6

3.1.2.3 Level 3 Inspection Checklist

Stack
- All elements of a basic Level 2 inspection

Continuous Monitors for Opacity, Sulfur Dioxide, Hydrogen Chloride, and Nitrogen Oxides
- All elements of a follow-up Level 2 inspection

Dry Scrubber
- All Level 2 follow-up inspection elements
- Spray dryer absorber wet bulb and dry bulb temperatures
- Absorber or contactor inlet gas temperature

Dry Scrubber - Fabric Filters, Electrostatic Precipitators, and Wet Scrubbers
See Sections 4, 5, and 6

3.1.2.4 Level 4 Inspection Checklist

Stack
- All elements of a basic Level 2 inspection

Continuous Emission Monitors for Opacity, Sulfur Dioxide, Hydrogen Chloride, and Nitrogen Oxides
- All elements of a follow-up Level 2 inspection

Dry Scrubber
- Level 3 inspection elements
- Flowchart of system
- Locations of possible measurement ports
- Start-up/shut-down procedures
- Potential inspection safety problems

3.2 Level 2 Inspection Procedures

3.2.1 Basic Level 2 Inspection Procedures

Dry scrubber system visible emissions

If weather conditions permit, determine the stack effluent average opacity in accordance with U.S. EPA Method 9 procedures (or other required procedures). The observation should be conducted during routine process operation and should last 6 to 30 minutes for each stack and bypass vents. The majority of units operate with effluent opacities less than 10% on a continuous basis. Higher opacities indicate emission problems.

The timing and duration of all significant spikes should be noted after the visible emissions observation. This information will be useful in determining some of the possible causes of the spiking condition. Significant puffs on either a regular frequency or on a random basis are not normal. However, in some cases, light puffing can occur even during optimal conditions.

If weather conditions are poor, an attempt should still be made to determine if there are any visible emissions. The presence of a significant plume indicates emission problems. Do not attempt to determine the "average opacity" at such times.

Condensing plume conditions

Condensing plume conditions in dry scrubber systems are highly unusual since most vapor state species which could cause such plumes are partially removed. The presence of a condensing plume would indicate a major malfunction of the dry scrubber system.

The principal characteristics of a condensing plume include a bluish-white color, opacities which are higher when the weather is cold or very humid, a low opacity at the stack discharge, and increasing opacities in the first few seconds of plume travel.

System flowchart

A simple flowchart of the entire dry scrubber system and the associated process equipment should be prepared if one is not already available in the agency files. This should consist of a block diagram which includes the absorber or gas contactor, the reagent preparation equipment, the particulate control device, the combustion source, and all instruments relevant to the inspection.

Double-pass transmissometer physical conditions

Most dry scrubbers have a transmissometer for the continuous monitoring of visible emissions. If a unit is present, and if it is in an accessible location, check the light source and retroreflector modules to confirm that these are in good workingorder. Check that the main fan is working and that there is at least one dust filter for the fan. On many commercial models, it is also possible to check the instrument alignment without adjusting the instrument. Note: On some models, moving the dial to the alignment check position will cause an alarm in the control room. This is to be moved only by plant personnel and only when it will not disrupt plant operations.

Double-pass transmissometer data

If the transmissometer appears to be working properly, evaluate the average opacity data for at least the previous 8 hours prior to the inspection. If possible, the average opacity data for selected days since the last inspection should also be reviewed. This evaluation is helpful in confirming that the units being inspected are operating in a representative fashion. If the unit is working better during the inspection than during other periods, it may be advisable to conduct an unscheduled inspection in the future.

As part of the review of average opacity, scan the data to determine the frequency of emission problems and to evaluate how rapidly the operators are able to recognize and eliminate the condition.

Sulfur dioxide, nitrogen oxides, and hydrogen chloride monitor physical conditions

If the monitors are in an accessible location, confirm that the instruments are in good mechanical operating condition and that any sample lines are intact. Check calibration and zero check records for all instruments. Whenever working in the areas around the continuous emissions monitors, inspectors should be cautious about positive pressure fugitive leaks of effluent gas.

Sulfur dioxide, nitrogen oxides, and hydrogen chloride emission data

If the gas monitors appear to be working properly, evaluate the average emission concentrations for at least the previous 8 hours prior to the inspection. If possible, the average emissions for selected days since the last inspection should also be reviewed. This evaluation is helpful in confirming that the units being inspected are operating in a representative fashion.

High emission rates of either sulfur dioxide or hydrogen chloride indicate significant problems with the dry scrubber system. The general classes of problems include but are not limited to poor alkaline reagent reactivity, inadequate approach-to-saturation (wet-dry systems), low reagent stoichiometric ratios, low inlet gas temperatures, and make-up reagent supply problems. Follow-up Level 2 inspection procedures or Level 3 inspection procedures will be necessary if high emission rates of either sulfur dioxide or hydrogen chloride are observed.

High nitrogen oxides concentrations indicates a problem with the combustion equipment operation, an increase in the waste nitrogen content, or a problem with the nitrogen oxides control system.

Spray Dryer Absorber "Approach-to-Saturation"

One of the most important operating parameters affecting the efficiency of a wet-dry type dry scrubber is the approach-to-saturation. This is simply the difference between the wet bulb and dry bulb temperature monitors at the exit of the spray dryer vessel. The normal approach-to-saturation varies between 90 and 180°F. Very high values suggest lower acid gas removal efficiencies since the baseline period.

The approach-to-saturation is monitored continuously by a set of dry bulb and wet bulb monitors. An change in this value is sensed by the automatic control system which either increases or decreases the slurry feed rate to the atomizer.

Due to the vulnerability of these temperature monitors to scaling and blinding, inspectors should not be surprised to find that some plants must occasionally bypass the automatic process control system and operate manually for limited time periods. This generally means slightly worse approach-to-saturation values so that operators have a margin for error in the event of sudden process changes such as load changes. Gradually plants should be able to increase the reliability of the temperature monitors by relocation of the sensors and by improved operation of the dryer.

Spray dryer absorber reagent feed rates

The calcium hydroxide (or other alkali) feed rates are important since they partially determine the stoichiometric ratio between the moles of reagent and the moles of acid gas. Low stoichiometric ratios result in reduced collection efficiencies. Higher than needed stoichiometric ratios use excessive reagent and may result in poor drying of the sorbent.

Spray dryer absorber reagent feed rates

The reagent feed rate is generally determined using a magnetic flow meter on the slurry supply line to the atomizer feed tank. It is also necessary to know the slurry density. This is monitored by a nuclear-type density monitor. Typical slurry densities are in the range of 5 to 20% by weight. It should be noted that both the magnetic flow meter and the nuclear density meter are vulnerable to scaling due to the nature of the slurry.

Another way to determine the reagent feed rate is to record the feed rates of new pebble lime and recycled solids indicated by the weigh belt feeders. The weigh belt for the pebble lime is between the lime storage silo and the slaker. The weigh belt feeder for the recycled solids is close to the spray dryer absorber vessel.

Both the slurry feed rates and the solids rates should be compared with baseline values at a similar combustion system load to determine if the stoichiometric ratio has dropped significantly.

Spray dryer absorber nozzle air and slurry pressures

For units equipped with nozzles rather than rotary atomizers, the air pressures and slurry pressures should be recorded and compared with baseline levels. Some variation in the slurry pressures are necessary in order to maintain proper approach-to-saturation values during combustion system load variations.

Dry injection system feed rates

The feed rate of calcium hydroxide to the pressurized pneumatic system is generally monitored by either a weigh belt feeder or a volumetric screw-type feeder. Both of these feeders are located close to the calcium hydroxide storage silos, and the feed rates are generally indicated on the main system control panel. These values should be recorded for at least the past 8 hours and compared against baseline values for similar combustion load periods. Decreased reagent feed rates indicate possible reductions in the stoichiometric ratio and thereby a reduction in acid gas collection effectiveness. The blower motor currents and the pneumatic line static pressures should also be recorded and checked against baseline data sets. Higher motor currents and higher conveying line static pressures indicate increases in the air flow rates.

Calcium silicate feed rates

The semi-wet/dry system, utilizes a calcium silicate/calcium hydroxide dry injection system downstream from the calcium hydroxide spray dryer absorber. The feed rate of calcium silicate/calcium hydroxide is monitored by weigh belt feeders or volumetric screw conveyors. Feed rates for the past 8 hours should be recorded and compared with baseline values.

Control device solids recycle rates

The semi-wet/dry system utilizes a recycle stream from the fabric filter in order to improve overall reagent utilization. The solids recycle rate during the inspection should be recorded and compared to baseline values.

Dry scrubber system general physical conditions

While walking around the dry scrubber and its inlet and outlet ductwork, check for obvious corrosion around the potential "cold" spots such as the bottom of the absorber vessel and the particulate control device hoppers and around the access hatches. Check for audible air infiltration.

3.2.2 Follow-up Inspection Points for Level 2 Inspections

Continuous monitoring data for the previous 12 months

Obtain the continuous monitoring records and quickly scan the data for the previous 12 months to determine time periods that had especially high and especially low emission rates. Select the dry scrubber operating logs and the process operating logs that correspond with the times of the monitoring instruments charts/ records selected. Compare the dry scrubber operating data and process operating data against baseline information to identify the general category of problem(s) causing the excess emission incidents. Evaluate the source's proposed corrective actions to minimize this problem(s) in the future.

Spray dryer absorber approach-to-saturation values during the previous 12 months

The approach-to-saturation value is an important parameter which relates directly to the pollutant removal effectiveness. If there is significant question concerning the ability of the dry scrubber system to maintain proper operation on a long term basis, the approach-to-saturation values indicated on the dry scrubber system daily operating log sheets should be checked. Values much higher than baseline values or permit stipulations indicate chronic problems such as the following.

- Absorber vessel temperature instruments
- Absorber vessel atomizer
- Absorber gas dispersion equipment
- Low absorber vessel inlet gas temperatures during low load periods
- Nozzle erosion or blockage
- Slurry supply line scaling

Spray dryer absorber reagent feed rate data during the previous 12 months

The feed rates of make-up pebble lime and recycle solids are generally indicated on the daily operating logs of the dry scrubber system. Values for the last 12 months should be compared with the corresponding combustion load data to determine if significant changes in the overall reagent stoichiometric ratios have occurred. Data concerning the system load must be obtained from the combustion system daily operating log sheets. If available, dry scrubber system inlet sulfur dioxide concentrations should also be used in this qualitative evaluation of reagent/acid gas stoichiometric ratios.

Slaker slurry outlet temperatures during the past 12 months

The slaker slurry outlet temperature provides a rough indication of the adequacy of the conversion from lime (calcium oxide) to calcium hydroxide. The temperatures should be compared to baseline values. Improper slaking can result in poor reagent reactivity and reduced acid gas collection efficiency.

Spray dryer absorber slurry flow rate and density monitor maintenance records

The calcium hydroxide slurry monitors generally consist of a magnetic flow meter and a nuclear density meter. Both of these are sensitive to scaling especially when slurry densities are high. The plant should have maintenance records for the monitors either in the form of completed work orders, a computerized maintenance record, an instrument maintenance log, or notes on the daily dry scrubbing operations log. The records should be reviewed for the previous 12 months whenever there is concern that there are periods of low slurry supply to the atomizer.

Spray dryer absorber inlet gas temperatures values during the previous 12 months

Dry scrubbing systems have a limited turndown capability due to the need for complete drying of the atomized slurry. Low gas inlet temperatures during periods of low combustion system load can cause poor drying of the droplets. The process control system is generally designed to block atomizer operation once inlet temperature drops below a preset value. The inlet gas temperature data should be reviewed to confirm that the controller is working properly, since operation under these conditions could lead to absorber vessel deposits and nonideal operation once loads increase.

Dry injection system feed rates during the past 12 months

The long term performance of the calcium hydroxide supply system should be checked if the emissions data indicates occasional emission excursions. (See earlier inspection step.) The feed rate data for the previous 12 months provided by the weigh belt feeder or the volumetric screw feeder should be compared against the combustion system loads and against the inlet acid gas concentration monitors (when available). The automatic control system should be able to vary calcium hydroxide (or other alkali) addition rates with load variations and inlet gas acid gas concentrations.

Calcium silicate/calcium hydroxide feed rates during the previous 12 months

The variability and reliability of the calcium silicate/calcium hydroxide dry injection system in the systems should be evaluated by reviewing the daily system operating logs. Some loss in acid gas collection efficiency could occur at low feed rates.

Dry injection system control device solids recycle rates

The recycle rates used in the semi-wet/dry type systems have some impact on the overall acid gas collection efficiency. Low recycle rates indicate slightly reduced acid gas collection efficiency.

3.3 Level 3 Inspection Procedures

The Level 3 inspection includes many inspection steps performed during Level 2 basic and Level 2 follow-up inspection procedures. These are described in earlier sections. The unique inspection steps of Level 3 inspections are described below.

Spray dryer absorber vessel dry bulb and wet bulb outlet gas temperatures

These measurements are taken if there is a significant question concerning the adequacy of the on-site gauges and if there are safe and convenient measurement ports between the absorber vessel and the particulate control device. The measurements should be made at several locations in the duct to ensure that the values observed are representative of actual conditions. The values should be averaged and compared with the value indicated by the on-site instruments (if operational) and with baseline data sets. It should be noted that it is rarely necessary to make this measurement since the on-site gauges are a critical part of the overall process control system for the dry scrubber system. Failure to maintain these instruments drastically increases the potential for absorber vessel wall deposits and increased emissions. These temperature monitors are normally very well maintained.

Spray dryer absorber vessel or dry injection system inlet gas temperature

This measurement is taken when the on-site gauge is not available, is malfunctioning, or is in a potentially nonrepresentative location. For spray dryers, the measurement should be taken in the main duct leading to the atomizer or in one or more of the ducts that lead to the gas dispersion system within the vessel. For dry injection systems, the measurement should be taken upstream of the gas stream/reagent mixing point. The measurements should be taken at several locations in the duct and averaged. Locations near air infiltration sites should be avoided.

3.4 Level 4 Inspection Procedures

The Level 4 inspection includes many inspection steps performed during Level 2/Level 3 inspections. These are described in earlier sections. The unique inspection steps of Level 4 inspections are described below.

Start-up and shut-down procedures

The start-up and shut-down procedures used at the plant should be discussed to confirm the following.

The plant has taken reasonable precautions to minimize the number of start-up/shut-down cycles.

The dry scrubber is operated in a reasonable time after start-up of the process equipment. Inspectors should remember that starting the atomizer (in spray dryer type systems) when the inlet gas temperatures are low can lead to absorber vessel deposits.

Possible locations for measurement ports

If the system does not have the necessary measurement ports to facilitate a Level 3 inspection, candidate sites should be identified. These should be in safe and convenient locations which do not disturb plant instruments or operations.

INSPECTION OF DRY SCRUBBERS
Level 4 Inspection Procedures

Potential dry scrubber system safety problems

Agency management personnel and/or senior inspectors should identify potential safety problems involved in standard Level 2/Level 3 inspections at this site. To the extent possible, the system owner/operators should eliminate these hazards. For those hazards which can not be eliminated, agency personnel should prepare notes on how future inspections should be limited and should prepare a list of the necessary personnel safety equipment. A partial list of common health and safety hazards include the following.

- Inhalation hazards due to fugitive leaks
- Corroded ductwork and particulate control devices
- Eye hazards due to alkali solids and slurries
- High voltage in control cabinets

Dry scrubber and process system flowchart

A relatively simple flowchart is very helpful in conducting a complete and effective Level 2/Level 3 inspection. This should be prepared by agency management personnel or senior inspectors during a Level 4 inspection. It should consist of a simple block diagram that includes the following elements.

- Source(s) of emissions controlled the system
- Location(s) of any fans and blowers used for gas movement and solids conveying
- Locations of any main stacks and bypass stacks
- Alkali preparation equipment, adsorber vessel or contactor, and particulate control device.
- Locations of major process instruments and gas stream continuous monitors

4. INSPECTION OF ELECTROSTATIC PRECIPITATORS

4.1 Inspection Summaries

4.1.1 Electrostatic Precipitator Inspection Overview

Stack Discharge

The average opacity and frequency of puffing are observed since these are a direct indications of particulate emissions and precipitator performance problems. Also, the visible emission limitations are separately enforceable regulatory limits.

Any symptoms of secondary plumes are noted during the visible emission observation. This is an indication of combustion problems and/or dry scrubbing system problems.

Transmissometer

Basic mechanical checks of the transmissometer are made prior to reviewing any of the present data.

The average opacity at the present time and immediately prior to the inspection is noted since it provides one index of the representativeness of the inspection.

Recorded data since the last inspection are reviewed since they provide a direct indication of the frequency and severity of particulate emission problems.

Electrostatic Precipitator

The field-by-field electrical operating conditions are carefully obtained and reviewed. These data provide an indirect indication of resistivity conditions and a direct indication of internal mechanical faults. The electrical conditions are compared against baseline data for the facility.

4.1.1 Electrostatic Precipitator Inspection Overview

Electrostatic Precipitators

Inlet and outlet gas temperature data are reviewed as one indicator of air infiltration into the system. Also, audible signs of air infiltration around the hoppers, access hatches, rapper seals, and expansion joints are noted. Air infiltration can lead to rapid and severe corrosion due to the hydrogen chloride, hydrogen fluoride, and calcium chloride present in the gas stream.

The general physical condition of the unit is observed during the inspection since this also indicates possible internal corrosion problems, solids build-up problems, and collection plate-wire frame misalignment problems.

The collection plate, discharge electrode frame, and gas distribution screen frame rappers are checked. Excessive rapping intensities can lead to rapping reentrainment due to the low-to-moderate resistivity range which often exists in the application. Rapper failures can lead to suppressed secondary currents and reduced particulate collection efficiency. The frequency of rapping in each field is compared with the frequency of routine spiking observed by the transmissometer.

The wire failure records are reviewed since they provide symptoms of internal problems and misguided maintenance.

4.1.2 Level 2 Inspection Procedures

4.1.2.1 Basic Level 2 Inspection Procedures

Stack
- Visible emissions for 6 to 30 minutes for each stack or discharge vent
- Duration and timing of puffing
- Presence of condensing plume

Transmissometer
- Double-pass transmissometer mechanical operating conditions
- Average opacity for at least the last 24 hours

Electrostatic Precipitator
- Transformer-rectifier set electrical data for each field (recorded in order from inlet field to outlet field)
- General physical condition

4.1.2.2 Follow-up Level 2 Inspection Procedures

Stack
- All elements of a Basic Level 2 inspection

Transmissometer
- All elements of a Basic Level 2 inspection

Electrostatic Precipitator
- Opacity strip charts/records and transformer rectifier set records (baseline files) since the last inspection
- Rapping frequency and intensity
  Inlet and outlet gas temperatures
- Wire failure rate and location records

4.1.2.3 Level 3 Inspections (Identical to Follow-up Level 2 Inspections)

4.1.2.4 Level 4 Inspections

Stack	o All elements of a Level 3 inspection
Transmissometer	o Adequacy of location
Electrostatic Precipitator	o All elements of a Level 2/Level 3 inspection o Start-up/shut-down procedures o Potential inspection safety problems o System flowchart

4.2 Basic Level 2 Inspection Procedures

Electrostatic precipitator visible emissions

If weather conditions permit, determine the precipitator effluent average opacity in accordance with U.S. EPA Method 9 procedures (or other required procedure). The observation should be conducted during routine process operation and should last 6 to 30 minutes for each stack and bypass. The majority of units operate with effluent average opacities less than 10% on a continuous basis. Higher opacities indicate emission problems.

The timing and duration of all significant spikes should be noted after the visible emission observation. This information will be useful in determining some of the possible causes of the spiking condition. Significant puffs at either a regular frequency or on a random basis are not normal. However, in some cases, light puffing can occur even when the operating conditions are optimal.

If weather conditions are poor, an attempt should still be made to determine if there are any visible emissions. The presence of a significant plume indicates emission problems. Do not attempt determine the "average opacity" at such times.

Condensing plume conditions

Condensing plume conditions in electrostatic precipitator systems serving municipal incinerators could be caused by sulfuric acid vapors, partially combusted organic vapors, and ammonium compounds (from NOx control systems).

The vaporous material condenses once the gas enters the cold ambient air. Condensing plumes usually have a bluish-white color. In some cases, the plume forms 5 to 10 feet after leaving the stack. Condensing plumes are more prevalent during cold weather or during periods of high ambient relative humidity.

Double-pass transmissometer physical conditions

Most precipitators have a transmissometer for the continuous monitoring of visible emissions. If a unit is present, and if it is in an accessible location, check the light source and retroreflector modules to confirm that these are in good working order. Check that the main fan is working and that there is a least one dust filter for the fan. On many commercial models it is also possible to check the instrument alignment without adjusting the instrument. Note: On some models, moving the dial to the alignment check position will cause an alarm in the control room. This is to be moved only by plant personnel and only when it will not disrupt plant operations.

Double-pass transmissometer data

If the transmissometer appears to be working properly, evaluate the average opacity data for at least the previous 24 hours prior to the inspection. If possible, the average opacity data for selected days since the last inspection should also be reviewed. This evaluation is helpful in confirming that the units being inspected are operating in a representative fashion. If a unit is working better during the inspection than during other periods, it may be advisable to conduct an unscheduled inspection in the future.

As part of the review of average opacity, scan the data to determine the frequency of emission problems and to evaluate how rapidly the operators are able to recognize and eliminate the condition.

Transformer-rectifier set electrical data

The first step in evaluating the transformer-rectifier (T-R) set electrical data is to obtain or prepare a sketch that indicates the arrangement of the T-R sets on the precipitator. This drawing should indicate the number of chambers in the precipitator and the number of T-R sets in series in each chamber. The T-R set numbers should be included on the sketch.

Transformer-rectifier set electrical data

For each chamber, the T-R set electrical data are recorded starting with the inlet field and proceeding to the outlet field. In some cases, the control cabinets are scrambled. The following data should be recorded.

	Primary Voltage (Volts)	Primary Current (Amps)	Secondary Voltage (Kilovolts)	Secondary Current (Millamps)	Spark Rate (No./Min.)
Inlet Field	_____	_____	_____	_____	_____
Second Field	_____	_____	_____	_____	_____
. . .					
nth Field	_____	_____	_____	_____	_____

The voltages and currents should be recorded when the appropriate gauge reaches the highest stable value for approximately one second or more.

If there is any question about the adequacy of the spark rate meter, the spark rate should be determined by counting the number of fluctuations of the primary voltage and/or secondary voltage meters.

Transformer-rectifier set electrical data

Compare the secondary and/or primary voltages against baseline levels for this unit and against typical values. Generally, the primary voltages are above 250 volts and they are usually in the range of 250 to 380 volts (A.C.). The secondary voltages are normally in the range of 20 to 45 kilovolts (D.C). A drop in the primary voltage of 30 volts (A.C.) or a drop in the secondary voltage of 5 kilovolts (D.C.) in a given field indicates significantly reduced particulate control capability for that field.

To check the particle resistivity conditions, plot the voltages, currents, and spark rates for each of the chambers (Figure 4-3). Compare these drawings with similar drawings prepared from baseline data. There has probably been a significant shift in the particle resistivity if all or most of the fields in a chamber have shifted in the the same direction at approximately the same time (outlet fields often lag several hours behind). The symptoms of resistivity shifts are summarized below.

Higher resistivity
- Reduced primary or secondary voltages
- Reduced primary or secondary currents
- Increased spark rates

Lower resistivity
- Reduced primary or secondary voltages
- Increased primary or secondary currents
- Decreased spark rates

In some units, the resistivity conditions in one chamber are quite different from the resistivity conditions in other adjacent chambers. In these types of units, the changes in the secondary voltages and currents are much greater in some of the chambers. This condition is often caused by slight differences in the flue gas temperatures entering the various chambers.

Precipitator general physical condition

While walking around the precipitator and its inlet and outlet ductwork, check for obvious corrosion around the potential "cold" spots such as the corners of the hoppers, near the solids discharge valve, and the access hatches. On negative pressure units, check for audible air infiltration through the corroded areas, warped access hatches, eroded solids discharge valves, or other sites. On positive pressure units, check for fugitive emissions of dust from any corroded areas of the system.

Rapper systems

The collection plate, discharge electrode, and gas distribution screen rapping systems are evaluated when low power inputs are observed in one or more fields or when there is puffing.

Note any rappers that do not appear to be working or that do not sound proper when activating. A sketch is often a useful way to summarize this information.

Request that plant personnel, if they are qualified, open the rapper control cabinets. Compare the present rapper system intensities with the baseline values.

- If the intensities are now higher, the unit may have high resistivity dusts, binding or broken rapper shaft connections, or poor start-up procedures. It should be noted that it is rarely possible to minimize high resistivity dust problems simply by increasing rapper intensities and that some rapper shaft and/or collection plate alignment problems can occur at high intensities.

- If the intensities are now much lower, the unit may have low resistivity dusts, or the rappers may have been temporarily turned down to minimize obvious puffing.

Determine the activition frequency of the various groups of rappers. This can often be done by watching selected groups of rappers for a period of 10 to 60 minutes. It can also be determined by checking the timers in the control cabinets. However, the indicated rapper frequencies on the timers are not always reliable. Compare the activation frequencies with the observed frequency of puffing.

- If the activation frequency is high, the unit may be having problems with high resistivity dust. It is rarely possible to minimize this condition simply by increasing rapper frequency.

Rapper systems

- If the activation frequency is low, the unit may have lower resistivity dust than during the baseline period. As long as the electrical conditions and the opacity are acceptable, low frequency is desirable.
- Puffing is often related to the activation frequency of the outlet field collection plate rappers.
- Note any occasions when more than one rapper is activated simultaneously or when two or more rappers are activated within a period of several seconds.

Opacity strip charts/records and the transformer-rectifier set records (baseline files)

This is a time consuming portion of the inspection. It should be done only when the plant is experiencing frequent and significant excess emission problems and there is some question concerning the proposed corrective actions.

Obtain the opacity records and quickly scan the data for the previous 1 to 12 months to determine time periods that had especially high and especially low average opacities. Time periods with and without severe spiking are also of interest. Select the precipitator operating logs and the process operating logs that correspond with the times of the opacity strip charts/records selected. Compare the precipitator operating data and process operating data against baseline information to identify the general category of problem(s) causing the excess emission incidents. Evaluate the source's proposed corrective actions to minimize the problem(s) in the future.

Wire failure and location records

Request the discharge wire failure records from the operators if it appears that wire failures have caused temporary outages of one or more fields since the last inspection. If specific wire failure records are not maintained, attempt to determine how many wires have failed since the last inspection. Most electrostatic precipitors operate with wire failure rates that are much less than 1 per month. Higher failure rates may indicate plate-wire misalignment, clearance problems, improper rapping operation, inadequate wire tension, and/or corrosion. Wire failure is often a symptom of other more substantial problems.

Evaluate the owner/operators' plan for minimizing excess emission incidents caused by wire failure. It is generally necessary to fix the underlying cause of the failures rather than simply reinstalling wires.

Inlet and outlet gas temperatures

The locations of inlet and outlet gas temperature monitors should first be identified. Data from these instruments is normally available in the main control room for the incinerator. The data during the inspection should be obtained. Furthermore, temperture records since the last inspection should be reviewed.

There should not be a significant drop in gas temperature while passing through the unit. Typical temperature drops are in the range of 25 to 50°F depending on the adequacy of the precipitator insulation, the ambient temperature, and the ambient wind speed. Increases in the temperature drop as compared to baseline data provide a strong indication of possible air infiltration and future problems with corrosion, wire failure, insulator leakage, hopper overflow, and collection plate misalignment.

Evaluate inlet and outlet gas temperatures.

The inlet temperature data should be reviewed to determine if there have been any high temperature excursions. These may have exceeded the thermal expansion capability of the precipitator electrodes and caused severe misalignment of the collection plates. This causes a significant decrease in the operating voltages and a major increase in particulate emissions.

4.3 Level 3 Inspection Procedures

These are identical to Level 2 inspection procedures since portable inspection instruments are not used for precipitators.

4.4 Level 4 Inspection Procedures

The Level 4 inspection includes all the inspection steps performed during Level 2/Level 3 inspections. These are described in earlier sections. The inspection steps unique to Level 4 inspections are described below.

Start-up and shut-down procedures

The start-up and shut-down procedures used at the plant should be discussed to confirm the following.

The plant has taken reasonable precautions to minimize the number of start-up/shut-down cycles.

The precipitator is energized in a reasonable time after start-up of the process equipment. Inspectors should remember that energizing too early in the start-up process can lead to precipitator explosions or to deposits on the collection plates that reduce performance.

Potential safety problems

Agency management personnel and/or senior inspectors should identify potential safety problems involved in standard Level 2/Level 3 inspections at this site. For those hazards which can not be eliminated, agency personnel should prepare notes on how future inspections should be limited and should prepare a list of the necessary personnel safety equipment. A partial list of common health and safety hazards include the following:

Inhalation hazards due to fugitive leaks from inlet breechings, access hatches, hoppers, the outlet contraction section, and fans

Corroded precipitator roofs and ladder supports

Ungrounded rappers

High voltage in control cabinets

System flowchart

A relatively simple flowchart is very helpful in conducting a complete and effective Level 2/Level 3 inspection. This should be prepared by agency management personnel or senior inspectors during a Level 4 inspection. It should consist of a simple block diagram that includes the following elements.

Source(s) of emissions controlled by a single precipitator

Location(s) of any fans used for gas movement through the system (used to evaluate inhalation problems due to positive static pressures and air infiltration problems)

Locations of any main stacks and bypass stacks

Layout and identification numbers of transformer-rectifier sets used in all chambers

Locations of major instruments (transmissometers, thermocouples)

5. INSPECTION OF FABRIC FILTERS

5.1 Inspection Summaries

5.1.1 Fabric Filter Inspection Overview

Stack	Observe the average opacity and puffing conditions as a direct indication of fabric filter performance.
	Observe any secondary plume conditions since these indicate a serious combustion problem and/or dry scrubbing problem.
Transmissometer	Evaluate transmissometer physical condition prior to reviewing opacity data.
	Observe average opacity (transmissometer data) at the present time and for the last 8 hours to determine the representativeness of the inspection period.
	Review average opacity records since the last inspection to determine the frequency and severity of excess emission problems.
Fabric Filter	Evaluate baghouse pressure drop as an indirect indication of bag blinding problems, bag cleaning problems, and gas flow changes.
	Observe baghouse physical condition as an indirect indication of corrosion and air infiltration.
	Evaluate present inlet gas temperature to confirm that it does not exceed the high temperature limitations of the fabric being used. Review inlet gas temperature records since the last inspection to determine frequency and severity of gas temperature excursions.

Fabric Filter	Evaluate fabric filter outlet gas temperatures as an indication of air infiltration and possible fabric chemical attack. The outlet temperature should be at least 20°F above the acid dewpoint. The gas temperature drop across the baghouse should be only 20 to 50°F depend ing on ambient temperature, ambient wind speed, and the adequacy of insulation.
	Listen for audible air infiltration around access hatches, hoppers, and expansion joints.
	Evaluate cleaning system operation to confirm that the bags are being cleaned at a regular frequency and to identify any bag problems possible due to nonideal cleaning.
	Observe clean side conditions on units in which one or more compartments can be isolated. Solids deposits are an indication of emission problems. Physical condition of the bags and other components are also observed to the extent possible without entering the baghouse.
	Review bag failure rate and location records as a indirect indication of baghouse excess emission problems.
	Perform or observe "rip" tests as a rough indicator of the reasons for frequent bag failures.
	Observe cage conditions (pulse jet only) to evaluate bag failures.
	Determine number of start-up/shut-down cycles and the number of hours that the baghouse bypass was necessary.

5.1.2 Inspection Checklists

5.1.2.1 Basic Level 2 Inspection Points

Stack	o Visible emissions for 6 to 30 minutes for each stack or discharge vent o Presence of condensing plume
Trans-missometer	o Double-pass transmissometer conditions o Double-pass transmissometer data
Pulse Jet Baghouses	o Static pressure drop o Clean side conditions o General physical condition
Reverse Air Baghouses	o Static pressure drop o Compartment static pressure drops, during cleaning o Clean side conditions o General physical condition

5.1.2.2 Follow-up Level 2 Inspections

Stack	o All elements of a Basic Level 2 inspection
Transmissometer	o All elements of a Basic Level 2 inspection
Pulse Jet Baghouses	o Compressed air cleaning system operation o Bag failure rate and location records o Present baghouse inlet gas temperature o Baghouse inlet gas temperature records o Bag "rip" tests and laboratory analyses o Cage characteristics
Reverse Air Baghouses	o Reverse air fan operation o Cleaning system equipment controller o Bag failure rate and location records o Present baghouse inlet gas temperature o Baghouse inlet gas temperature records o Bag "rip" tests and laboratory analyses

5.1.2.3 Level 3 Inspection Checklist

Stack	o All elements of a Basic Level 2 inspection
Transmissometer	o All elements of a Basic Level 2 inspection
Pulse Jet Baghouses	o All elements of a Follow-up Level 2 inspection o Measure baghouse static pressure drop o Measure inlet and outlet gas temperatures o Measure inlet and outlet gas oxygen content
Reverse Air	o All elements of a Follow-up Level 2 inspection o Measure static pressure drop o Measure compartment static pressure drops during cleaning o Measure inlet and outlet gas temperatures o Measure inlet and outlet gas oxygen content

5.1.2.4 Level 4 Inspection Checklist

Stack	o All elements of a Basic Level 2 inspection
Transmissometer	o All elements of a Basic Level 2 inspection
Baghouse (Both Types)	o All elements of a Follow-up Level 2 inspection o Flowchart of compressed air supply (Pulse jet fabric filters only) o Start-up/shut-down procedures o Locations for measurement ports o Potential inspection safety problems o System flowchart

5.2 Level 2 Inspections

5.2.1 Basic Level 2 Inspection Procedures

Baghouse visible emissions

If weather conditions permit, determine baghouse effluent average opacity in accordance with U.S. EPA Method 9 procedures (or other required procedure). The observation should be conducted during routine process operation and should last 6 to 30 minutes. Fabric filters generally operate with an average opacity less than 5%. Higher opacities indicate baghouse emission problems.

Some large, multi-compartment pulse jet baghouses have separate stacks for each compartment. Long term visible emission observations on each of these stacks should be made only when the baghouse is suffering major emission problems.

If weather conditions are poor, an attempt should still be made to determine whether there are any visible emissions. Do not attempt to determine "average opacity" during adverse weather conditions. The presence of a noticeable plume generally indicates baghouse operating problems.

Puffing conditions (PULSE JET UNITS ONLY)

Evaluate the frequency and severity of puffs. These are often caused by small holes in one or more rows of bags.

Condensing plume conditions

Condensing plume conditions in fabric filter systems serving municipal incinerators could conceivably be caused by partially combusted organic vapors, sulfuric acid vapors, or ammonium compounds. The vaporous material condenses once the gas enters the cold ambient air. Condensing plumes usually have a bluish-white color. In some cases, the plume forms 5 to 10 feet after leaving the stack. If the baghouse operating temperature drops substantially, this material can condense inside the baghouse and cause fabric blinding problems. Corrective actions must focus on the incinerator or dry scrubber system.

Double-pass transmissometer physical conditions

If a transmissometer is present, and if it is in an accessible location, check the light source and retroreflector modules to confirm that these are in good working order. Check that the main fan is working and that there is a least one dust filter for the fan. On many commercial models, it is also possible to check the instrument alignment without adjusting the instrument. Note: On some models, moving the dial to the alignment check position will cause an alarm in the control room. This is to be moved only by plant personnel and only when it will not disrupt plant operations.

Some fabric filters have one or more single pass transmissometers on outlet ducts. While these can provide some useful information to the system operators, these instruments do not provide data relevant to the inspection.

Double-pass transmissometer data

Evaluate the average opacity data for selected days since the last inspection, if the transmissometer appears to be working properly. Determine the frequency of emission problems and evaluate how rapidly the baghouse operators are able to recognize and eliminate the conditions.

Baghouse static pressure drop

The baghouse static pressure drop should be recorded if the gauge appears to be working properly. The gauge "face" should be clear of obvious water and deposits. The gauge should fluctuate slightly each time one of the diaphragm valves activates. These valves can be heard easily when close to the pulse jet baghouse. If there is any question about the gauge, ask plant personnel to disconnect each line one at a time to check if the gauge responds. If it does not move when a line is disconnected, the line may be plugged.

Fabric filters operate with a wide range of static pressure drops (2 to 12 inches W.C.). It is preferable to compare the present readings with the baseline values for this specific source. Increased static pressure drops generally indicate high gas flow rates, and/or fabric blinding, and/or system cleaning problems. Lower static pressure drops are generally due to reduced gas flow rates, excessive cleaning intensities/frequencies, or reduced inlet particulate loadings.

Baghouse general physical conditions

While walking around the baghouse and its inlet and outlet ductwork, check for obvious corrosion around the potential "cold" spots such as the corners of the hoppers, near the solids discharge valve, and the access hatches. On negative pressure baghouses, check for any audible air infiltration through the corroded areas, warped access hatches, eroded solids discharge valves, or other sites. On positive pressure baghouses, check for fugitive emissions of dust from any corroded areas of the system.

Clean side conditions

If there is any question about the performance of the baghouse, request that plant personnel open one or more hatches on the clean side (not available on some commercial models). Note the presence of any fresh dust deposits more than 1/8" deep since this indicates particulate emission problems.

In the case of pulse jet fabric filters, also observe the conditions of the bags, cages, and compressed air delivery tubes. The compressed air delivery tubes should be oriented directly into the bags so that the sides of the bags are not subjected to the blast of cleaning air. The cages and bags should be securely sealed to the tube sheet in units where the bag comes up through the tube sheet. There should be no oily or crusty deposits at the top of the bags due to oil in the compressed air line.

In reverse air units, also observe the bag tension and condition of the bag attachments at the tube sheet. The bags should have noticeable tension in the vertical direction (some inward deflection of the bags is normal when a compartment is isolated). The majority of bag problems generally occur within the bottom 1 to 2 feet of the bags in both types of baghouses. Regulatory agency inspectors should observe conditions from the access hatches and should not enter the compartments under any circumstances.

In some cases, operators will be unable to isolate any compartments without causing major gas flow problems with the incinerator and/or the dry scrubber. Obviously, the request to check clean side conditions should be withdrawn under such circumstances.

5.2.2 Follow-up Inspection Points for Level 2 Inspections

Compressed air cleaning system (PULSE JET BAGHOUSES)

The purpose of checking the compressed air cleaning system is to determine if this contributes to a significant shift in the baghouse static pressure drop and/or if this contributes to an excess emission problem. The inspection procedures for the compressed air cleaning system can include one or more of the following.

Record the compressed air pressure if the gauge appears to be working properly. It should fluctuate slightly each time a diaphragm valve is activated. Do not remove this gauge since the compressed air lines and manifold have high pressure air inside.

Listen for operating diaphragm valves. If none are heard over a 10 to 30 minute time period, the cleaning system controller may not be operating.

Check the compressed air shutoff valve to confirm that the line is open.

Count the number of diaphragm valves that do not activate during a cleaning sequence. This can be done by simply listening for diaphragm valve operation. Alternatively, the puff of compressed air released from the trigger lines can sometimes be felt at the solenoid valve (pilot valve) outlet.

Check for the presence of a compressed air drier. This removes water which can freeze at the inlet of the diaphragm valves. Also check for compressed air oil filter.

Check for a drain on the compressed air supply pipe or on the air manifold. This is helpful for routinely draining the condensed water and oil in the manifold.

Operation of reverse air fan (REVERSE AIR BAGHOUSES)

Confirm that the reverse air fan is operating by noting that the fan shaft is rotating. This fan is usually located near the top of the baghouse.

Operation of cleaning equipment controllers (REVERSE AIR AND SOME MULTI-COMPARTMENT PULSE JET UNITS)

Observe the baghouse control panel during cleaning of one or more compartments to confirm that the controller is operating properly. Each compartment should be isolated for cleaning before the static pressure drop increases to very high levels that preclude adequate gas flow. Also, cleaning should not be so frequent that the bags do not build-up an adequate dust cake to ensure high efficiency filtration.

Operation of cleaning equipment controllers (REVERSE AIR AND SOME MULTI-COMPARTMENT PULSE JET UNITS)

It is generally good practice to allow a short "null" period of between 5 and 30 seconds between the time a compartment is isolated and the time that reverse air flow begins. This reduces the flexing wear on the fabric. It is also good practice to have a "null" period of 15 to 60 seconds following cleaning to allow fine dust to settle out of the bags prior to returning to filtering mode.

Present baghouse inlet gas temperature

The primary purpose of determining the present gas inlet temperature is to evaluate possible excess emission problems and/or high bag failure rate conditions that can be caused by very high or very low gas inlet temperatures. Locate any on-site thermocouples mounted on the inlet to the baghouse. If this instrument appears to be in a representative position, record the temperature value displayed in the control room.

Present baghouse inlet gas temperature

The average inlet gas temperature should be 25 to 50 °F below the maximum rated temperature limit of the fabric. Fifteen to thirty minute spikes of less than 25 °F above the maximum rated limit can usually be tolerated without fabric damage.

The average inlet gas temperature should be 25 to 50 °F above the acid gas dewpoint temperature. For most commercial combustion processes, the acid dewpoint is usually between 225 to 300 °F. The inlet gas temperature should also be above the water vapor dewpoint.

Baghouse gas temperature records

The purpose of reviewing continuous temperature recorder data is to determine if temperature excursions contribute to excess emission problems and/or high bag failure rates. Review selected strip charts to determine if the gas inlet temperatures have been above the maximum rated fabric temperature or below the acid vapor or water vapor dewpoints.

Fabric "rip" test and fabric laboratory analyses

The purpose of evaluating fabric condition is to determine if any corrective actions planned by the owner/operators have a reasonable probability of reducing frequent excess emissions.

To perform a "rip" test, ask the plant personnel for a bag that has been recently removed from the baghouse. Attempt to rip the bag near the site of the bag hole or tear. If the bag can not be ripped easily, then the probable cause of the failure is abrasion and/or flex damage. These bags can usually be patched and reinstalled. If the bag can be ripped easily, then the fabric has been weakened by chemical attack or high temperature damage. Weakened bags should not be patched and reinstalled. It may be necessary to install new bags throughout the entire chamber if the bag failure rates are high.

Bag failure records

The purpose of reviewing bag failure records is to determine the present bag failure rate and to determine if the rate of failure is increasing. Plot the number of bag failures per month for the last 6 to 24 months. If there has been a sudden increase, the owner/operators should consider replacing all of the bags in the compartment(s) affected. If there is a distinct spatial pattern to the failures, the owner/operators should consider repair and/or modification of the internal conditions causing the failures.

Bag cages (PULSE JET FABRIC FILTERS)

The bag cages are evaluated whenever there are frequent abrasion/flex failures at the bottoms of the bags or along the ribs of the cage. Ask the plant personnel to provide a spare cage for examination. There should be adequate support for the bag and there should not be any sharp edges along the bottom cups of the cage. Also check the cages for bows that would cause rubbing between two bags at the bottom of the baghouse.

5.3 Level 3 Inspection Procedures

Procedures for measurement of reverse fabric filter system o ing conditions are described below. Other observat to be completed as part of the Level 3 inspecti identical to those included in the basic and foll Level 2 inspection. See the Level 2 inspectic cedures section for a discussion of these steps.

<u>Baghouse static pressure drop</u>

The static pressure drop provides an indication of gas flow rate changes (changes in actual gas-to-cloth ratio), fabric blinding, and cleaning system problems. The steps in measuring the static pressure drop are described below.

Locate safe and convenient measurement ports on the inlet and outlet ductwork or on the baghouse shell. In some cases it may be possible to temporarily disconnect the on-site gauge in order to use the portable gauge. Under no circumstances should on-site plant instruments be disconnected without the explicit approval of responsible plant personnel. Also, instruments connected to pressure transducers should not be disconnected.

Clean any deposits out of the measurement ports.

If the inlet and outlet ports are close together, connect both sides of the static pressure gauge to the ports and observe the static pressure for 1 to 5 minutes.

If the ports are not close together, measure the static pressure in one port for 10 to 30 seconds and then proceed to the other port for 10 to 30 seconds. As long as the static pressure drop is stable the two values can be subtracted to determine the static pressure drop.

<u>Inlet and outlet gas temperatures</u>

These measurements are conducted whenever it is necessary to determine if air infiltration is causing fabric chemical attack due to reduced gas outlet temperatures. It is also helpful to measure the inlet gas temperature to evaluate the potential for high gas temperature damage to the bags. The steps in measuring the gas temperature are outlined below

Locate safe and convenient measurement ports on the inlet and outlet ductwork of the collector. Often small ports less than 1/4" diameter are adequate. Measurements using ports on the baghouse shell are often inadequate since moderately cool gas is trapped against the shell.

Attach a grounding/bonding cable to the probe if vapor, gas, and/or particulate levels are potentially explosive.

Seal the temperature probe in the port to avoid any air infiltration.

Measure the gas temperature at a position near the middle of the duct, if possible. Conduct the measurement for several minutes to ensure a representative reading.

Measure the gas temperature at another port and compare the values. On combustion sources, a gas temperature drop of more than 20 to 40°F indicates severe air infiltration.

Compare the inlet gas temperature with the maximum rated temperature limit of the fabric present. If the average gas temperature is within 25 to 50°F of the maximum, short bag life and frequent bag failures are possible. Also, if there are short term excursions more than 25 to 50°F above the maximum temperature limits, irreversible fabric damage may occur.

Inlet and outlet gas oxygen levels

These measurements are performed to further evaluate the extent of air infiltration. An increase of more than 1% oxygen going from the inlet to the outlet indicates severe air infiltration (e.g. inlet oxygen at 6.5% and outlet oxygen at 7.5%). The steps involved in measuring the flue gas oxygen levels are itemized below.

Locate safe and convenient measurement ports. Generally, the ports used for the temperature measurements are adequate for the oxygen measurements.

Attach a grounding/bonding cable to the probe if there are potentially explosive vapors, gases, and/or particulate.

Seal the port to prevent any ambient air infiltration around the probe.

Measure the oxygen concentration at a position near the center of the duct to avoid false readings due to localized air infiltration. The measurement should be repeated twice in the case of gas absorption instruments. For continuous monitoring instruments, the measurement should be conducted for 1 to 5 minutes to ensure a representative value.

If possible, measure the carbon dioxide concentration at the same locations. The sum of the oxygen and carbon dioxide concentrations should be in the normal stoichiometric range for the fuel being burned (a sum of 18 to 22%). If the sum is not in this range, a measurement error has occurred.

As soon as possible, complete the measurements at the other port. Compare the oxygen readings obtained. If the outlet values are substantially higher, severe air infiltration is occurring.

5.4 Level 4 Inspection Procedures

The Level 4 inspection includes many inspection steps performed during Level 2 and 3 inspections. These are described in earlier sections. The unique inspection steps of Level 4 inspections are described below.

Flowchart of the compressed air system (PULSE JET FABRIC FILTERS)

The purpose of the flowchart is to indicate the presence of compressed air system components that could influence the vulnerability of the pulse jet baghouse to bag cleaning problems. The flowchart should consist of a simple block diagram showing the following components.

- Source of compressed air (plant air or compressor)
- Air drier (if present)
- Oil filter (if present)
- Main shutoff valve(s)
- Compressed air manifolds on baghouse
- Drains for manifolds and compressed air lines
- Heaters for compressed air lines and manifolds
- Controllers for pilot valves (timers or pneumatic sensors)

Locations for measurement ports

Many existing fabric filters do not have convenient and safe ports that can be used for static pressure, gas temperature, and gas oxygen measurements. One purpose of the Level 4 inspection is to select (with the assistance of plant personnel) locations for ports to be installed at a later date to facilitate Level 3 inspections. Information regarding possible sample port locations is provided in the U.S. EPA Publication titled, " Preferred Measurement Ports for Air Pollution Control Systems", EPA 340/1-86-034.

Start-up and shut-down procedures

The start-up and shut-down procedures used at the plant should be discussed to confirm the following.

- The plant has taken reasonable precautions to minimize the number of start-up/shut-down cycles.
- The baghouse system bypass times have been minimized.
- The baghouse system bypass times have not been limited to the extent that irreversible damage has not occurred.

Potential safety problems

Agency management personnel and/or senior inspectors should identify any potential safety problems involved in standard Level 2 or Level 3 inspections at this site. To the extent possible, the system owner/operators should eliminate these hazards. For those hazards that can not be eliminated, agency personnel should prepare notes on how future inspections should be limited and should prepare a list of the necessary personal safety equipment. A partial list of common health and safety hazards includes the following.

- Inhalation hazards due to low stack discharge points
- Weak catwalk and ladder supports
- Hot baghouse roof surfaces
- Compressed air gauges in close proximity to rotating equipment or hot surfaces
- Fugitive emissions from baghouse system
- Inhalation hazards from adjacent stacks and vents Access to system components only available by means of weak roofs or catwalks

System Flowchart

A relatively simple flowchart is very helpful in conducting a complete and effective Level 2 or Level 3 inspection. This should be prepared by agency management personnel or senior inspectors during a Level 4 inspection. It consists of a simple block diagram that includes the following elements.

- Source(s) of emissions controlled by a single baghouse
- Location(s) of any fans used for gas movement through the system (used to evaluate inhalation problems due to positive static pressures)
- Locations of any main stacks and bypass stacks
- Location of baghouse
- Locations of major instruments (transmissometers, static pressure gauges, thermocouples)

6. INSPECTION OF WET SCRUBBERS

6.1 Wet Scrubber Inspection Summaries

6.1.1 Wet Scrubber Inspection Overview

Stack	Average opacity of the residual plume is observed since this provides an indication of particulate matter penetration and vapor condensation in the scrubber.
	Short term variations in residual opacity are an indication of variations in combustion conditions.
	Obvious mist reentrainment is a clear indication of demister failure.
Induced Draft Fan	Inspectors must remain aware of severely vibrating fans downstream from wet scrubbers. The inspection is terminated immediately when this is noticed.
Scrubber	Static pressure drop across the scrubber is used as an indirect indicator of the particulate removal effectiveness. The present value is compared with baseline values to determine if there has been a significant pressure drop decrease.
	Scrubber static pressure drop records for the time since the last inspection are reviewed to identify any operating periods with low pressure drops.
	Scrubber vessel general physical condition is observed during the walkaround inspection to identify any obvious physical conditions which could threaten the compliance status of the unit in the immediate future.

6.1.2 Wet Scrubber Inspection Checklists

6.1.2.1 Basic Level 2 Inspection Checklist

Stack
- Visible emissions for 6 to 30 minutes for each stack or discharge vent
- Minimum and maximum short term opacities due to process cycles
- Droplet reentrainment

Induced Draft Fan
- Obvious severe vibration

Scrubber Vessels

Spray Tower Scrubbers
- Inlet liquor pressure
- General physical condition

Packed Bed Scrubbers
- Static pressure change
- Liquor turbidity
- General physical condition

Venturi Scrubbers
- Static pressure change
- General physical condition

6.1.2.2 Follow-up Level 2 Inspection Checklist

Stack
- All elements of a Basic Level 2 inspection

Fan
- Obvious severe vibration
  Fan motor currents

Scrubber Vessels

Spray Tower Scrubbers
- Gas flow rate
- Liquor turbidity
- Liquor distribution from nozzles
- Demister condition

Packed Bed Scrubbers
- Liquor pH
- Liquor recirculation flow rate
- Scrubber gas flow rate

Venturi Scrubbers
- Liquor pH
- Liquor turbidity
- Liquor recirculation rate
- Scrubber gas flow rate
- Venturi scrubber adjustable throat mechanism condition
- Demister condition

6.1.2.3 Level 3 Inspections

Stack
- All elements of a Basic Level 2 inspection

Fan
- Obvious severe vibration
- Fan motor currents

Scrubber Vessels

Spray Tower Scrubbers
- Gas flow rate from scrubber
- Liquor pH
- Outlet gas temperature

Packed Bed Scrubbers
- Static pressure change
- Gas flow rate from scrubber
- Outlet liquor pH
- Outlet gas temperature

Venturi Scrubbers
- Static pressure change
- Gas flow rate from scrubber
- Outlet liquor pH
- Outlet gas temperature

6.1.2.4 Level 4 Inspections

Stack
- All elements of a Basic Level 2 inspection

Fan
- Obvious severe vibration
- Fan motor currents

Scrubber Vessel (All Types)
- All elements of a Level 3 inspection
- Locations for measurement ports
- Potential inspection safety problems
- System flowchart

6.2 Level 2 Inspection Procedures

Wet scrubber visible emissions

If weather conditions permit, determine the wet scrubber effluent average opacity in accordance with U.S. EPA Method 9 procedures (or other required procedure). The observation should be conducted during routine process operation and should last 6 to 30 minutes for each stack and bypass vent. The observation should be made after the water droplets contained in the plume vaporize (where the steam plume "breaks") or at the stack discharge if there is no steam plume present. The presence of a particulate plume greater than 10% opacity generally indicates a scrubber operating problem, and/or the generation of high concentrations of submicron particles in the process, and/or the presence of high concentrations of vaporous material in the effluent gas stream.

In addition to evaluating the average opacity, inspectors should scan the visible emission observation to identify the maximum and minimum short term opacities. This is especially useful information if there are variations in the incinerator operating condition during charging, soot blowing, or other cyclic activity. The differences in the minimum and maximum opacities provides an indication of changing particle size distributions.

If weather conditions are poor, an attempt should still be made to determine if there are or are not any visible emissions. Do not attempt to determine "average opacity" during adverse weather conditions. The presence of a noticeable plume indicates wet scrubber operating problems.

Induced Draft Fan Vibration

If the fan downstream of the scrubber vessel is vibrating severely, the inspection should be terminated at once and responsible plant personnel should be advised of the condition. Fans can disintegrate due to fan wheel corrosion, fan wheel solids build-up, bearing failure, and operation in an unstable aerodynamic range. All of these are possible downstream of a wet scrubber. Shrapnel from the disintegrating fan can cause fatal injuries.

Droplet reentrainment

Droplet reentrainment indicates a significant demister problem which can create a local nuisance and which can affect stack sampling results. The presence of droplet reentrainment is indicated by the conditions listed below.

- Obvious rainout of droplets in the immediate vicinity of the stack
- Moisture and stains on adjacent support columns, tanks, and stacks
- Mud lip around the stack discharge

<u>Wet scrubber static pressure drop</u>

The wet scrubber static pressure drop should be recorded if the gauge appears to be working properly. The following items should be checked to confirm the adequacy of the on-site gauge.

> The gauge "face" should be clear of obvious water and deposits.

> The lines leading to the inlet and outlet of the scrubber appear to be intact.

If there is any question concerning the gauge, ask plant personnel to disconnect each line one at a time to see if the gauge responds. If it does not move when a line is disconnected, the line may be plugged or the gauge is inoperable. Note: The lines should only be disconnected by plant personnel and only when this will not affect plant operations.

Wet scrubber systems operate with a wide range of static pressure drops as indicated in the list below (data not provided for spray tower scrubbers since static pressure drop is not an useful inspection parameter for this type of unit).

Packed bed	2 to 6 inches W.C.
Venturi	10 to 40 inches W.C.

Wet scrubber static pressure drop

It should also be noted that there is a wide range of required static pressure drops for identical wet scrubbers operating on similar industrial processes due to the differences in particle size distributions. For these reasons, it is preferable to compare the present readings with the baseline values for this specific source.

Increased static pressure drops generally indicate the following possible condition(s).

Packed bed scrubbers	o High gas flow rates o Partial bed pluggage
Venturi scrubbers	o High gas flow rates o High liquor flow rates o Constricted venturi throats

Decreased static pressure drops generally indicate the following possible condition(s).

Packed bed scrubbers	o Low gas flow rates o Bed collapse
Venturi scrubbers	o Low gas flow rates o Low liquor flow rates o Eroded venturi dampers o Increased venturi throat openings

Liquor inlet pressure

The pressure of the header which supplies the scrubber spray nozzle can provide an indirect indication of the liquor flow rate and the nozzle condition. When the present value is lower than the baseline value(s) the liquor flow rate has increased and there is a possibility of nozzle orifice erosion. Conversely, if the present value is higher than the baseline value(s) the liquor flow rate has decreased and nozzle and/or header pluggage is possible.

Unfortunately, these pressure gauges are very vulnerable to error due to solids deposits and due to corrosion. It is also difficult to confirm that they are working properly. For these reasons, other indicators of low liquor flow such as the pump discharge pressure and the outlet gas temperature should be checked whenever low header or pipe pressures are observed.

Wet scrubber system general physical conditions

While walking around the wet scrubber system and its inlet and outlet ductwork, check for obvious corrosion and erosion. If any material damage is evident, check for fugitive emissions (positive pressure systems) or air infiltration (negative pressure systems). Avoid inhalation hazards and walking hazards while checking the scrubber system general physical condition. Prepare a sketch showing the locations of the corrosion and/or erosion damage. In addition to corrosion and erosion, inspectors should also check for any of the conditions listed below.

- Cracked or worn ductwork expansion joints
- Obviously sagging piping
- Pipes which can not be drained and/or flushed

Liquor turbidity

Ask a responsible and experienced plant representative to obtain a sample of the liquor entering the scrubber vessel. This can usually be obtained at a sample tap downstream from the main recirculation pump. The agency inspector should provide a clear sample bottle. Observe the turbidity of the liquor for a few seconds immediately after the sample is taken. The turbidity should be qualitatively evaluated as: clear, very light, light, moderate, heavy, or very heavy.

6.2.2 Follow-up Level 2 Inspection Procedures

Liquor pH

Locate the on-site pH meter(s). Permanently mounted units are generally in the recirculation tank or in the liquor outlet lines from the scrubber vessel. Confirm that the instrument is working properly by reviewing the routine calibration records. In some cases, it is possible to watch plant personnel calibrate these instruments during the inspection.

If the pH meter(s) appears to be working properly, review the pH data for at least the previous month. In units with instruments on the outlet and the inlet, the outlet values are often 0.5 to 2.0 pH units lower due to the absorption of carbon dioxide, sulfur dioxide, hydrogen chloride, and other acid gases. Generally, all of the pH measurements should be within the range from 5.5 to 10.0. Furthermore, any significant shifts in the pH values from baseline conditions can indicate acid gas removal problems and corrosion problems.

Corrosion can be severe in most systems when the pH levels are less than 5.5. Also, high chloride concentrations accelerate corrosion at low pH levels. Precipitation of calcium and magnesium compounds at pH levels above 10 can lead to severe scaling and gas-liquor maldistribution.

Scrubber liquor recirculation rate

One frequent cause of scrubber emission problems is inadequate liquor recirculation rate. Unfortunately, many commercial types of liquor flow monitors are subject to frequent maintenance problems and many small systems do not have any liquor flow meters at all. For these reasons, a combination of factors are considered to determine if the scrubber liquor recirculation rate is much less than the baseline level(s). These factors include the following:

- Liquor flow meter (if available, and if it appears to be working properly)
- Pump discharge pressure (higher values indicate lower flow)
- Pump motor current (lower values indicate lower flow)
- Nozzle header pressure (higher values indicate lower flow)
- Scrubber exit gas temperature (higher values indicate lower flow)
- Quantity of liquor draining back into recirculation tank or pond (lower flow rates indicate lower recirculation rates)

Fan motor currents

Changes in gas flow rate occur routinely in most incinerators due to variations in charging rates and waste heating values. Information concerning gas flow rate changes is necessary when evaluating changes in the scrubber static pressure drop.

Check the scrubber system fan motor current. Correct the fan motor current to standard conditions using the equation below.

$$\text{Corrected Current} = \text{Actual Current} \times (\text{Gas Temp. in } ^{\circ}\text{F} + 460)/520$$

An increase in the fan motor current indicates an increase in the gas flow rate.

Demister conditions

The static pressure drop across the demister should be noted and compared with the baseline values. An increase in the pressure drop normally is due to partially plugged demister vanes. The static pressure drops of clean demisters are usually in the range of 1 to 2 inches of water.

Physical condition of scrubber packed beds and and venturi throat dampers

This inspection step can be performed only when the scrubber system is out-of-service. Locate a hatch on the scrubber vessel shell which is either above or below the internal component of interest. Look for the problems listed below.

Packed bed scrubbers	Corroded or collapsed bed supports Plugged or eroded liquor Distribution nozzles
Venturi scrubbers	Eroded throat dampers Restricted throat damper movement due to solids deposits

Note: Safety conditions sometimes preclude observations of internal conditions. Respirators and other personal protection equipment should be worn even if the scrubber vessel has been purged out prior to the observations.

Turbidity of presaturator/gas cooler liquor

On older incinerators without heat recovery, the inlet gas temperature must be reduced prior to gas entry to the scrubber. This may be done by means of a presaturator immediately upstream of the scrubber vessel. Since some of the liquor droplets sprayed in this vessel can evaporate to dryness, there is the potential for small particle formation from the solids originally present in the liquor. The turbidity of the liquor used in the presaturator should be very low to avoid this condition.

6.3 Level 3 Inspection Procedures

Procedures for measurement of wet scrubber system operating conditions are described below. Other observations to be completed as part of the Level 3 inspection are identical to those included in the basic and follow-up Level 2 inspection.

Wet scrubber static pressure drop

The static pressure drop is directly related to the effectiveness of particle impaction for particle capture. Generally, the particulate removal efficiency increases as the static pressure drop increases. The steps in measuring the static pressure drop are described below.

- Locate safe and convenient measurement ports. In some cases it may be possible to temporarily disconnect the on-site gauge in order to use the portable static pressure gauge. It also may be possible to find small ports in the ductwork ahead of and after the scrubber vessel.

- Clean any deposits out of the measurement ports.

- If the inlet and outlet ports are close together, connect both sides of the static pressure gauge to the ports and observe the static pressure drop for a period of 1 to 5 minutes.

- If the ports are not close together, measure the static pressure in one port for 10 to 30 seconds and then proceed to the other port for 10 to 30 seconds. As long as the static pressure drop is reasonably stable then the two values can be subtracted to determine the static pressure drop.

- Under no circumstances should on-site plant instruments be disconnected without the explicit approval of responsible plant personnel. Also, instruments connected to differential pressure transducers should not be disconnected.

Outlet gas temperatures

This measurement is conducted whenever it is necessary to determine if poor liquor-gas distribution and/or inadequate liquor flow rate is seriously reducing particulate collection efficiency. The steps in measuring the gas temperature are outlined below.

- Locate safe and convenient measurement ports on the outlet portion of the scrubber vessel shell or on the outlet ductwork of the system. Often small ports of 1/2" to 1/4" diameter are adequate.

- Attach a grounding/bonding cable to probe if vapor, gas, and/or particulate are potentially explosive.

- Seal temperature probe in the port to avoid any air infiltration which would result in a low reading.

- Measure the gas temperature at a position near the middle of the duct, if possible. Conduct the measurement for several minutes to ensure a representative reading. Some fluctuation in the readings is possible if the probe is occasionally hit by a liquor droplet.

- Compare the outlet gas temperature with the baseline value(s). If the present value is more than 10 °F higher, then either gas-liquor maldistribution or inadequate liquor is possible.

Scrubber outlet liquor pH

Prior to obtaining a liquor sample, warm-up the portable pH meter and check it using at least two different fresh buffer solutions which bracket the normal liquor pH range. Then request a responsible and experienced plant representative to obtain a sample of the scrubber outlet liquor. Measure the liquor pH as soon as possible after obtaining the sample so that the value does not change due to dissolution of alkaline material or due to on-going reactions. Compare this to the baseline value(s).

6.4 Level 4 Inspection Procedures

The Level 4 inspection includes many inspection steps performed during Level 2 and 3 inspections. These are described in earlier sections. The unique inspection steps of Level 4 inspections are described below.

Locations for measurement ports

Many existing wet scrubber systems do not have safe and convenient ports which can be used for static pressure, gas temperature, and gas oxygen measurements. One purpose of the Level 4 inspection is to select (with the assistance of plant personnel) locations for ports to be installed at a later date to facilitate Level 3 inspections. Information regarding possible sample port locations is provided in the U.S. EPA Publication titled, " Preferred Measurement Ports for Air Pollution Control Systems", EPA 340/1-86-034.

Potential safety problems

Agency management personnel and/or senior inspectors should identify any potential safety problems involved in standard Level 2 or Level 3 inspections at this site. To the extent possible, the system owner/operators should eliminate these hazards. For those hazards which can not be eliminated, agency personnel should prepare notes on how future inspections should be limited and should prepare a list of the necessary personnel safety equipment. A partial list of common health and safety hazards include the following:

- Inhalation hazards due to fugitive leaks from high static pressure scrubber vessels and ducts
- Eye hazards during sampling of scrubber liquor
- Slippery walkways and ladders
- Fan disintegration

System flowchart

A relatively simple flowchart is very helpful in conducting a complete and effective Level 2 or Level 3 inspection. This should be prepared by agency management personnel or senior inspectors during a Level 4 inspection. This should consist of a simple block diagram which includes the following elements:

- Source or sources of emissions controlled by a single wet scrubber system
- Location(s) of any fans used for gas movement through the system (used to evaluate inhalation problems due to positive static pressures)
- Locations of any main stacks and bypass stacks
- Location of wet scrubber
- Locations of major instruments (pH meters, static pressure gauges, thermocouples, liquor flow meters)

SUPPORTING INFORMATION

USE OF PORTABLE INSTRUMENTS - TEMPERATURE MONITORS
Types and Operating Principles

1. Temperature Monitors

Thermocouples and dial-type thermometers are used in inspections of municipal waste incinerator sources. The dial-type units are used primarily for low temperature applications downstream of pollutant control systems. The thermocouples may be used to check incinerator outlet gas temperatures in some cases.

1.1 Types and Operating Principles

Thermocouples

The electromotive force generated by two dissimilar metals is a function of the temperature. The thermocouple voltage is compared with a reference voltage (equivalent to 32°F) and amplified by the thermometer.

There are a variety of thermocouple types, each designated by letters adopted originally by the Instrument Society of America (ISA) and adopted as American National Standard C96.1-1964. A summary of the thermocouple properties is provided below:

Type K - This is the most common type of thermocouple due to the broad temperature range of -400 F to + 2300°F. The thermoelectric elements must be protected by a sheath since both wires are readily attacked by sulfurous compounds and most reducing agents. This sheath must be selected carefully to ensure that it also can take the maximum temperature that the unit will be exposed to. The positive wire is nickel with 10% chromium (trade name - chromel) and the negative wire is nickel with 5% aluminum and silicon (trade name - alumel).

Type E - These generate the highest voltage of any thermocouple, but are limited to a maximum temperature of 1600°F. The positive wire is nickel with 10% chromium (chromel) and the negative wire is a copper-nickel alloy (constantan).

Type J - These have a positive wire composed of iron and a negative wire composed of a copper-nickel alloy (constantan). They can be used up to 1000°F in most atmospheres and up to 1400°F if properly protected by a sheath. They are subject to chemical attack in sulfurous atmospheres.

Type T - These can be used under oxidizing and reducing conditions. However, they have a very low temperature limit of 700°F. They are composed of copper positive wire and a copper-nickel alloy (constantan) negative wire.

Type R and S - These can be used in oxidizing or inert conditions to 2500°F when protected by nonmetallic protection tubes. The Type R thermocouples are composed of a positive wire of platinum with 13% rhodium and a negative wire of platinum. The Type S thermocouples have a positive wire of platinum with 10% rhodium. Both types can be subject to calibration shifts to lower temperature indications due to rhodium diffusion or rhodium volatilization.

Type B - The positive wire is composed of platinum with 30% rhodium and the negative wire is platinum with 6% rhodium. These are less sensitive to the calibration drift problems of Type R and S thermocouples. They can be used to a maximum temperature of 3100°F when protected by nonmetallic protective tubes.

Thermocouple Sheaths

The maximum temperature that a thermocouple can withstand is dependent on the wire compositions and on the type of sheath wrapped around the thermocouple junction. The temperature limits of common sheath materials are indicated in Table 1-1.

Table 1-1. Maximum Operating Temperatures for Common Sheath Materials

Sheath Material	Temperature Limit, °F
Aluminum	700
304 Stainless	1650
316 Stainless	1650
Inconel	2100
Hastelloy	2300
Nickel	2300

A hand-held potentiometer is used to convert the thermocouple voltage to a temperature reading. This is a battery powered unit which is generally not rated as intrinsically safe. For this reason, thermocouples can not be taken into hazardous locations.

Dial Type Thermometers

Temperature is sensed by the the movement of a bimetallic coil composed of materials having different coefficients of thermal expansion. The coil movement is transmitted mechanically to a dial on the front of the thermometer.

One of the principle advantages of this type of unit is that there are no batteries required and the unit can be used safely in most areas.

The main disadvantage is the relatively short probes of 6 to 12" which make it very difficult to reach locations at representative gas temperatures. Due to the short "reach", the dial-type instruments often indicate lower than actual temperatures.

The dial-type units are best when there is very little temperature variation in the measurement location and when there is little or no insulation surrounding the measurement ports. They are generally used for low temperature applications.

1.2 Calibration and Routine Checks

Ice and Boiling Water Temperature Measurements

Both the thermocouple based thermometers and the dial-type thermometers should be checked prior to leaving for the inspection site. The temperatures of boiling water and finely crushed ice-water mixture should be checked. The indicated temperature of the boiling water should be 212°F or less depending on elevation. The temperature of the ice-water mixture should be between 32°F and 34°F depending on how well the ice has been ground and how long the mixture has had to reach thermal equilibrium.

Record the thermometer temperatures for boiling water and ice-water in a notebook or file which is kept at the agency lab. This simple two point check verifies that the unit is operating satisfactorily.

Annual Calibration

The thermocouple should be calibrated on an annual basis. This is often done by comparison of the voltage developed by the thermocouple with the voltage developed by a NBS traceable thermocouple. A set of potentiometers is used to measure the voltages of the two thermocouples placed together in a furnace.

Annual calibration of the dial type thermometers is generally not required. The boiling point and ice point measurements are sufficient for dial type thermometers used in the temperature range of the 32°F to 212°F.

2. Static Pressure Gauges

Static pressure gauges are used primarily to evaluate the static pressure across particulate control devices and to evaluate overfire air pressures.

2.1 Types of Static Pressure Gauges

Slack tube manometers, inclined manometers, and diaphragm gauges are used for measurement of static pressure. The inclined manometer is the most accurate instrument for low static pressures of less than 10 inches W.C. However, it is relatively bulky. Slack tubes can be used up to static pressures of 36 inches W.C. Larger slack tube manometers are cumbersome to use. The diaphragm gauges come in various styles, most of which are accurate to plus or minus 3% or 5% of the instrument scale. These gauges are easy to carry. The diaphragm gauges are composed of two chambers separated by a flexible diaphragm. The diaphragm moves when there are unequal pressures on each of the ports leading to the two chambers. The diaphragm deflection is mechanically transmitted to the dial on the front of the unit. No batteries are required. Also, there is no sample gas flow through the instrument.

2.2 Calibration

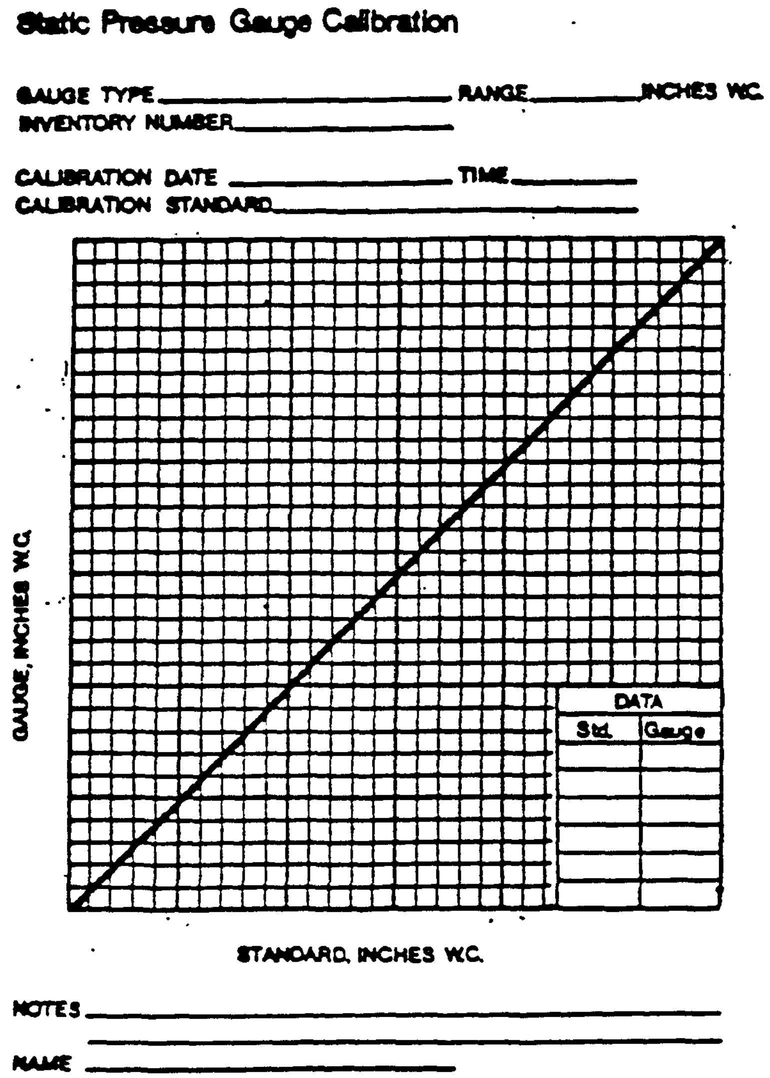
The slack tube manometer and the inclined manometer do not need to be calibrated since these indicate a static pressure directly. The diaphragm gauges are calibrated by comparison with an inclined manometer or a slack tube manometer.

The diaphragm gauges can be calibrated by connecting both the manometer and the diaphragm gauge to a source of pressure (one port of each gauge is left open to the atmosphere). A squeeze bulb with check valves on both sides provides a source of positive and negative pressure in the range of -40 inches W.C. to + 40 inches W.C.

USE OF PORTABLE INSTRUMENTS - STATIC PRESSURE GAUGES
Calibration

Separate calibration curves should be prepared for the positive and negative pressures. Each curve should be comprised of a minimum of three points to indicate any non-linearities in the gauge response. A sample form for recording and plotting the calibration data is provided in Figure 2-1.

Diaphragm gauge calibration should be performed prior to each inspection day. Total time requirements are less than 5 minutes when the manometers and squeeze bulbs are kept in a convenient location.



Static Pressure Gauge Calibration

GAUGE TYPE ________________ RANGE ________ INCHES W.C.
INVENTORY NUMBER ____________

CALIBRATION DATE ____________ TIME ________
CALIBRATION STANDARD ________________

GAUGE, INCHES W.C.

DATA	
Std.	Gauge

STANDARD, INCHES W.C.

NOTES ______________________________
____
NAME ____________________

Figure 2-1. Possible Form for Diaphragm Gauge Calibration

3.1 Types of Combustion Analyzers

The three major types of portable combustion gas analyzers that are used for the inspection of municipal waste incinerators are listed below.

Multi-gas combustion analyzers
ORSAT analyzers
Manual gas absorption instruments

The multi-gas combustion analyzers have the capability to monitor oxygen, carbon dioxide, and carbon monoxide. A sample is pumped continuously from the measurement location and the gases are analyzed by a variety of techniques including electroconductivity cells and infrared absorption.

The ORSAT analyzers have similar capability, however, a manually pumped sample is used. Sequential chemical absorption in a set of three solutions is used to determine the combustion gas concentrations for oxygen, carbon dioxide, and carbon monoxide. The main advantage of this instrument is the ability to make measurements without power.

The manual gas absorption kits are sold only for oxygen and carbon dioxide. These are less expensive than the ORSAT analyzers and they also use manually pumped gas samples. They are slightly less accurate and precise than the ORSAT instruments. However, they are easy to use and provide adequate data for municipal waste incinerator system evaluation.

3.2 Calibration

Consult the manufacturers literature concerning the specific calibration procedures. Calibration gas standards (compressed gas cylinders) are needed for the multi-component gas combustion analyzers. Ambient air is generally used for the ORSAT and manual instruments.

3.3 Measurement Checks

Combustion systems such as incinerators operate with a definite relationship between the carbon dioxide and oxygen concentrations in the flue gas. The measurement made by any of the techniques should be checked using the information provided in the following table. If the sum of the oxygen and carbon dioxide measurements are not within the general ranges specified in the table, it is probable that there are measurement errors.

Table 3-1. Oxygen and Carbon Dioxide Totals

Fuel	Sum of Oxygen and Carbon Dioxide Concentrations, (% of Dry Gas)
Natural Gas	13 to 19
#2 Oil	15 to 20
#6 Oil	17 to 20
Bituminous Coal, Lignite, and Sub-bituminous Coal	18 to 21
Anthracite Coal	19 to 21
Wood	18 to 22
Refuse	18 to 22

The ranges shown in Table 3-1 take into account the stoichiometry of combustion and the gas concentration measurement errors. It should be noted that the presence of extreme carbon monoxide concentrations (>1% or 10,000 ppm) also affects the total.

EMISSION TEST METHODS FOR MUNICIPAL WASTE COMBUSTORS

This section summarizes the sampling and analysis procedures for those municipal waste incinerator air pollutants most frequently regulated. These are:

- Particulate matter
- Acid gases (including sulfur dioxide)
- Carbon monoxide
- Metals
- Dioxins/furans

A document addressing the guidelines for emission testing of MWCs is available from the U.S. EPA [1].

Particulate Matter

MWCs are sampled for particulate matter using EPA Method 5 [2]. Although both the front and back halves of the Method 5 train are generally used, the particulate is often considered only the material caught in the probe or on the heated filter. However, to save money, particulate sampling is often conducted in conjunction with sampling for one or more other pollutants using the same train or by making slight modifications to the sampling train (e.g. different impinger reagents).

Sulfur oxides

EPA Method 8 is the reference test method for combined sulfuric acid mist and sulfur dioxide and EPA Method 6 is the reference method when only sulfur dioxide is to be determined [2]. Both sampling methods collect and separate the sulfuric acid mist. The fractions are measured using the barium-thorin titration method.

Hydrochloric and hydrofluoric acids

Currently, there is no EPA reference method for measurement of HCl emissions. Published methods for HCl [3, 4, and 5] use a dilute alkaline impinger reagent (0.1 N NaOH or $NaHCO_3/Na_2CO_3$) in a midget impinger train for sample collection and dissolution to chloride ion, followed either by chloride ion analysis by mercuric nitrate titration or by ion chromatography (IC). A slightly modified method currently being validated by EPA which eliminates potential interference from diatomic chlorine (Cl_2), utilizes two acidified impingers (0.1 N H_2SO_4) followed by two alkaline impingers. The HCl is caught in the first two impingers while the Cl_2 passes through and is collected in the third and fourth impingers. The first method is still routinely used at MWCs (sometimes being altered to use distilled water in the first two impingers) because diatomic chlorine is not typically an interferent at these sources.

EPA Method 13B [2] for determination of total fluoride emissions from stationary sources has been used to measure HF emissions from MWCs. The fluoride ion is collected in distilled water (and on a filter if any particulate fluoride is present) and analyzed by specific ion electrode (or HPLC). As a cost savings, HCl and HF testing can be combined by using the Method 13B train with 0.1 N NaOH as the impinger reagent followed by chloride ion and fluoride ion analyses by IC or chloride titration. NaOH causes a problem with a direct specific ion electrode analysis for fluoride and so this is not used.

The location of the filter in the backup position for Method 13B, however, sometimes can present problems because chloride salts (such as $CaCl_2$) from dry scrubbing) may reach the impingers causing a high bias in the HCl measurement. In this case, sampling can be conducted nonisokinetically (for gaseous HCl and HF), using glass wool in the probe to filter the particulate salts.

HCl sampling has also been combined with particulate matter sampling and dioxin/furan sampling. In both cases, 0.1 N NaOH replaces the water in the back half of the Method 5 or modified Method 5 sampling train and an aliquot of the combined impinger reagent is analyzed for chloride ion.

Carbon Monoxide

Carbon monoxide emissions from MWCs are measured using EPA Method 10 [2]. An integrated or continuous sample is extracted from the duct and analyzed using a nondispersive infrared analyzer. The bias introduced by carbon dioxide and water in the gas stream is eliminated by use of a drying tube and an Ascarite carbon dioxide adsorption tube.

Metals

There are currently three EPA reference methods for sampling metal emissions that are applicable to MWCs. These are Method 12 for lead [2], Method 101A for mercury [6], and Method 104 for beryllium [6]. During the last several years, modified Method 5 trains have been used to collect various combinations of metals. One method utilizing a modified Method 5 train for sampling 16 metals (including: lead, zinc, cadmium, arsenic, and mercury) is presently undergoing evaluation by EPA. This train employs an all glass probe including the nozzle and a glass or quartz fiber filter with a low background level of the target metals. The five impingers are charged as follows:

Impinger	Contents
1	empty
2 and 3	5% HNO_3/10% H_2O_2
4	acidic $KMnO_4$
5	silica gel

For analysis, inductively-coupled argon plasmography (ICAP) is used to measure the concentrations of all metals but mercury in (1) the digested front half sample, and (2) the contents of the first three impingers.

Lead and arsenic must be remeasured using atomic absorption spectrophotometry (AA) if found at levels less than 2 ppm since aluminum and iron (which are commonly found in MWC emissions) are principal interferents in the ICAP analysis of lead and arsenic. The mercury concentration in: (1) the fourth impinger, and in (2) an aliquot of the first three impingers is measured using cold vapor AA.

Particulate sampling may be combined with metals sampling. A gravimetric analysis is performed on the filter catch prior to digestion. The probe is rinsed with acetone followed by a nitric acid solution. The acetone rinse is dessicated and weighed and this weight is added to the filter catch weight. The acetone rinse residue is then resolubilized and added to the nitric acid rinse to be taken through the analytical protocol for metals analysis.

Dioxins/Furans

Dioxins/furans in stack gas emissions are typically collected and quantified following the draft ASME/DOE/EPA protocols [7]. Sampling involves using a modified Method 5 train with a nickel-plated or glass nozzle, borosilicate glass probe, glass filter holder, Teflon or Teflon-coated frit, solvent extracted low background level glass fiber filter, water-cooled condensor, XAD sorbent trap for organics, and essentially organic-free distilled water in the impingers. The train is prepared, handled, and recovered according to a rigorous scheme to prevent contamination in order to measure the CDDs/CDFs at extremely low levels (ppt). Analysis of the samples is generally performed using high resolution gas chromatography/high resolution mass spectrometry (HRSC/HRMS). Although there are 210 possible CDD/CDF isomers, analyses are typically limited to quantifying the isomers currently believed to be most toxic along with total amounts in the various isomeric groups (e.g. isomers chlorinated in the 2,3,7, and 8 positions).

References - Emission Test Methods

1. Haile, C.L. and J.C. Harris, "Guidelines for Stack Testing at Municipal Waste Combustion Facilities," U.S. EPA Publication 600/8-88-085, June 1988.

2. Code of Federal Regulations, Title 40, Part 60, Appendix A, July 1, 1987.

3. Rollins, R., and J.B. Homolya, "Measurement of Gaseous Hydrogen Chloride Emissions from Municipal Refuse-to-Energy Recovery Systems in the United States," Environmental Science and Technology, 13(11), pages 1380-1383, 1979.

4. Cheney, J.L., and C. R. Fortune, "Evaluation of a Method for Measuring Hydrochloric Acid in Combustion Source Emissions," The Science of the Total Environment, 13, pages 9-16, 1979.

5. State of California, Air Resources Board, Method 421, "Determination of Hydrochloric Acid Emissions from Stationary Sources," January 22, 1987.

6. Code of Federal Regulations, Title 40, Part 61, Appendix A, July 1, 1987.

7. "Sampling for the Determination of Chlorinated Organic Compounds in Stack Emissions" and "Analytical Procedures to Assay Stack Effluent Samples and Residual Combustion Products for Polychlorinated Dibenzo-p-dioxins and Dibenzofurans," prepared by Group C - Environmental Standards Workshop, sponsored by ASME/DOE/EPA, Revised Draft, December 31, 1984.