WASATCH
INTEGRATED
waste management district

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UTAH DIVISION OF
SOLID & HAZARDOUS WASTE

October 3, 2007

Dennis R. Downs, Director
Utah Division of Solid and Hazardous Waste
288 North 1460 West
P.O. Box 144880
Salt Lake City, Utah 84114-4880
Attention: Rob Powers

RE: Modification Permit Application, Davis Energy Recovery Facility

Dear Mr. Downs:

Wasatch Integrated Waste Management District operates the Davis Energy Recovery Facility in Layton, Utah in accordance with Utah Solid and Hazardous Waste Regulations and Solid Waste Permit #9423 issued June 15, 1996.

On or about December 15, 2000, Wasatch submitted an Application to Renew a Permit to Operate an Energy Recovery Facility (Application) to the Utah Division of Solid and Hazardous Waste. Since that time several modifications to the facility and operations have taken place.

Please find, attached to this letter, a revised Application which reflects current facility operation and configuration.

Please do not hesitate to contact me if you have any questions or concerns regarding this or any other project.

Sincerely,

Wasatch Integrated Waste Management District

Nathan Rich, P.E.
Executive Director

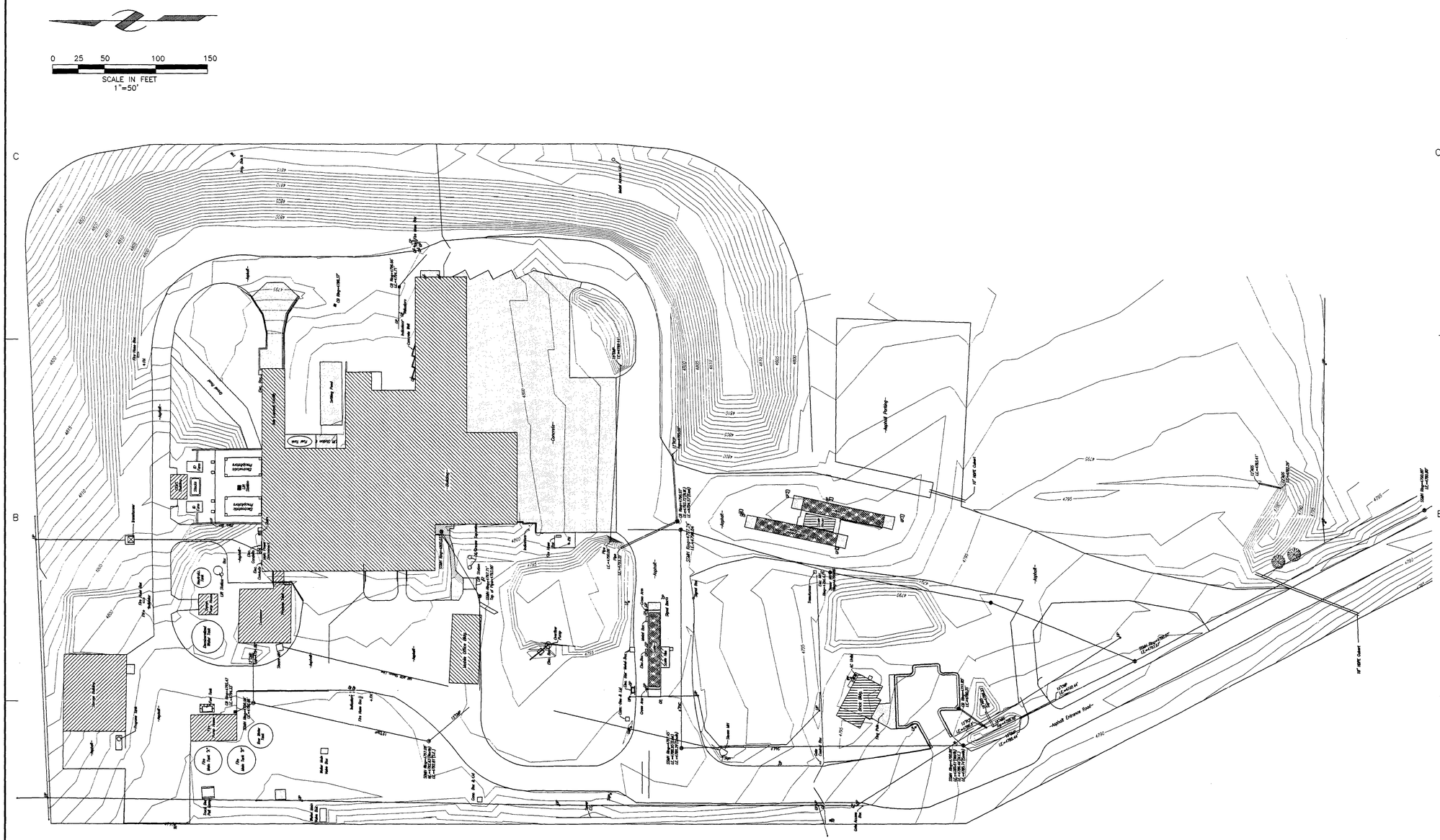
cc: John Watson

Attachment

P.O. Box 900
Layton, Utah 84041-0900

1997 East 3500 North
Layton, Utah 84040

801.614.5600
801.771.6438 fax



WASATCH ENERGY SYSTEMS

650 East Highway 193
Layton, Utah 84041
(801) 771-5661

CONSULTANTS

IGES

ideas for a changing world

182 South 600 East, Suite 206
Salt Lake City, Utah 84102
(801)521-1800 Fax: (801)521-2800

MARK	DATE	DESCRIPTION

ISSUE:

PROJECT NO.:	00169-005
CAD DWG FILE:	00169-005-1
DRAWN BY:	JIO
DESIGNED BY:	KAH
CHECKED BY:	BDM
COPYRIGHT:	IGES 2000

SHEET TITLE

Wasatch Energy Systems

Burn Plant LAYOUT

1

APPLICATION
TO RENEW A PERMIT TO OPERATE
AN ENERGY RECOVERY FACILITY

at

WASATCH INTEGRATED WASTE MANAGEMENT DISTRICT
3404 North 650 East
Layton, Utah

by

WASATCH INTEGRATED WASTE MANAGEMENT DISTRICT
September 2007

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APPLICATION
TO RENEW A PERMIT TO OPERATE
AN ENERGY RECOVERY FACILITY

WASATCH INTEGRATED WASTE MANAGEMENT DISTRICT

PART I – GENERAL INFORMATION

UTAH DEPARTMENT OF ENVIRONMENTAL QUALITY

DIVISION OF SOLID AND HAZARDOUS WASTE

APPLICATION FOR A PERMIT TO OPERATE AN INCINERATOR OR

ENERGY RECOVERY FACILITY

The applicant shall submit, in duplicate, an original permit application, a general report, and a technical report to:

Dennis R. Downs, Director
Division of Solid and Hazardous Waste
Utah Department of Environmental Quality
PO Box 144880
Salt Lake City, Utah 84114 – 4880

PART 1 – GENERAL INFORMATION

1. Name of Facility: Wasatch Integrated Waste Management District

2. Site Location: 3404 N. 650 E., Layton, UT 84041

3. Facility Owner: Wasatch Integrated Waste Management District

4. Facility Operator: Wasatch Integrated Waste Management District

5. Contact Person: Nathan Rich

   Address: 3404 N. 650 E.
   Layton, UT 84041

   Telephone: (801) 614-5601

6. Type of Facility and Type of Application:
   - □ Incinerator ■ Energy Recovery Facility
   - ■ Non-Commercial Facility □ Commercial Facility
   - □ Initial Application ■ Permit Renewal

7. Property Ownership

- ■ Presently owned by applicant
- □ To be purchased by applicant
- □ To be leased by applicant

Property owner (if different from applicant)

Name: _____

Address: _____

_____

Telephone: _____

8. Certification of submitted information:

Name of Official: Nathan Rich Title: Executive Director

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature: _____ Date: _____

SUBSCRIBED AND SWORN to before This _____ day of _____, 20_____.

My commission expires on the _____ day of _____, 19_____.

Notary Public in and for: _____

(SEAL) _____ County, Utah.

Important Note: An application for a permit to construct and operate an incinerator or an energy recovery facility is the documentation that the landfill will be located, designed, constructed, and operated to meet the requirements of Rules R315-302, R315-306, and R315-309 of the *Utah Solid Waste Permitting and Management Rules* and the *Utah Solid and Hazardous Waste Act* (UCA 19-6). The application should be written to be understandable by regulatory agencies, facility operators, and the general public. The application should also be written so that the facility operator, after reading it, will be able to operate the facility according to the requirements with a minimum of additional training. Two copies of the complete application are required.

CHECKLIST OF ADDITIONAL INFORMATION REQUIRED

(Please see Section R315-310-7 of the *Utah Solid Waste Permitting and Management Rules*)

PART II – GENERAL REPORT

INTRODUCTION

- Completed PART I – GENERAL INFORMATION (R315-310-3(1)(a))
- General description of the facility (R315-310-3(1)(b))
- Legal description; proof of ownership, lease agreement, or other mechanism; latitude and longitude of the site; and land use and zoning of surrounding area (R315-310-3(1)(c))
- The types of waste and area served by the facility (R315-310-3(1)(d))

PLAN OF OPERATION (R315-310-3(1)(e))

- An intended schedule of construction (R315-302-2(2)(a))
- A description of on-site waste handling procedures and an example of the form used to record the weights or volumes of waste received (R315-302-2(2)(b) and R315-310-3(1)(f))
- A schedule for conduction inspections and monitoring and examples of the forms used to record the results of the inspections and monitoring (R315-302-2(2)(c), R315-310-3(1)(g), and R315-310-7(2)(b)(iii))
- Contingency plans in the event of a fire or explosion (R315-302-2(2)(d))
- Corrective action programs to be initiated if ground water is contaminated (R315-302-2(2)(e))
- Contingency plans for other releases, e.g. explosive gases or failure of run-off collection system (R315-302-2(2)(f))
- Description of maintenance of installed equipment (R315-302-2(2)(g))

- A plan for cleaning of storage areas (R315-310-7(2)(b)(i))
- Alternative storage plans for breakdowns (R315-310-7(2)(b)(ii))
- A schedule for testing the ash and residues and a plan for the disposal of the ash and residues (R315-306-2(6) and R315-310-7(2)(b)(iv))
- Procedures for excluding the receipt of regulated hazardous or PCB containing waste (R315-302-2(2)(h) and R315-310-7(2)(b)(v))
- Procedures for controlling disease vectors (R315-302-2(2)(i))
- A plan for alternative waste handling (R315-302-2(2)(j))
- A general training and safety plan for site operations (R315-302-2(2)(m))
- Recycling program planned at the facility (R315-306-2(13))
- Any other site specific information pertaining to the plan of operation required by the Executive Secretary (R315-302-2(2)(n))

SPECIAL REQUIREMENTS FOR A COMMERCIAL FACILITY (R315-310-3(3))

- Submit information required by the *Utah Solid and Hazardous Waste Act* Subsections 19-6-108(9) and 19-6-108(10) (R315-310-3(2)(a))

  Note: After the receipt of a solid waste permit, a commercial facility must receive approval from the local government, the Legislature, and the governor prior to the start of construction and operation (R315-310-3(2)(b))

PART III TECHNICAL REPORT

PLOT PLAN

- ☐ Plot Plan map of the proposed facility drawn to a scale of 200 ft to the inch showing the boundaries of the facility; the locations of all existing and proposed structures; the location of all access routes; the location of the run-off collection, treatment, and disposal system (R315-310-3(1)(a))

ENGINEERING REPORT – PLANS, SPECIFICATIONS, AND CALCULATIONS

- The design of the on-site storage and handling facilities for incoming waste, fly ash, bottom ash, and any other wastes produced by air or water polluting controls (R315-310-7(2)(a)(ii))
- The design of the incinerator or thermal reactor including charging or feeding systems; combustion air system; combustion or reaction chambers; heat recovery systems; ash handling systems; air and water pollution control systems; and instrumentation and monitoring systems (R315-310-7(2)(a)(iii))

- A discussion of the design and operation of the air pollution control systems and documentation to show that an air quality permit has been granted or the application is being reviewed by the Division of Air Quality (R315-310-7(2)(c))

- A discussion of the design and operation of the run-off collection, treatment, and disposal system and documentation to show that any run-off treatment system or other water pollution control treatment system is being or has been reviewed by the Division of Water Quality (R315-310-7(2)(c))

CLOSURE PLAN (R315-310-7(2)(d))

- Closure schedule (R315-310-7(2)(d)(i))

- Methods of closure and methods of removing wastes and equipment and location of final disposal (R315-310-7(2)(d)(iii))

- Final inspection by regulatory agencies (R315-310-7(2)(d)(iii))

FINANCIAL ASSURANCE

- Identification of closure costs including cost calculations and the funding mechanism (R315-310-3(1)(j) and R315-310-7(2)(d)(i))

APPLICATION
TO RENEW A PERMIT TO OPERATE
AN ENERGY RECOVERY FACILITY

DAVIS COUNTY ENERGY RECOVERY FACILITY

PART II – GENERAL REPORT

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Appendix II – A

Resolution 84-2000

After the conduct of other business, the following resolution was introduced in written form by Commissioner Saunders, was read and discussed, and pursuant to motion made by Commissioner Gerlach and seconded by Commissioner Tippetts and was adopted by the following vote:

Aye: Commissioner Saunders

Commissioner Gerlach

Commissioner Tippetts

Nay: None

The resolution is as follows: 84-200

A RESOLUTION establishing the Davis County Solid Waste Management and Energy Recovery Special Service District, Davis County, Utah, providing for the establishment of an Administrative Control Board as the governing authority thereof and providing for other related matters.

*** *** ***

WHEREAS pursuant to a resolution (the "Resolution"), adopted on August 8, 1984, the Board of County Commissioners of Davis County, Utah (the "Board") gave notice of its intention to create a special service district to be known as "Davis County Solid Waste Management and Energy Recovery Special Service District" (hereinafter referred to as the "District"), having the boundaries set out in Section 2 hereof and to provide garbage services; and

WHEREAS pursuant to the Resolution the Board ordered that a public hearing be held on September 5, 1984, at 10:00 o'clock A.M., at the regular meeting place of the Board in the Davis County Courthouse, in Farmington, Utah, on the establishment of the District and the provision of garbage services thereby; and

WHEREAS public notice of said intention and of the time and place of said public hearing was given by the County Clerk through the publication of an appropriate notice in the Davis County Clipper and the Weekly Reflex, newspapers published and of general circulation in Davis County, Utah, once a week during three consecutive weeks on

August 15, 1984, August 22, 1984, and August 29, 1984, the first of such publications having been not less than twenty-one (21) days nor more than thirty-five (35) days prior to the date of the public hearing; and

WHEREAS said public hearing has been held pursuant to said notice at the aforesaid time and place, the Board has considered all protests filed and has heard and considered all interested persons desiring to be heard, and the time for filing protests as provided in Section 11-23-9, Utah Code Annotated 1953, as amended, has expired; and

WHEREAS on August 9/10, 1984, the County Clerk filed a certified copy of the Resolution with the City Recorders of the cities of Bountiful, Centerville, Clearfield, Clinton, Farmington, Fruit Heights, Kaysville, Layton, North Salt Lake, South Weber, Sunset, Syracuse, West Bountiful, West Point and Woods Cross, Utah, being the only incorporated cities or towns located within the boundaries of the proposed District, together with the request of this Board that the governing authority of such cities consent to the inclusion of such cities within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Sept. 4, 1984, the City Council of the City of Centerville, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Aug. 28, 1984, the City Council of the City of Clinton, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Aug. 15, 1984, the City Council of the City of Farmington, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Aug. 21, 1984, the City Council of the City of Fruit Heights, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Sept. 4, 1984, the City Council of the City of Kaysville, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Aug. 21, 1984, the City Council of the City of North Salt Lake, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Aug. 28, 1984, the City Council of the City of South Weber, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Aug. 21, 1984, the City Council of the City of Sunset, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Aug. 28, 1984, the City Council of the City of Syracuse, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Sept. 4, 1984, the City Council of the City of West Bountiful, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Sept. 6, 1984, the City Council of the City of West Point, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS by resolution duly adopted on Sept. 7, 1984, the City Council of the City of Woods Cross, consented to the inclusion of such city within the boundaries of the proposed District; and

WHEREAS the City Councils of the cities of Bountiful, Clearfield and Layton have not consented to the inclusion of such cities within the boundaries of the proposed District; and

WHEREAS it is provided in Section 11-23-24, Utah Code Annotated 1953, as amended, that the governing authority of a county which has established a service district pursuant to the provisions of the Utah Special Service District Act, Chapter 23 of Title 11, Utah Code Annotated 1953, as amended, may, by resolution adopted at the time of the establishment of such district, create an administrative control board (the "Administrative Control Board") for the service district, provided that each municipality within a service district established by a county shall be entitled to appoint one member to represent the municipality on the Administrative Control Board; and

WHEREAS it is desired to create an Administrative Control Board for the District which shall consist of fifteen persons, the Administrative Control Board to constitute the governing authority of the District as provided in Section 11-23-24, Utah Code Annotated 1953, as amended;

NOW, THEREFORE, Be It and It Is Hereby Resolved by the Board of County Commissioners of Davis County, Utah, as follows:

Section 1. That the Board does hereby find and determine:

(a) That public notice of the hearing upon the establishment of the District and the furnishing of garbage services thereby was given by the Clerk of this Board by publication of an appropriate notice in the Davis County Clipper and the Weekly Reflex, newspapers published and of general circulation in Davis County, Utah, once a week for three consecutive weeks prior to September 5, 1984, to-wit, on August 15, 1984, August 22, 1984, and August 29, 1984, the first of said publications having been made not more than thirty-five (35) days nor less than twenty-one (21) days prior to the date of such hearing.

(b) That on August 9/10, 1984, the County Clerk filed a certified copy of the Resolution with the City Recorders of the cities of Bountiful, Centerville, Clearfield, Clinton, Farmington, Fruit Heights, Kaysville, Layton, North Salt Lake, South Weber,

Sunset, Syracuse, West Bountiful, West Point and Woods Cross, Utah, being the only incorporated cities or towns within the boundaries of the proposed District as then contemplated, together with the request of this Board that the governing authority of each such city consent to the inclusion of said city within the boundaries of the proposed District.

(c) That by resolution duly adopted on Sept. 4, 1984, the City Council of the City of Centerville, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(d) That by resolution duly adopted on Aug. 28, 1984, the City Council of the City of Clinton, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(e) That by resolution duly adopted on Aug. 15, 1984, the City Council of the City of Farmington, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(f) That by resolution duly adopted on Aug. 21, 1984, the City Council of the City of Fruit Heights, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(g) That by resolution duly adopted on Sept. 4, 1984, the City Council of the City of Kaysville, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(h) That by resolution duly adopted on Aug. 21, 1984, the City Council of the City of North Salt Lake, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(i) That by resolution duly adopted on Aug. 28, 1984, the City Council of the City of South Weber, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(j) That by resolution duly adopted on Aug. 21, 1984, the City Council of the City of Sunset, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(k) That by resolution duly adopted on Aug. 28, 1984, the City Council of the City of Syracuse, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(l) That by resolution duly adopted on Sept. 4, 1984, the City Council of the City of West Bountiful, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(m) That by resolution duly adopted on Sept. 6, 1984, the City Council of the City of West Point, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(n) That by resolution duly adopted on Sept. 7, 1984, the City Council of the City of Woods Cross, Utah, consented to the inclusion of such city within the boundaries of the proposed District.

(o) That the City Councils of the cities of Bountiful, Clearfield and Layton have not consented to the inclusion of such cities within the boundaries of the proposed District.

(p) That the following persons filed written protests against the establishment of the District, at or prior to the public hearing, which written protests were not withdrawn prior to the adoption of this resolution:

NAME	ADDRESS
Jim Hurst	1670 East 700 South, Clearfield, Utah

NAME	ADDRESS

(q) That a public hearing on the establishment of the District and the furnishing of garbage services thereby was held and conducted by this Board as required by law and the Resolution giving notice thereof, on September 5, 1984, at 10:00 o'clock A.M. at the regular meeting place of the Board in the Davis County Courthouse, in Farmington, Utah, at which public hearing the Board gave full consideration to all protests which were filed and heard and considered all interested persons desiring to be heard.

(r) That after careful consideration of all factors involved and of all objections and protests, it has been and is hereby found, determined and declared that all property included within the boundaries of the District, as such boundaries are set out in the Resolution with such modifications as are set forth in Section 2 hereof, will be benefited by the garbage services to be furnished by the proposed District, and that all proceedings taken in establishing the District have been in compliance with law.

Section 2. That there is hereby established a special service district within avis County, Utah, to be known as "Davis County Solid Waste Management and Energy ecovery Special Service District". The boundaries of the District shall be as follows:

Beginning at a point in the middle of the channel of the Weber river where crossed by the summit line of the Wasatch range, thence westerly down the middle of said channel to a point north of the northwest corner of Kingston's fort; thence west to the east shore of Great Salt Lake; thence southwesterly along and to the middle point of a straight line running between said point on the east shore and a point on the west shore of said lake at latitude 41 degrees north; thence southeasterly along a straight line running between Black Rock on the southern shore of said lake and said middle point of said line to the base line of the United States survey; thence northeasterly and equidistant between Antelope island and the south shore of said lake to a point west of the mouth of the Jordan river on the west line of range 1 west; thence east to the mouth of the Jordan river; thence southeasterly up the middle of the channel of the Jordan river to a point west of a point 136 rods north of Hot Spring in the northern part of Salt Lake City; thence east to the summit of the spur range terminating at said Hot Spring; thence northeasterly along said last mentioned summit to its intersection with, and thence northerly along, the summit of the Wasatch range to the point of beginning; excluding therefrom all territory encompassed within the boundaries of the cities of Bountiful, Clearfield and Layton, each of such cities being located wholly within Davis County, Utah, as such boundaries exist as of September 24, 1984.

Section 3. That the District is created for the purpose of providing garbage services within the area included within its boundaries, through facilities or systems acquired or constructed for that purpose through construction, purchase, lease, contract, gift, condemnation or any combination thereof.

Section 4. That the Board hereby finds and determines that neither more than fifty percent (50%) of the qualified voters of the territory proposed to be included within the District, nor the owners of more than fifty percent (50%) of the assessed value of the taxable property included within the District, have filed written protests with the County Clerk against (1) the establishment of the District, or (2) a specified type or types of services within the District.

Section 5. That any person who, within fifteen (15) days after the conclusion of the public hearing held on September 5, 1984, filed a written protest with the County Clerk against the establishment of the District or against the furnishing of a specified type or types of services within the District and who is a qualified voter residing within the District or whose property has been included within the boundaries of the District notwithstanding such protest, may, within thirty (30) days after the adoption of this resolution, apply to the District Court of the Second Judicial District for a writ of review of the actions of the Board in establishing the District. Under Section 11-23-11, Utah Code Annotated 1953, as amended, the only ground upon which a person may apply for a writ of review is that the protestor's property will not be benefited by one or more of the types of services authorized to be furnished by the District or upon the ground that the proceedings taken in establishing the District have not been in compliance with law.

A failure to timely apply for a writ of review forecloses the right of all owners of property or qualified voters within the District herein established to further object.

Section 6. That the District shall be a separate body politic and corporate and a quasi-municipal public corporation distinct from Davis County, Utah, and each municipality in which the District is located. Notwithstanding, the Board, as it exists from time to time, shall control and have supervisory authority over all activities of the District, except that this Board may, as provided in Section 7 hereof, by resolution delegate to an administrative control board established under Section 11-23-24, Utah Code Annotated 1953, as amended, or to designated officers and employees (who may, but need not, be officers or employees of Davis County, Utah) the performance of any such activities and the exercise of any rights, powers and authority of the District, to the extent permitted by law. The District shall have all rights, powers and authority granted to such districts under the Utah Special Service District Act, Title 11, Chapter 23, Utah Code Annotated 1953, as amended.

Section 7. That there is hereby created as the governing authority of the District an Administrative Control Board under Section 11-23-24(1), Utah Code Annotated 1953, as amended, which shall consist of fifteen persons, twelve of whom shall be the total appointed representatives from each of the twelve incorporated cities within the boundaries of the District, and three of whom shall be appointed by the Board as representatives of other than a municipality. Under Section 11-23-24(1), Utah Code Annotated 1953, as amended, each city or town included within the boundaries of the District, such cities or towns being the cities of Centerville, Clinton, Farmington, Fruit Heights, Kaysville, North Salt Lake, South Weber, Sunset, Syracuse, West Bountiful, West Point and Woods Cross, Utah, has the right to appoint one member to the Administrative Control Board, which appointments, together with the three appointments which may be made by the Board pursuant to Section 11-23-24(1), Utah Code Annotated 1953, as amended, shall be established by a subsequent resolution of the Board.

Section 8. That the budget of the District shall be adopted and administered by the Administrative Control Board and said budget under Section 11-23-14(1)(a), Utah Code Annotated 1953, as amended, shall be separate from the general Davis County, Utah, budget.

Section 9. That as provided in Section 11-23-24, Utah Code Annotated 1953, as amended, the Administrative Control Board shall act as the governing authority of the District pursuant to the provisions of the Utah Special Service District Act, with full power and authority to exercise any of the rights, powers and authority of a service district, including without limitation, all or any of the powers provided in Sections 11-23-13, 11-23-15, 11-23-18, 11-23-19 and 11-23-20, Utah Code Annotated 1953, as amended; provided, however, that the Administrative Control Board shall have no power to levy a tax on the taxable property of the District, to issue bonds or to call or hold an election for the authorization of such tax or such bonds.

Section 10. That the Board may from time to time hereafter by resolution duly adopted, delegate such additional powers to the Administrative Control Board as may be specified in such resolution; provided, however, that any delegation to the Administrative Control Board contained in this or any subsequent resolution may, as provided in Section 11-23-24, Utah Code Annotated 1953, as amended, be revoked, in whole or in part, by resolution of the Board hereafter adopted.

Section 11. That pursuant to Section 11-23-24(7), Utah Code Annotated 1953, as amended, the Board hereby establishes the compensation of the members of the Administrative Control Board, which shall be paid at a per diem rate of $ -0- and such further compensation as shall be hereafter set by resolution of the Board. The Board hereby further authorizes the Administrative Control Board to employ staff commensurate with the duties and functions assigned to it hereunder.

Section 12. That the County Clerk shall advise the members of the Administrative Control Board of their appointment, and the County Clerk shall fix a time and place for the initial organizational meeting of the Administrative Control Board. The Administrative Control Board shall, at the organizational meeting, after subscribing to their oaths of office, elect from their members a chairman and secretary, and appoint such other officers as the Administrative Control Board shall deem necessary and desirable. The Administrative Control Board shall adopt bylaws, which bylaws shall be approved by the County Attorney as to form and content.

Section 13. That pursuant to the requirements of Section 11-12-1, Utah Code Annotated 1953, as amended, the Board will file a notification of establishment of the District with the state tax commission within ten (10) days after the adoption of this resolution.

Section 14. That all acts and resolutions in conflict with this resolution or any part thereof are hereby repealed.

Section 15. That this resolution shall take immediate effect upon its adoption and approval.

ADOPTED AND APPROVED this 24th day of September, 1984.

Chairman
Board of County Commissioners
Davis County, Utah

Attest:

County Clerk
Davis County, Utah

(Other business not pertinent to the above appears in the minutes of the meeting.)

Pursuant to motion duly made and carried, the meeting was adjourned.

Chairman
Board of County Commissioners
Davis County, Utah

Attest:

County Clerk
Davis County, Utah

STATE OF UTAH)
)
COUNTY OF DAVIS)

I, the undersigned, do hereby certify that I am the duly qualified and acting County Clerk of Davis County, Utah.

I further certify that the foregoing constitutes a true and correct copy of the minutes of a regular meeting of the Board of County Commissioners of Davis County, Utah, held at the regular meeting place of the board in the Davis County Courthouse in Farmington, Utah, at 10:00 o'clock A.M. on September 24, 1984, as recorded in the regular official book of minutes of the proceedings of the Board of County Commissioners, kept in my office, that said proceedings were duly had and taken as herein shown, that all members were given due, legal and timely notice of said meeting, that the meeting therein shown was in all respects called, held and conducted in accordance with law, and that the persons therein named were present at said meeting, as therein shown.

IN WITNESS WHEREOF, I have hereunto set my hand and affixed the official seal of Davis County, Utah, this 24th day of September, 1984.

County Clerk
Davis County, Utah

[SEAL]

HH/JWB/jlf/850313-v

Appendix II – B

Documentation DTO1281

STATE OF UTAH)

COUNTY OF DAVIS) ss.

I, the undersigned, do hereby certify that I am an Authorized Officer of the Davis County Solid Waste Management and Energy Recovery Special Service District, Utah (the "District").

I further certify that there is attached hereto a true a correct copy of the "FIRST SUPPLEMENTAL RESOLUTION TO THE DAVIS COUNTY SOLID WASTE MANAGEMENT AND ENERGY RECOVERY SPECIAL SERVICE DISTRICT RESOLUTION AUTHORIZING THE ISSUANCE OF SOLID WASTE MANAGEMENT REVENUE BONDS, ADOPTED ON DECEMBER 26, 1984" which was duly adopted by the Administrative Control Board of the District at a regular meeting held at the regular meeting place of the Administrative Control Board on June 26, 1985, and which was adopted by the Board of County Commissioners of Davis County, Utah, acting as the governing authority of the District, at a special meeting held at the regular meeting place of the Board on July 22, 1985; and that said First Supplemental Resolution has not been altered, amended or repealed and is in full force and effect.

IN WITNESS WHEREOF, I have hereunto set my hand and affixed the official seal of the District, this 26th day of July, 1985.

Authorized Officer

[SEAL]

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FIRST SUPPLEMENTAL RESOLUTION
to
THE DAVIS COUNTY SOLID WASTE MANAGEMENT AND ENERGY RECOVERY SPECIAL SERVICE DISTRICT RESOLUTION AUTHORIZING THE ISSUANCE OF SOLID WASTE MANAGEMENT REVENUE BONDS ADOPTED ON DECEMBER 26, 1984

BE IT RESOLVED by Davis County Solid Waste Management and Energy Recovery Special Service District (the "District"), as follows:

ARTICLE I

DEFINITIONS AND STATUTORY AUTHORITY

SECTION 101. SUPPLEMENTAL RESOLUTION. This resolution (the "First Supplemental Resolution") is supplemental to, and is adopted in accordance with Article XII of, the resolution adopted by the District on December 26, 1984, entitled "Davis County Solid Waste Management and Energy Recovery Special Service District Resolution Authorizing the Issuance of Solid Waste Management Revenue Bonds" (herein called the "Bond Resolution").

SECTION 102. DEFINITIONS. Except as amended or supplemented herein, all terms which are defined in Section 101 of the Bond Resolution shall have the same meanings, respectively, in this First Supplemental Resolution as such terms are given in said Section 101 of the Bond Resolution.

SECTION 103. AUTHORITY FOR THIS FIRST SUPPLEMENTAL RESOLUTION. This First Supplemental Resolution is adopted pursuant to the provisions of the Act.

ARTICLE II

AMENDMENTS AND SUPPLEMENTS TO SECTIONS 101, 103, 202, 206, 307, 401, 402, 403, 404, 504, 505, 506, 512, 701, 801, 901, 906, 910, 1001 and 1506 AND THE ADDITION OF A NEW ARTICLE II-A AND NEW SECTIONS 410, 411 AND 905-A TO THE BOND RESOLUTION

SECTION 201. AMENDMENTS AND SUPPLEMENTS TO SECTION 101 OF THE BOND RESOLUTION. Section 101 is hereby supplemented by the addition of the following definitions:

"Advance" shall have the meaning set forth in Section 201-A of this Resolution.

"Date of Issuance" shall mean the date specified by the District as the date of issuance of the Letter of Credit.

"Prime Rate" for any day shall mean the rate of interest for such day publicly announced by Banque Indosuez in New York City from time to time as its prime rate, it being understood and agreed that such rate shall not necessarily be the best or lowest rate of interest made available to such bank's best or most preferred prime large commercial customers; provided that the Prime Rate shall in no event be greater than 105% of the average prime rates of Citibank, N.A., The Chase Manhattan Bank, N.A., and Manufacturers Hanover Trust Company.

"Supplemental Interest Payment Date" shall mean each January 1, April 1, July 1 and October 1.

"Tender Advance" shall have the meaning set forth in Section 202-A(3).

"Termination Date" shall mean the date one year after the Expiration Date as defined in the Reimbursement Agreement.

(b) "Debt Service Requirement" under Section 101 of the Bond Resolution is hereby supplemented to read as follows:

"Debt Service Requirement" means, for any date of calculation, the sum of (i) the amount of the interest to accrue on all Bonds then Outstanding and the Letter of Credit Note during the then current Fiscal Year excluding however interest on all Series 1984 Bonds then bearing interest at the Variable Rate, and (ii) the aggregate principal amount of the Bonds then Outstanding and the Letter of Credit Note coming due during the then current Fiscal Year, plus the aggregate principal amount of all such Bonds required to be redeemed from sinking fund installments during the then current Fiscal Year provided, however, that any calculation with respect to the Letter of Credit Note for purposes of determining the Debt Service Requirement shall be based on written certification by an officer of the Bank and, in the absence of such certification, on the next preceding certification of an officer of the Bank and further, provided, however, that the amount contained in such certification shall be based on the Prime Rate on the date of such certification.

(c) "Gross Operating Receipts" under Section 101 of the Bond Resolution is hereby supplemented to read as follows:

"Gross Operating Receipts" means

(1) all moneys derived by the District from the sale of steam and Recovered Materials after the Actual

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Commercial Operation Date from, in connection with, or as a result of the operation of the Project, including User Tipping Fees and Service Charges as defined in the Services Contract.

(2) proceeds of business interruption insurance maintained by the Operator pursuant to the Operating Contract.

(3) damages paid by the Contractor under Article XIII(B) of the Construction Contract, and

(4) damages paid by the Operator to the District under Section 6.2, 6.3 or 6.4 of the Operating Contract.

(d) Section 101 of the Bond Resolution is hereby supplemented by the addition of the following definition:

"Letter of Credit Note" means the note of the District, authorized hereby, made as of December 1, 1984 evidencing the obligations of the District to the Bank under the Reimbursement Agreement.

(e) "Pledged Funds" under Section 101 of the Bond Resolution is hereby amended to read as follows:

"Pledged Funds" means all funds and accounts established by the Resolution, other than the Remarketing Account, the Standby Account and the Letter of Credit Account.

(f) "Services Contracts" under Section 101 of the Bond Resolution is hereby supplemented to read as follows:

"Services Contracts" means the various Solid Waste Disposal Services Contracts each dated as of December 1, 1984 and each entered into by the District and a political subdivision of the State of Utah and any contracts in substantially such form hereafter entered into by the District and a political subdivision of the State of Utah each as amended from time to time, in accordance with the terms of such contract and the terms hereof.

(g) "Trust Estate" under Section 101 of the Bond Resolution is hereby supplemented to read as follows:

"Trust Estate" means the property pledged under Section 401 hereof.

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SECTION 202. SUPPLEMENT TO SECTION 103 OF BOND RESOLUTION. Section 103 of the Bond Resolution is hereby supplemented to read as follows:

Resolution to Constitute Contract. In consideration of the acceptance by the Trustee of the trusts created hereby and of the purchase and acceptance of any and all of the Bonds authorized to be issued hereunder by those who shall hold the same from time to time, and of the issuance of the Letter of Credit by the Bank this Resolution shall be deemed to be and shall constitute a contract among the District, the Trustee, the Bank and the Holders from time to time of the Bonds; and the pledges made in this Resolution and the covenants and agreements herein set forth to be performed on behalf of the District shall be for the equal benefit, protection and security of the holder of the Letter of Credit Note as its interests may appear and the Holders of any and all of the Bonds all of which, regardless of the time or times of their authentication and delivery or maturity, shall be of equal rank without preference, priority or distinction of any of the Bonds over any other thereof except as expressly provided in or permitted by this Resolution.

SECTION 203. SUPPLEMENT TO SECTION 202 OF THE BOND RESOLUTION. Section 202 of the Bond Resolution is hereby supplemented to read as follows:

Issuance of Additional Bonds. So long as no Event of Default has occurred and is continuing, except for Events of Default that will be cured by the application of the proceeds from the sale of the Additional Bonds then being issued in accordance with this Resolution and the Series Resolution providing for the issuance thereof, the District, to the extent permitted by law in effect at the time thereof may issue Additional Bonds on a parity with the Series 1984 Bonds from time to time for the purpose of providing funds (i) to complete the Project by paying further Costs of the Project; (ii) to finance Authorized Capital Expenditures; (iii) to finance Capital Improvements; and (iv) to refund Outstanding Bonds, provided, however, that so long as either the Letter of Credit or the Letter of Credit Note remain outstanding (A) the Additional Bonds shall be totally secured as to principal, interest and premium, if any, by a letter of credit (i) which is issued by a bank or other lending institution approved by the Bank, which approval shall not be unreasonably withheld and (ii) the terms and conditions of which letter of credit shall be approved by the Bank, which approval shall not be unreasonably withheld, (B) the payments to the bank or other financial institution issuing such letter of credit shall be paid from the Operating Fund and (C) such letter of credit as well as the resolution authorizing the Additional Bonds shall include a provision that as an immediate first remedy in the event of the occurrence of

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an event of default thereunder there shall be an acceleration of the Additional Bonds and a drawing under such letter of credit.

Such Additional Bonds shall be issued in such series and principal amounts within the limitations herein provided, shall be dated, shall bear interest at such rate or rates, shall be subject to redemption at such times and prices, and shall mature on such date or dates as the Series Resolution authorizing the issuance thereof shall fix and determine, and shall be deposited with the Trustee for authentication and delivery. Such Additional Bonds need not be payable from drawings under the Letter of Credit provided, however, no such Additional Bonds are to be payable from drawings under the Letter of Credit, so long as the Bonds are Outstanding and payable from drawings under the Letter of Credit, unless the Letter of Credit is increased to an amount sufficient to pay principal, interest and premium, if any on such Additional Bonds.

SECTION 204. SUPPLEMENT TO SUBSECTION 206(a)(2) OF THE BOND RESOLUTION. Subsection 206(a)(2) of the Bond Resolution is hereby supplemented to read as follows:

A request and authorization to the Trustee on behalf of the District signed by an Authorized Officer to authenticate and deliver the Bonds of such series to the purchaser or purchasers therein identified upon payment to the Trustee for the account of the District of a specified sum equal to the purchase price of the Bonds of such series, plus a specified sum equal to accrued interest, if any, to the date of such delivery. The proceeds of sale of the Bonds of such series shall be paid over to the Trustee and deposited to the credit of the Debt Service Fund, the Debt Service Reserve Fund, the Extension and Repair Fund and the Construction Fund as provided herein or, if and to the extent required in such Series Resolution, in the Series Resolution under which the Bonds of such series are issued.

SECTION 205. SUPPLEMENT TO BOND RESOLUTION BY ADDING NEW ARTICLE II-A. The Resolution is hereby supplemented by the addition of a new Article II-A to read as follows:

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ARTICLE II-A

SECTION 201-A. Authorization of Letter of Credit Note. The District hereby authorizes the issuance, execution and delivery, on the date of the execution of the second amendment to the Letter of Credit authorized simultaneously herewith, of the Letter of Credit Note designated "Letter of Credit Note Davis County Solid Waste Management and Energy Recovery Special Service District, Davis County, Utah" payable to the order of the Bank to evidence obligations under the Reimbursement Agreement. Such Letter of Credit Note shall be issued to the Bank in substantially the form attached to this Resolution at Appendix D and the Bank shall, and is hereby authorized by the District to, endorse on the schedule forming a part of the Letter of Credit Note appropriate notations evidencing the date, amount and maturity of each Advance evidenced by such Letter of Credit Note and the date or amount of each payment therefor.

The Letter of Credit Note shall be on the following terms:

(A) The Letter of Credit Note shall be dated the Date of Issuance;

(B) any amount drawn under the Letter of Credit and not reimbursed pursuant to Section 2.03 of the Reimbursement Agreement on the day drawn shall constitute an advance (individually, an "Advance" and collectively, "Advances") to the District on the date of such drawing, which the District shall be obligated to repay as provided in the Letter of Credit Note;

(C) Each Advance shall bear interest on the unpaid principal amount thereof at a rate per annum equal to the Prime Rate from time to time in effect. Interest payable pursuant to this Section shall be payable quarterly in arrears on each Supplemental Interest Payment date and upon prepayment or maturity of the relevant Advance;

(D) Each Advance shall bear interest from and including the date of payment upon the drawing under the Letter of Credit giving rise to such Advance until but not including the date on which it is repaid in full. Interest shall be computed on the basis of a year of 365 days (366 days in a leap year) and paid for the actual number of days elapsed (including the first day but excluding the last day). Any overdue principal and, to the extent permitted by law, overdue interest shall bear interest, payable on demand, for each day until paid at a rate per annum equal to the sum of one percent plus the Prime Rate.

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SECTION 202-A. Repayment of Principal of Letter of Credit Note. The principal amount of Advances evidenced by the Letter of Credit Note shall become due and payable and shall be repaid as provided below:

(1) The outstanding principal and accrued interest of each Advance shall be repaid in full on the Termination Date.

(2) each Advance that arises from payment of an Interest Draft under the Letter of Credit (an "Interest Advance") shall be repaid in full on demand.

(3) Each Advance that arises from payment of a Tender Draft under the Letter of Credit (a "Tender Advance") shall be repaid in full on the earliest of (i) the date on which Bonds purchased with the proceeds of a Tender Advance are resold, (ii) the date on which such Bonds are redeemed by the District pursuant to Section 304 or Section 305 of this Resolution or (iii) the Termination Date. The proceeds of any resale of such Bonds pursuant to Section 304 or Section 305 of this Resolution shall be applied by the Bank in full in repayment of such outstanding Tender Advance, and the District shall, on the day of such resale, pay to the Bank any additional amounts required to pay such outstanding Tender Advance in full.

SECTION 203-A. Prepayment of Letter of Credit Note. The District may at any time and from time to time repay or cause to be repaid any principal amount of the Letter of Credit not represented by an Advance, in whole or in part, and, if in part, in amounts aggregating not less than $50,000 and any integral multiple thereof, without penalty or premium, together with interest accrued thereon to the date of payment.

SECTION 204-A. Payments. (a) All payments made, or caused to be made, by the District to the Bank with respect to the Letter of Credit Note shall be made from the Operating Fund upon requisition of the Bank upon which the Trustee may conclusively rely, in lawful currency of the United States and by check or draft or by wire transfer in immediately available funds at the account of the Bank in New York specified in the Letter of Credit Note. Payment in accordance with the foregoing to the Bank shall discharge the obligation of the District to make such payment.

(b) Whenever any payment by the District under any provision of the Letter of Credit Note shall be due on a day which is not a Business Day, the date for payment thereof shall be extended to the

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next succeeding Business Day, together with interest thereon for such extended time at the applicable rate in effect.

(c) Any payment to be made to the Bank on the day of a draw under the Letter of Credit shall be applied by the Bank in reimbursement of such draw unless the District informs the Bank that such payment is in repayment of an Advance. The preceding sentence shall not be applicable to any payment of proceeds of the resale of Bonds tendered pursuant to Section 304 of the Resolution, which shall be applied as set forth in Section 3.03(c) of the Reimbursement Agreement.

(d) Any interest paid pursuant to the terms of the Resolution to the Bank as a holder of any Bonds purchased with the proceeds of a Tender Advance shall be applied by the Bank (i) if received on a Supplemental Interest Payment Date, toward the payment of interest due under the Letter of Credit Note on such date or (ii) if received on a date other than a Supplemental Interest Payment Date, toward the payment of interest due on the Letter of Credit Note on the next succeeding Supplemental Interest Payment Date.

SECTION 205-A. Execution; Limited Obligations. The Letter of Credit Note shall be executed on behalf of the District by the manual signature of the Chairman. The Letter of Credit Note shall be a limited obligation of the District payable solely from the Revenues and the moneys from time to time on deposit in the funds and accounts created hereunder including the Qualified Investments in which such moneys are invested. The Letter of Credit Note shall not constitute or give rise to a general obligation of the state or any political subdivision or agency thereof or a charge against the general credit or taxing power of the District, or the State or any political subdivision or agency thereof.

SECTION 206. SUPPLEMENT TO SECTION 307 OF THE BOND RESOLUTION. Section 307 of Bond Resolution is hereby supplemented to read as follows:

Notice of Redemption. Notice of the call for redemption of Bonds pursuant to Section 301, 302, 303 or 305(a) or pursuant to any Series Resolution unless such Series Resolution shall provide that this Section shall not be applicable to such redemption, identifying the Bonds to be redeemed shall be given by the Trustee in the name of the District by mailing a copy of the redemption notice by first class mail at least fifteen (15) days, in the case of redemptions pursuant to Section 302(b), and at least thirty (30) days in the case of all other redemptions, prior to the redemption date to the Holder of each such Bond to be redeemed at the address shown on the registration books kept by the Trustee. Notice of the call for redemption of Bonds under Section 305(b) shall be given at the time

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provided in Section 207(b)(ii) and otherwise in accordance with the provisions of this Section. The District shall notify the Trustee in writing of any redemption pursuant to Section 301 or Section 302 not less than forty-five (45) days prior to the date set for redemption.

No notice provided for in this Section 307 for redemption of Bonds under Section 301 shall be given by the Trustee, until (i) the District shall have provided to the Bank evidence reasonably satisfactory to the Bank, that there will be on deposit in the Redemption Fund on the redemption date, amounts sufficient to redeem the Bonds to be redeemed and (ii) the Letter of Credit Note shall not have any principal amount outstanding, provided, no such notice may be given less than 30 days before the redemption date.

SECTION 207. SUPPLEMENT TO SUBSECTION 403(c) OF THE BOND RESOLUTION. Section 403(c) of the Bond Resolution is hereby amended to read as follows:

In furtherance of the foregoing provisions of this Section 403, and to the extent the District is permitted by law so to covenant, the District covenants to enact, maintain (and so long as the Letter of Credit or Letter of Credit Note is outstanding not to modify or repeal) and, to the extent practicable within its power, to enforce the Waste Stream Ordinance.

SECTION 208. SUPPLEMENT TO SECTION 401 OF THE BOND RESOLUTION. Section 401 of the Bond Resolution is hereby supplemented to read as follows:

Pledge; Payment of Principal, Interest and Premium. To secure the punctual payment of the principal of, and premium, if any, and interest on the Bonds and the Letter of Credit Note and to secure all amounts due from time to time under the Reimbursement Agreement to the Bank, the District hereby pledges and grants a security interest to the Trustee and the Bank, for the equal and ratable benefit of the Holders from time to time of the Bonds, the Letter of Credit Note and for the Bank, in and to all of its right, title and interest (but not the obligations thereunder) in the Services Contracts including but not limited to its right to receive User Tipping Fees and Service Charges as defined therein and in the Revenues and the Pledged Funds and the amounts from time to time on deposit therein and the Qualified Investments in which such amounts are invested and the proceeds thereof subject to the provisions hereof permitting the application of the Pledged Funds to the purposes set forth herein and covenants to use the Pledged Funds for no other purpose than to pay the principal of and premium, if any, and interest on the Bonds and the Letter of Credit Note and amounts due from time to time under the Reimbursement Agreement, except as otherwise expressly authorized in this Resolution, all subject to the provisions of this Resolution.

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The District covenants to deposit all Gross Operating Receipts received by it with the Trustee promptly, and in any event by the close of business on the third Business Day following such receipt. The District covenants that it will promptly pay the principal of and interest, any premium on the Bonds and the Letter of Credit Note and amounts due from time to time under the [Reimbursement Agreement] at the place, on the dates and in the manner provided herein, in the Bonds, the Letter of Credit Note and the Reimbursement Agreement according to the true intent and meaning hereof and thereof. Such principal and interest, any such premium and amounts due under the Letter of Credit Note and amounts due from time to time under the Reimbursement Agreement are limited obligations of the District payable solely from the Services Contracts, the Revenues and the moneys from time to time deposited in the Pledged Funds, including the Qualified Investments in which such moneys are invested, which Revenues, Services Contracts, moneys and investments are hereby specifically pledged and assigned to the payment thereof in the manner and to the extent herein specified, subject, in the case of moneys deposited in the Pledged Funds, to the provisions hereof permitting the application of such moneys for the purposes set forth herein. The Bonds shall not constitute nor give rise to a general obligation or liability of the District or the State or any political subdivision or agency thereof or a charge against the general credit or taxing power of any of the foregoing and the District shall not be obligated to pay the same except from the Revenues and moneys pledged or assigned therefor or derived from the rights, title and interests pledged or assigned therefor.

SECTION 209. SUPPLEMENT TO SECTION 402 OF THE BOND RESOLUTION. Section 402 of the Bond Resolution is hereby supplemented to read as follows:

Limitation on District's Liability. Each of the covenants by the District with the Trustee and the holder of the Letter of Credit Note, Bondholders and the Bank set forth in this Article or elsewhere herein shall be subject to the provisions of Section 401 hereof with respect to the status of the Bonds, the Letter of Credit Note and amounts due from time to time under the Reimbursement Agreement as limited obligations of the District and the limitations set forth in this Section 402. No breach by the District of any provision, condition or warranty of this Resolution shall impose any pecuniary liability upon the District or any charge upon its general credit. The liability of the District under this Resolution or any provision, condition or warranty herein included or for any breach or default by the District of any of the foregoing shall be limited solely and exclusively to the Trust Estate created hereby.

The District shall be entitled to the advice of counsel and shall be wholly protected as to action taken or omitted to be taken

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in good faith in reliance on such advice. The District may rely conclusively on any communication or other document furnished to it hereunder and reasonably believed to be genuine. The District shall not be liable for any action (a) taken by it in good faith and reasonably believed by it to be within the discretion or powers conferred upon it, or (b) in good faith omitted to be taken by it because reasonably believed to be beyond the discretion or powers conferred upon it, or (c) taken by it pursuant to any direction or instruction by which it is governed hereunder or (d) omitted to be taken by it by reason of the lack of any direction or instruction required hereunder for such action; nor shall it be responsible for the consequences or any error in judgment reasonably made by it. The District shall in no event be liable for the application or misapplication of funds, of for other acts or defaults, by any person except its own officers and employees and the Members of the Governing Authority. When any consent or other action by the District is called for herein, it may defer such action for a reasonable period of time pending such investigation or inquiry or receipt of such evidence (if any) as it may require in support thereof. No permissive right or power to act which the District may have shall be construed as a requirement to act; and no delay in the exercise of any such right or power shall effect the subsequent exercise of that right or power. No recourse shall be had by the Trustee, the Bank or any Bondholder for any claim based on this Resolution, the Letter of Credit Note, or the Bonds against any officer, employee or agent of the District or Member of the Governing Authority alleging personal liability on the part of such person unless such claim is based upon the willful dishonesty of or intentional violation of law by such person.

SECTION 210. SUPPLEMENT TO SECTION 404 OF THE BOND RESOLUTION. Section 404 of the Bond Resolution is hereby supplemented to read as follows:

Performance of Covenants by District. The District covenants that it will faithfully perform at all times any and all covenants, agreements, undertakings, stipulations and provisions contained in this Resolution, in any and every Bond executed and delivered hereunder and in the Letter of Credit Note and the Reimbursement Agreement, and in all proceedings of the District pertaining thereto. The District covenants that it is duly authorized under the Constitution and laws of the State to issue the Bonds which have been authorized hereby, to adopt this Resolution deliver the Letter of Credit Note, enter into the Reimbursement Agreement and to pledge and grant a security interest in the Service Contracts, Revenues and Pledged Funds in the manner and to the extent herein set forth.

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SECTION 211. NEW SUPPLEMENTAL SECTION 410. The Bond Resolution is hereby supplemental by the addition of a new Section 410 to read as follows:

Amendments to Services Contracts. The Services Contracts may be amended from time to time in accordance with the terms thereof provided, however that so long as the Letter of Credit or the Letter of Credit Note is in full force and effect and the Bank is not wrongfully dishonoring any drawing thereunder any amendment may be made only with the consent of the Bank and further provided that any amendment may be made to the Services Contracts without the consent of the Trustee.

SECTION 212. NEW SUPPLEMENTAL SECTION 411. The Bond Resolution is hereby supplemented by the addition of a new section 411 to read as follows:

So long as the Letter of Credit is outstanding and the Bank is not wrongfully dishonoring a drawing thereunder, the District hereby covenants that prior to giving of any notice under Section 307 to the Trustee with respect to a redemption described in Section 301, the District shall deposit or cause to be deposited in the Redemption Fund amounts sufficient to pay the Bonds to be redeemed in accordance with such notice.

SECTION 213. AMENDMENT TO SUBSECTION 504(d) OF THE BOND RESOLUTION. Subsection 504(d) of the Bond Resolution is hereby amended to read as follows:

Subject to the next succeeding sentence the Trustee shall, from time to time, withdraw from the Debt Service Fund and within such fund from the appropriate Series Debt Service Account and (i) remit by mail to the Holder of each Bond the amount required to pay interest on such Bond as such interest becomes due and (ii) set aside in trust an amount equal to the amount of, and for the sole and exclusive purpose of paying, the principal of all Bonds, or portions thereof in the case of redemption by application of sinking fund installments, as such principal becomes due at maturity or by reason of redemption by application of sinking fund installments. Notwithstanding the foregoing sentence, the Trustee shall in lieu of withdrawing moneys from the Series 1984 Debt Service Account of the Debt Service Fund for payment of principal of and interest on any Series 1984 Bonds of each maturity payable from amounts drawn under the Letter of Credit, withdraw moneys from the Letter of Credit Account, to the extent moneys are on deposit in such Letter of Credit Account, and apply the moneys so withdrawn to the payment of the principal of and interest on the Series 1984 Bonds of such maturity. On the second Wednesday of each month, or if such Wednesday is not a Business Day on the next succeeding Business Day, the Trustee shall

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withdraw from the Series 1984 Debt Service Account and deposit into the Revenue Fund, the amount deposited therein pursuant to Section 503(b)(2) which has not been used to reimburse the Bank pursuant to Section 504 or to pay interest to the Series 1984 Bonds. In addition, at the written direction of the Bank prior to the Actual Commercial Operation Date, the Trustee shall transfer to the Bank from the Debt Service Fund the amount necessary to pay the Letter of Credit Fee.

SECTION 214. SUPPLEMENT TO SUBSECTION 505(c) OF THE BOND RESOLUTION. Subsection 505(c) of the Bond Resolution is hereby supplemented to read as follows:

Moneys deposited into a Series Redemption Account shall be used to redeem in whole or in part the Bonds of the related series Outstanding to the extent of such moneys so long as no Event of Default described in Section 901(a) or (b) has occurred and is continuing hereunder; provided, however that, in the case of the Series 1984 Redemption Account, moneys deposited therein shall, in lieu of such use, be used to pay the principal portion of the Letter of Credit Note, to the extent of such moneys, to reimburse the Bank for drawings under the Letter of Credit, to pay the principal due on redemption prior to maturity (except for redemption pursuant to Section 303) of Series 1984 Bonds of each maturity which are payable from amounts drawn under the Letter of Credit by transfer of immediately available funds on the date of such drawing provided, however, that any calculation with respect to the Letter of Credit Note with respect to such payments shall be based upon written certification by the Bank and, in the absence of such certification on the next preceding certification by the Bank; and provided further, however, that as and when directed by the District in writing, so long as there shall remain in such Series Redemption Account moneys sufficient for the redemption of Bonds of the related Series called for redemption and not purchased by the Trustee pursuant to this Section, the Trustee shall use such moneys in such Series Redemption Account to purchase (and in such event shall cancel) Bonds of the related series either (i) at a public or private sale, with or without advertisement, in such manner, from such person or persons, at such prices as the District shall direct in writing or (ii) pursuant to such other directions in writing as the District may in its discretion give the Trustee, but in either case only to the extent such moneys are in excess of the amount required for payment of the Bonds of the related series theretofore matured or called for redemption, the premium thereon, if any, and past due interest in all cases when Bonds of the related series have not been presented for payment. No redemption shall be required if the amount in the applicable Series Redemption Account shall be less than $100,000.

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To the extent moneys have been paid into the Redemption Fund pursuant to Section 505(i) and notice of redemption shall not have been given pursuant to Section 307, money deposited therein shall be used to pay the Letter of Credit Note for drawings under the Letter of Credit, provided, however, that any calculation with respect to the Letter of Credit Note with respect to such payments shall be based upon written certification by the Bank and, in the absence of such certification on the next preceding certification by the Bank.

SECTION 215. SUPPLEMENT TO SECTION 512 OF THE BOND RESOLUTION. Section 512 of the Bond Resolution is hereby supplemented to read as follows:

Repayment of Funds. After payment in full of the Bonds and any amounts due and owing under the Letter of Credit Note and the Reimbursement Agreement (the calculation of such amounts due and owing being based upon written certification by an authorized officer of the Bank) and the fees, charges and expenses of the Trustee and any paying agents and all other amounts required to be paid under this Resolution any amount remaining in any of the funds held by the Trustee hereunder shall be paid to the District.

SECTION 216. SUPPLEMENT TO SECTION 701 OF THE BOND RESOLUTION. Section 701 of the Bond Resolution is hereby supplemented to read as follows:

Construction Fund Investments. Any moneys held in the various Construction Accounts shall be invested and reinvested by the Trustee, at the written direction of the District, in specified Qualified Investments and so long as the Letter of Credit is in full force and effect and the Bank is not wrongfully dishonoring any drawing thereunder with the consent of the Bank (which consent will be deemed given as to any investment or reinvestment of moneys if no objection has been received by the Trustee from the Bank either in writing, by telecopy or telex or orally by telephone by the time such investments or reinvestments are to be made). Such investments shall be held by or under the control of the Trustee and shall be deemed at all times a part of the Construction Fund. The interest accruing thereon and any profit resulting therefrom prior to the Actual Commercial Operation Date shall be credited first to the Operating Fund to the extent necessary so that the amount of such interest and profit so credited to the Operating Fund equals the sum of (1) $1,200,000 plus (2) the amount of Letter of Credit Fees paid from the Operating Fund prior to delivery of the Bank Notice to the Trustee, and thereafter to be retained in the Construction Fund. Any such interest accruing and profit resulting therefrom after the Actual Commercial Operation Date shall be credited to the Revenue Fund. Such investments shall mature in such amounts and have maturity dates

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or be subject to redemption at the option of the holder thereof on or prior to the date on which the amounts so invested will be needed for the purposes of the various Construction Accounts. The Trustee is directed to sell and convert to cash a sufficient amount of such investments whenever the cash held in the Construction Fund is insufficient to pay a requisition when presented or to make a timely disbursement required to be made therefrom.

The District hereby covenants to provide the Bank with notification of any direction to the Trustee to invest Construction Fund moneys in the manner provided in the above paragraph, either in writing, by telecopy or telex or orally by telephone not less than thirty (30) minutes prior to any such investment or reinvestment.

SECTION 217. SUPPLEMENT TO SECTION 801 OF THE BOND RESOLUTION. Section 801 of the Bond Resolution is hereby supplemented to read as follows:

Discharge of the Lien of the Resolution. When all of the Bonds shall have been paid, or shall be deemed to have been paid as provided in Section 802 hereof, and all amounts due under the Letter of Credit Note and the Reimbursement Agreement have been paid as evidenced by a certificate of the Bank and if the District shall not then be in default under any of its other obligations under this Resolution, the Bonds, the Letter of Credit Note or the Reimbursement Agreement as evidenced by a certificate of the Bank, and if the District shall have caused to be paid all other sums of money due or to become due hereunder to the Trustee (or shall have made provision for such payment satisfactory to the Trustee), then the lien of this Resolution, these presents and the rights hereby granted shall cease, terminate and be void, and thereupon the Trustee shall, at the written direction of the District, cancel and discharge this Resolution and execute and deliver to the District such instruments in writing as shall be required by the District to cancel and discharge this Resolution and assign and deliver to the District any property at the time subject to the Resolution which may be in its possession or subject to its control, except for moneys and obligations held in the Debt Service Fund, Debt Service Reserve Fund and Redemption Fund for the purpose of paying Bonds which have not yet been presented for payment.

SECTION 218. SUPPLEMENT TO SECTION 901 OF THE BOND RESOLUTION. Section 901 of the Bond Resolution is hereby supplemented to read as follows:

Defaults. The occurrence of any of the following events, subject to the provisions of Section 910 hereof, is hereby defined as and declared to be and to constitute an "Event of Default":

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(a) Default in the payment of any interest on any Bond;

(b) Default in the due and punctual payment of the principal of or any premium on any Bond, whether at the stated maturity thereof, or upon sinking fund or other proceedings for redemption thereof, or upon the maturity thereof by declaration;

(c) Failure by the District to observe and perform any other covenant, condition or agreement on the part of the District in this Resolution or in the Bonds;

(d) Failure by the Bank to honor a proper draft under the Letter of Credit;

(e) Failure to make due and punctual payment of principal or interest under the Letter of Credit Note or an "Event of Default" under the Reimbursement Agreement".

SECTION 219. NEW SUPPLEMENTAL SECTION 905-A. The Bond Resolution is hereby supplemented by the addition of a new Section 905-A to read as follows:

Rights of Bank When There Are No Bondholders. In the event that there are no Bondholders within the meaning of the Resolution, and the obligations under the Letter of Credit Note or the Reimbursement Agreement remain outstanding, then the rights granted to "the holders of a majority of aggregate principal amount of Bonds then Outstanding" under Sections 904 and 905 hereof and to "the holders or owners of not less than twenty-five per cent (25%) in aggregate principal amount of Bonds then Outstanding" under Section 908 hereof may be exercised by the Bank to the extent and in the manner such rights could have been exercised by such Bondholders under such Sections.

SECTION 220. SUPPLEMENT TO SECTION 906 OF THE BOND RESOLUTION. Section 906 of the Bond Resolution is hereby supplemented to read as follows:

Application of Moneys. All moneys received by the Trustee pursuant to any right given or action taken under the provisions of this Article shall, after payment of the costs and expenses of the proceedings resulting in the collection of such moneys and of the expenses, liabilities and advances incurred or made by the Trustee, be deposited into the Debt Service Fund and all moneys in the Debt Service Fund together with all moneys in the Revenue Fund, the

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Construction Fund, the Surplus Fund, the Redemption Fund and the Debt Service Reserve Fund shall be applied as follows:

(a) Unless the principal of all the Bonds shall have become or shall have been declared due and payable, all such moneys shall be applied:

First--To the payment to the persons entitled thereto of all installments of interest then due on the Bonds in the order of the maturity of the installments of such interest and, if the amount available shall not be sufficient to pay in full any particular installment, then to the payment ratably, according to the amount due on such installments, to the persons entitled thereto, without any discrimination or privilege; and

Second--To the payment to the persons entitled thereto of the unpaid principal of any of the Bonds which shall have become due (other than principal of Bonds with respect to the payment of which moneys are held pursuant to the provisions of this Resolution), in the order of their due dates, with interest on such Bonds from the respective dates upon which they or such principal became due and, if the amount available shall not be sufficient to pay in full Bonds or the principal thereof due on any particular date, together with such interest, then to the payment ratably, according to the amount of principal due on such date, to the persons entitled thereto without any discrimination or privilege.

Third--To the payment to the persons entitled thereto of all amounts of principal and interest due and owing under the Letter of Credit Note and all amounts due and owing under the Reimbursement Agreement.

(b) If the principal of all the Bonds shall have become due or shall have been declared due and payable, all such moneys shall be applied to the payment of the principal and interest then due and unpaid upon the Bonds without preference or priority of principal over interest or of interest over principal, or of any installment of interest over any other installment of interest, or of any Bond over any other Bond, ratably,

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according to the amounts due respectively for principal and interest, to the persons entitled thereto without any discrimination or privilege and then to the payment to the persons entitled thereto of all amounts of principal and interest due under the Letter of Credit Note and all amounts due under the Reimbursement Agreement.

(c) If the principal of all the Bonds shall have been declared due and payable, and if such declaration shall thereafter have been rescinded and annulled under the provisions of this Article then, subject to the provisions of paragraph (b) of this Section in the event that the principal of all the Bonds shall later become due or be declared due and payable, the moneys shall be applied in accordance with the provisions of paragraph (a) of this Section.

Notwithstanding the foregoing provisions of this Section 906, any moneys derived from a drawing under the Letter of Credit may be used only to pay the unpaid principal of or interest on the Series 1984 Bonds then due.

Whenever moneys are to be applied pursuant to the provisions of this Section, such moneys shall be applied at such times, and from time to time, as the Trustee shall determine, having due regard to the amount of such moneys available for application and the likelihood of additional moneys becoming available for such application in the future. Whenever the Trustee shall apply such funds, it shall fix the date (which shall be an interest payment date unless it shall deem another date more suitable) upon which such application is to be made and upon such date interest on the amounts of principal to be paid on such dates shall cease to accrue. The Trustee shall give such notice as it may deem appropriate of the deposit with it of any such moneys and of the fixing of any such date, and shall not be required to make payment to the holder of any Bond until such Bond shall be presented to the Trustee for appropriate endorsement or for cancellation if paid in full.

Whenever all Bonds and premiums, if any, and interest thereon and all principal and interest due and owing under the Letter of Credit Note and all amounts due and owing under the Reimbursement Agreement have been paid under the provisions of this

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Section and all expenses and charges of the Trustee have been paid, any balance remaining in the Debt Service Fund shall be paid to the District.

SECTION 221. SUPPLEMENT TO SECTION 910 OF THE BOND RESOLUTION. Section 910 of the Bond Resolution is hereby supplemented to read as follows:

Waivers of Defaults. The Trustee may in its discretion waive any Event of Default hereunder and its consequences and rescind and annul any declaration of maturity of principal, and shall do so upon the written request of the holders of: (1) a majority in aggregate principal amount of all Bonds then Outstanding with respect to which a default in the payment of principal or interest on the Bonds exists in the case of a default in the payment of principal of or interest on the Bonds; or (2) a majority in aggregate principal amount of all Bonds then Outstanding in the case of any other default; provided, however, that there shall not be waived (a) any Event of Default respecting the payment of the principal of any Bond at its maturity date or redemption date prior to maturity, or (b) any Event of Default which resulted in a drawing under the Letter of Credit unless the stated amount thereof has been fully reinstated, or (c) any Event of Default respecting the payment of the interest on any Bond (d) any Event of Default under (e) of Section 901 of this Resolution, unless prior to such waiver or rescission, all arrears of principal (due otherwise than by declaration) and interest, with interest (to the extent permitted by law) at the rate borne by the Bonds with respect to which such default shall have occurred on overdue installments of interest and all arrears of payments of principal when due, as the case may be, and all expenses of the Trustee in connection with such default, shall have been paid or provided for, and in the case of any such waiver or rescission or in case any proceeding(s) taken by the Trustee on account of any such default shall have been discontinued or abandoned or determined adversely, then and in every such case the District, the Trustee and the Bondholders shall be restored to their former positions and rights hereunder, respectively, but no such waiver or rescission shall extend to any subsequent or other default, or impair any right consequent thereon and further provided that so long as the Letter of Credit is in full force and effect and the Bank is not wrongfully dishonoring any drawing thereunder no default under Section 901(e) can be waived without the consent of the Bank.

SECTION 222. SUPPLEMENT TO SECTION 1001(C) OF THE BOND RESOLUTION. Section 1001(o) of the Bond Resolution is hereby amended to read as follows:

(o) With respect to the Bank, the Trustee undertakes to perform and observe only such of its covenants and

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obligations as are specifically set forth in this Resolution, and no implied covenants or obligations with respect to the Bank shall be read into this Resolution against the Trustee, and the Trustee shall not be deemed to owe any fiduciary duty to the Bank in its capacity as such and shall have no obligation to enforce the Reimbursement Agreement.

SECTION 223. SUPPLEMENT TO SECTION 1506 OF THE BOND RESOLUTION. Section 1506 of the Bond Resolution is supplemented to read as follows:

Certain Provisions Relating to the Bank. Notwithstanding anything to the contrary herein, references to the Bank in this Resolution shall be deemed to be effective only during the period prior to the date the Series 1984 Bonds are no longer payable from the Letter of Credit and the Letter of Credit Note is outstanding and thereafter shall be of no further force or effect.

SECTION 224. SUPPLEMENT TO APPENDIX C OF THE BOND RESOLUTION Appendix C of the Bond Resolution is hereby amended to read as follows:

ORDINANCE REQUIRING DELIVERY OF PROCESSIBLE WASTE TO THE SOLID WASTE MANAGEMENT FACILITY

WHEREAS, the Davis County Solid Waste Management and Energy Recovery Special Service District (the "District") has determined that construction of a solid waste management facility (the "Facility") as defined in Section 2(2) of the Utah Solid Waste Management Act, chapter 32 of Title 26, Utah Code Annotated (1953), as amended, is necessary in Davis County in order to protect, preserve and enhance the environment within Davis County, and

WHEREAS, the District has entered into Davis Solid Waste Disposal Services Contracts with certain cities (the "Contracts") in Davis County pursuant to which Contracts the Cities have agreed to supervise and regulate the collection, transportation and disposition of all Processible Waste ("Processible Waste," constituting "Solid Waste" as defined in the Solid Waste Management Act which is processible by the Facility) generated within their respective jurisdictions (including any territory annexed thereto in the future) as authorized by the Solid Waste Management Act, and

WHEREAS, the Utah Solid Waste Management Act provides among other things, that the governing body of a public entity may

(1) regulate the collection, transportation and disposition of all Solid Waste within its jurisdiction;

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(2) require that all such Solid Waste generated within its jurisdiction be delivered to a solid waste management facility;

(3) control the right to collect, transport, and dispose of all Solid Waste generated within its jurisdiction;

NOW, THEREFORE, BE IT ORDAINED by the Board of Commissioners of Davis County, Utah acting as the governing authority of the District;

(1) All ordinances and resolutions or parts thereof in conflict herewith are hereby repealed to the extent of such conflict.

(2) Beginning on the date provided in the notice given by the owner of the Facility (referred to in the preamble hereinabove) directly to any City for the commencement of delivery of Processible Waste to the Facility or in the Notice given by the District as to the Effective Date for the commencement of delivery of Processible Waste to the Landfill (each as defined in Section 2.1 of the Contracts), all persons (including private collectors of Solid Waste operating within the jurisdiction of the District), except persons within Cities that have executed and delivered effective Contracts, shall deliver all Processible Waste (as defined in the preamble hereinabove) generated within the District and any territory annexed thereto in the future, to the Facility or the Landfill in accordance with the contract; provided, however, that in the event the Facility is operating at capacity or is Shutdown as provided in the Contracts referred to in the preamble hereinabove, such persons, including private collectors of Solid Waste operating within the jurisdiction of the District, shall, upon the direction of the owner of the Facility, deliver all Processible Waste to a landfill or landfills within Davis County.

(3) If any one or more of the provisions of this ordinance should be contrary to law, then such provisions shall be null and void and shall be deemed separable from the remaining provisions, and shall in no way affect the validity of any of the other provisions.

(4) this ordinance shall become effective as provided by law.

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ARTICLE III

Miscellaneous

SECTION 301. OTHER PARAGRAPHS NOT EFFECTED. All paragraphs of the Bond Resolution, other than those referred to in Article II of this First Supplemental Resolution, are hereby ratified, confirmed and continued in their entirety and are not hereby amended or supplemented in any respect.

SECTION 302. EFFECTIVE DATE. This First Supplemental Resolution shall take effect immediately upon its adoption.

ADOPTED: July 22, 1985.

/s/ Harry B. Gerlach, Sr.
Chairman Pro Tem

ATTEST:

/s/ Michael G. Allphin
County Clerk

[SEAL]

LETTER OF CREDIT NOTE

DAVIS COUNTY SOLID WASTE MANAGEMENT AND ENERGY RECOVERY SPECIAL SERVICE DISTRICT, DAVIS COUNTY, UTAH

LC No. _____

The DAVIS COUNTY SOLID WASTE MANAGEMENT AND ENERGY RECOVERY SPECIAL SERVICE DISTRICT, DAVIS COUNTY, UTAH (the "Service District") hereby promises to pay to the order of Banque Indosuez (the "Bank") at the account specified below, the sum of the aggregate unpaid principal amount of all Advances made by the Bank to the Service District pursuant to the Reimbursement Agreement. Each Advance shall bear interest on the unpaid principal amount thereof at the rate or rates provided for in the Reimbursement Agreement. All such payments of principal and interest shall be made in lawful currency of the United States and in immediately available funds at the account of Banque Indosuez at

_____

This note is the Letter of Credit Note referred to in the Reimbursement Agreement dated as of December 1, 1984 between the District and the Bank, as the same may be amended from time to time (the "Reimbursement Agreement"). Terms defined in the Reimbursement Agreement are use herein with the same meanings. Reference is made to the Reimbursement Agreement for provisions for the prepayment hereof.

Any principal amount of this Note which arises from a Tender Advance and any Bonds purchased with the proceeds of such Tender Advance shall evidence the same indebtedness; any interest paid pursuant to the terms of the Resolution to the Bank as a holder of such Bonds shall be applied by the Bank toward the payment of interest due on this Note, and the proceeds of any resale of such Bonds shall be applied by the Bank in full in repayment of the amount outstanding hereunder from such Tender Advance.

This Letter of Credit Note is issued to evidence the Advances, if any, made for the purpose of providing funds to pay the principal of and any interest on Bonds, as defined in the Reimbursement Agreement.

All Advances made by the Bank to the District and all repayments of the principal thereof shall be recorded at the time of the making of such Advance or repayment by the Bank on the Schedule attached hereto, or on a continuation of such Schedule.

Reference is hereby made to the Reimbursement Agreement for the provisions, among other things, with respect to the nature and extent of the security for this Letter of Credit Note, the manner and enforcement of such security, the custody and application of the proceeds of this Letter of Credit Note, and the rights, duties and obligations of the Service District and the Bank.

This Letter of Credit Note shall be governed by and construed in accordance with the laws of the State of Utah.

IN WITNESS WHEREOF, the Service District, has caused this note to be signed for and on its behalf and in its name by the Chairman of the Board of County Commissioners of Davis County, and the official seal of the Service District to be affixed hereto, all as of the __ day of , 198 .

DAVIS COUNTY SOLID WASTE
MANAGEMENT AND ENERGY RECOVERY
SPECIAL SERVICE DISTRICT

By_____
Title: Chairman

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Appendix II – C

Commissioners Minutes

Indosuez, New York Branch, as Letter of Credit Bank under Resolution document Appendix B; Letter from District to Moody's Investors Service; Amending and Consent Agreement, dated July 15, 1985 by and between the District and the Trustee; Amendatory Solid Waste Disposal Services Contracts by and between the District and various Davis County entities and the First Supplemental Resolution of the District, amending and supplementing the Resolution. After a short discussion, Mr. Hess recommended and Commissioner Tippetts made a motion to adopt the First Supplemental Resolution (#85-150) Amending and Supplementing the Bond Resolution, to adopt a resolution (#85-151) authorizing the execution of an amendment to the Reimbursement Agreement dated December 1, 1984 as heretofore amended, between the District and Banque Indosuez and to adopt a resolution (#85-152) to authorize the Chairman to execute a Letter of Credit Note and to authorize, confirm, ratify, adopt and approve the following documents, including all actions taken by the Administrative Control Board of the District with respect thereto: Amending and Consent Agreement, dated May 8, 1985 by and between the District and the Trustee pursuant to the Resolution; Amendatory Agreement, dated May 8, 1985 by and between the District and Banque Indosuez, New York Branch as Letter of Credit Bank under the Resolution; Letter from the District to Moody's Investors Service; Amending and Consent Agreement, dated July 15, 1985 by and between the District and the Trustee; Amendatory Solid Waste Disposal Services Contracts by and between the District and the Cities and the First Supplemental Resolution of the District amending and supplementing the Resolution. Commissioner Gerlach gave the second to approve the above motion which unanimously carried with each voting "aye".

RESOLUTION #85-150 FOR RELEASE OF FUNDS APPROVED

RESOLUTION #85-151 FOR EXECUTION & DELIVERY OF AMENDMENT

RESOLUTION #85-152 FOR RELEASE OF FUNDS APPROVED

#85-150
FIRST SUPPLEMENTAL RESOLUTION
to
THE DAVIS COUNTY SOLID WASTE MANAGEMENT AND ENERGY RECOVERY SPECIAL SERVICE DISTRICT RESOLUTION AUTHORIZING THE ISSUANCE OF SOLID WASTE MANAGEMENT REVENUE BONDS ADOPTED ON DECEMBER 26, 1984

BE IT RESOLVED by Davis County Solid Waste Management and Energy Recovery Special Service District (the "District"), as follows:

ARTICLE I

DEFINITIONS AND STATUTORY AUTHORITY

SECTION 101. SUPPLEMENTAL RESOLUTION. This resolution (the "First Supplemental Resolution") is supplemental to, and is adopted in accordance with Article XII of, the resolution adopted by the District on December 26, 1984, entitled "Davis County Solid Waste Management and Energy Recovery Special Service District Resolution Authorizing the Issuance of Solid Waste Management Revenue Bonds" (herein called the "Bond Resolution").

SECTION 102. DEFINITIONS. Except as amended or supplemented herein, all terms which are defined in Section 101 of the Bond Resolution shall have the same meanings, respectively, in this First Supplemental Resolution as such terms are given in said Section 101 of the Bond Resolution.

SECTION 103. AUTHORITY FOR THIS FIRST SUPPLEMENTAL RESOLUTION. This First Supplemental Resolution is adopted pursuant to the provision of the Act.

ARTICLE II

AMENDMENTS AND SUPPLEMENTS TO SECTIONS 101, 103, 202, 206, 307, 401, 402, 403, 404, 504, 505, 506, 512, 701, 801, 901, 906, 910, 1001 AND 1506 AND THE ADDITION OF A NEW ARTICLE II-A AND NEW SECTIONS 410, 411 AND 905-A TO THE BOND RESOLUTION

SECTION 201. AMENDMENTS AND SUPPLEMENTS TO SECTION 101 OF THE BOND RESOLUTION. Section 101 is hereby supplemented by the addition of the following definitions:

"Advance" shall have the meaning set forth in Section 201-A of this Resolution.

"Date of Issuance" shall mean the date specified by the District as the date of issuance of the Letter of Credit.

"Prime Rate" for any day shall mean the rate of interest for such day publicly announced by Banque Indosuez in New York City from time to time as its prime rate, it being understood and agreed that such rate shall not necessarily be the best or lowest rate of interest made available to such bank's best or most preferred prime large commercial customers; provided that the Prime Rate shall in no event be greater than 105% of the average prime rates of Citibank, N.A., The Chase Manhattan Bank, N.A., and Manufacturers Hanover Trust Company.

"Supplemental Interest Payment Date" shall mean each January 1, April 1, July 1 and October 1.

"Tender Advance" shall have the meaning set forth in Section 202-A(3).

"Termination Date" shall mean the date one year after the Expiration Date as defined in the Reimbursement Agreement.

(b) "Debt Service Requirement" under Section 101 of the Bond Resolution is hereby supplemented to read as follows:

"Debt Service Requirement" means, for any date of calculation, the sum of (i) the amount of the interest to accrue on all Bonds then Outstanding and the Letter of Credit Note during the then current Fiscal Year excluding however interest on all Series 1984 Bonds then bearing interest at the Variable Rate, and (ii) the aggregate principal amount of the Bonds then Outstanding and the Letter of Credit Note coming due during the then current Fiscal Year, plus the aggregate principal amount of all such Bonds required to be redeemed from sinking fund installments during the then current Fiscal Year provided, however, that any calculation with respect to the Letter of Credit Note for purposes of determining the Debt Service Requirement shall be based on written certification by an officer of the Bank and, in the absence of such certification, on the next preceding certification of an officer of the Bank and further, provided, however, that the amount contained in such certification shall be based on the Prime Rate on the date of such certification.

(c) "Gross Operating Receipts" under Section 101 of the Bond Resolution is hereby supplemented to read as follows:

"Gross Operating Receipts" means

(1) all moneys derived by the District from the sale of steam and Recovered Materials after the Actual Commercial Operation Date from, in connection with, or as a result of the operation of the Project, including User Tipping Fees and Service Charges as defined in the Services Contract.

(2) proceeds of business interruption insurance maintained by the Operator pursuant to the Operating Contract.

(3) damages paid by the Contractor under Article XIII(b) of the Construction Contract, and

(4) damages paid by the Operator to the District under Section 6.2, 6.3 or 6.4 of the Operating Contract.

(d) Section 101 of the Bond Resolution is hereby supplemented by the addition of the following definition:

"Letter of Credit Note" means the note of the District, authorized hereby, made as of December 1, 1984 evidencing the obligations of the District to the Bank under the Reimbursement Agreement.

(e) "Pledged Funds" under Section 101 of the Bond Resolution is hereby amended to read as follows:

"Pledged Funds" means all funds and accounts established by the Resolution, other than the Remarketing Account, the Standby Account and the Letter of Credit Account.

(f) "Services Contracts" under Section 101 of the Bond Resolution is hereby supplemented to read as follows:

"Services Contracts" means the various Solid Waste Disposal Services Contracts each dated as of December 1, 1984 and each entered into by the District and a political subdivision of the State of Utah and any contracts in substantially such form hereafter entered into by the District and a political subdivision of the State of Utah each as amended from time to time, in accordance with the terms of such contract and the terms hereof.

(g) "Trust Estate" under Section 101 of the Bond Resolution is hereby supplemented to read as follows:

"Trust Estate" means the property pledged under Section 401 hereof.

SECTION 202. SUPPLEMENT TO SECTION 103 OF BOND RESOLUTION. Section 103 of the Bond Resolution is hereby supplemented to read as follows:

Resolution to Constitute Contract. In consideration of the acceptance by the Trustee of the trusts created hereby and of the purchase and acceptance of any and all of the Bonds authorized to be issued hereunder by those who shall hold the same from time to time, Resolution shall be deemed to be and shall constitute a contract among the District, the Trustee, the Bank and the Holders from time to time of the Bonds: and the pledges made in this Resolution and the covenants and agreements herein set forth to be performed on behalf of the District shall be for the equal benefit, protection and security of the holder of the Letter of Credit Note as its interests may appear and the Holders of any and all of the Bonds all of which, regardless of the time or time of their authentication and delivery or maturity, shall be of equal rank without preference, priority or distrinction of any of the Bonds over any other thereof except as expressly provided in or permitted by this Resolution.

SECTION 203. SUPPLEMENT TO SECTION 202 OF THE BOND RESOLUTION. Section 202 of the Bond Resolution is hereby supplemented to read as follows:

Issuance of Additional Bonds. So long as no Event of Default has occurred and is continuing, except for Events of Default that will be cured by the application of the proceeds from the sale of the Additional Bonds then being issued in accordance with this Resolution and the Series Resolution providing for the issuance thereof, the District, to the extent permitted by law in effect at the time thereof may issue Additional Bonds on a parity with the Series 1984 Bonds from time to time for the purpose of providing funds (i) to complete the Project by paying further Costs of the Project; (ii) to finance Authorized Capital Expenditures (iii) to finance Capital Improvements; and (iv) to refund Outstanding Bonds, provided, however, that so long as either the Letter of Credit or the Letter of Credit Note remain outstanding (A) the Additional Bonds shall be totally secured as to principal, interest and premium, if any, by a letter of credit (i) which is issued by a bank or other lending institution approved by the Bank, which appproval shall not be unreasonably withheld and (ii) the terms and conditions of which letter of credit shall be approved by the Bank, which approval shall not be unreasonably withheld, (b) the payments to the bank or other financial institution issuing such letter of credit shall be paid from the Operating Fund and (C) such letter of credit as well as the resolution authorizing the Additional Bonds shall include a provision that as an immediate first remedy in the event of the occurrence of an event of default thereunder there shall be an acceleration of the Additional Bonds and a drawing under such letter of credit.

Such Additional Bonds shall be issued in such series and principal amounts within the limitations herein provided, shall be dated, shall bear interest at such rate or rates, shall be subject to redemption at such times and prices, and shall matrue on such date or dates as the Series Resolution authorizing the issuance thereof shall fix and determine, and shall be deposited with the Trustee for authentication and delivery. Such Additional Bonds need not be payable from drawings under the Letter of Credit provided, however, no such Additional Bonds are to be payable from drawings under the Letter of Credit, so long as the Bonds are outstanding and payable from drawings under the Letter of Credit, unless the Letter of Credit is increased to an amount sufficient to pay principal, interest and premium, if any on such Additional Bonds.

SECTION 204. SUPPLEMENT TO SUBSECTION 206(a) (2) OF THE BOND RESOLUTION. Subsection 206(a)(2) of the Bond Resolution is hereby supplemented to read as follows:

A request and authorization to the Trustee on behalf of the District signed by an Authorized Officer to authenticate and deliver the Bonds of such series to the purchaser or purchasers therein identified upon payment to the Trustee for the account of the District of a specified sum equal to the purchase price of the Bonds of such series, plus a specified sum equal to accrued interest, if any, to the date of such delivery. The proceeds of sale of the Bonds of such series shall be paid over to the Trustee and deposited to the credit of the Debt Service Fund, the Debt Service Reserve Fund, the Extension and Repair Fund and the Construction Fund as provided herein or, if and to the extent required in such Series Resolution, in the Series Resolution under which the Bonds of such series are issues.

SECTION 205. SUPPLEMENT TO BOND RESOLUTION BY ADDING NEW ARTICLE II-A. The Resolution is hereby supplemented by the addition of a new Article II-A to read as follows:

ARTICLE II-A

SECTION 201-A. Authorization of Letter of Credit Note. The District hereby authorizes the issuance, execution and delivery, on the date of the execution of the second amendment to the Letter of Credit authorized simultaneously herewith, of the Letter of Credit Note designated "Letter of Credit Note Davis County Solid Waste Management and Energy Recovery Special Service District, Davis County, Utah" payable to the order of the Bank to evidence obligations under the Reimbursement Agreement. Such Letter of Credit Note shall be issued to the Bank in substantially the form attached to this Resolution at Appendix D and the Bank shall, and is hereby authorized by the District to, endorse on the schedule forming a part of the Letter of Credit Note appropriate notations evidencing the date, amount and maturity of each Advance evidenced by such Letter of Credit NOte and the date or amount of each payment therefor.

The Letter of Credit Note shall be on the following terms:

(A) The Letter of Credit Note shall be dated the Date of Issuance;

(B) Any amount drawn under the Letter of Credit and not reimbursed pursuant to Section 2.03 of the Reimbursement Agreement on the day drawn shall constitute an advance (individually, an "Advance" and collectively, "Advances") to the District on the date of such drawing, which the District shall be obligated to repay as provided in the Letter of Credit Note;

(C) Each Advance shall bear interest on the unpaid principal amount thereof at a rate per annum equal to the Prime Rate from time to time in effect. Interest payable pursuant to this Section shall be payable quarterly in arrears on each Supplemental Interest Payment date and upon prepayment or maturity of the relevant Advance;

(D) Each Advance shall bear interest from and including the date of payment upon the drawing under the Letter of Credit giving rise to such Advance until but not including the date on which it is repaid in full. Interest shall be computed on the basis of a year of 365 days (366 days in a leap year) and paid for the actual number of days elapsed (including the first day but excluding the last day). Any overdue principal and, to the extent permitted by law, overdue interest shall bear interest, payable on demand, for each day until paid at a rate per annum equal to the sum of one percent plus the Prime Rate.

SECTION 202-A. Repayment of Principal of Letter of Credit Note. The principal amount of Advances evidenced by the Letter of Credit Note shall become due and payable and shall be repaid as provided below:

(1) The outstanding principal and accrued interest of each Advance shall be repaid in full on the Termination Date.

(2) Each Advance that arises from payment of an Interest Draft under the Letter of Credit (an "Interest Advance") shall be repaid in full on demand.

(3) Each Advance that arises from payment of a Tender Draft under the Letter of Credit (a "Tender Advance") shall be repaid in full on the earliest of (i) the date on which Bonds purchased with the proceeds of a Tender Advance are resold, (ii) the date on which such Bonds are redeemed by the District pursuant to Section 304 or Section 305 of this Resolution or (iii) the Termination Date. The proceeds of any resale of such Bonds pursuant to Section 304 or Section 305 of this Resolution shall be applied by the Bank in full in repayment of such outstanding Tender Advance, and the District, shall, on the day of such resale, pay to the Bank any additional amounts required to pay such outstanding Tender Advance in full.

SECTION 203-A. Prepayment of Letter of Credit Note. The District may at any time and from time to time repay or cause to the repaid any principal amount of the Letter of Credit not represented by an Advance, in whole or in part, and, if in part, in amounts aggregating not less than $50,000 and any integral multiple thereof, without penalty or premium, together with interest accrued thereon to the date of payment.

SECTION 204-A. Payments. (a) All payments made, or caused to be made, by the District to the Bank with respect to the Letter of Credit Note shall be made from the Operating Fund upon requisition of the Bank upon which the Trustee may conclusively rely, in lawful currency of the United States and by check or draft or by wire transfer in immediately available funds at the account of the Bank in New York specified in the Letter of Credit Note. Payment in accordance with the foregoing to the Bank shall discharge the obligation of the District to make such payment.

(b) Whenever any payment by the District under any provisions of the Letter of Credit Note shall be due on a day which is not a Business Day, the date for payment thereof shall be extended to the next succeeding Business Day, together with interest thereon for such extended time at the applicable rate in effect.

(c) Any payment to be made to the Bank on the day of a draw under the Letter of Credit shall be applied by the Bank in reimbursement of such draw unless the District informs the Bank that such payment is in repayment of an Advance. The preceding sentence shall not be applicable to any payment of proceeds of the resale of Bonds tendered pursuant to Section 304 of the Resolution, which shall be applied as set forth in Section 3.03(c) of the Reimbursement Agreement.

(d) Any interest paid pursuant to the terms of the Resolution to the Bank as a holder of any Bonds purchased with the proceeds of a Tender Advance shall be applied by the Bank (i) if received on a supplemental interest Payment Date, toward the payment of interest due under the Letter of Credit Note on such date or (ii) if received on a date other than a Supplement Interest Payment Date, toward the payment of interest due on the Letter of Credit Note on the next succeeding Supplemental Interest Payment Date.

SECTION 205-A. Execution; Limited Obligations. The Letter of Credit Note shall be executed on behalf of the District by the manual signature of the Chairman. The Letter of Credit Note shall be a limited obligation of the District payable solely from the Revenues and the moneys from time to time on deposit in the funds and accounts created hereunder including the Qualified Investments in which such moneys are invested. The Letter of Credit Note shall not constitute or give rise to a general obligation of the state or any political subdivision or agency thereof or a charge against the general credit or taxing power of the District, or the State or any political subdivision or agency thereof.

SECTION 206. SUPPLEMENT TO SECTION 307 OF THE BOND RESOLUTION. Section 307 of Bond Resolution is hereby supplemented to read as follows:

Notice of Redemption. Notice of the call for redemption of Bonds pursuant to Section 301, 302, 303 or 305(a) or pursuant to any Series Resoltuion unless such Series Resolution shall provide that this Section shall not be applicable to such redemption, identifying the Bonds to be redeemed shall be given by the Trustee inthe name of the District by mailing a copy of the redemption notice by first class mail at least fifteen (15) days, in the case of redemptions pusuant to Section 302(b), and at least thirty (30) days in the case of all other redemptions, prior to the redemption date to the Holder of each such Bond to be redeemed at the address shown on the registration books kept by the Trustee. Notice of the call for redemption of Bonds under Section 305(b) shall be given at the time

provided in Section 207 (b)(ii) and otherwise in accordance with the provisions of this Section. The District shall notify the Trustee in writing of any redemption pursuant to Section 301 or Section 302 not less than forty-five (45) days prior to the date set for redemption.

No notice provided for in this Section 307 for redemption of Bonds under Section 301 shall be given by the Trustee, until (i) the District shall have provided to the Bank evidence reasonably satisfactory to the Bank, that there will be on deposit in the Redemption Fund on the redemption date, amounts sufficient to redeem the Bonds to be redeemed and (ii) the Letter of Credit Note shall not have any principal amount outstanding, provided, no such notice may be given less than 30 days before the redemption date.

SECTION 207. SUPPLEMENT TO SUBSECTION 403 (c) OF THE BOND RESOLUTION. Section 401 of the Bond Resolution is hereby amended to read as follows:

In furtherance of the foregoing provisions of this Section 403, and to the extent the District is permitted by law so to covenant, the District covenants to enact, maintain (and so long as the Letter of Credit or Letter of Credit Note is outstanding not to modify or repeal) and, to the extent practicable within its power, to enforce the Waste Stream Ordinance.

SECTION 208. SUPPLEMENT TO SECTION 401 OF THE BOND RESOLUTION. Section 401 of the Bond Resolution is hereby supplemented to read as follows:

Pledge; Payment of Principal, Interest and Premium. To secure the punctual payment of the principal of, and premium, if any, and interest on the Bonds and the Letter of Credit Note and to secure all amounts due from time to time under the Reimbursement Agreement to the Bank, the District hereby pledges and grants a security interest to the Trustee and the Bank, for the equal and ratable benefit of the Holders from time to time of the Bonds, the Letter of Credit Note and for the Bank, in and to all of its right, title and interest (but not the obligations thereunder) in the Services Contracts including but not limited to its right to receive User Tipping Fees and Service Charges as defined therein and in the Revenues and the Pledged Funds and the amounts from time to time on deposit therein and the Qualified Investments in which such amounts are invested and the proceeds thereof subject to the provisions hereof permitting the applications of the Pledged Funds to the purposes set forth herein and covenants to use the Pledged Funds for no other purpose than to pay the principal of and premium, if any, and interest on the Bonds and the Letter of Credit Note and amounts due from time to time under the Reimbursement Agreement, except as otherwise expressly authorized in this Resolution, all subject to the provisions of this Resolution. This District covenants to deposit all Gross Operating Receipts received by it with the Trustee promptly, and in any event by the close of business on the third Business Day folowing such receipt. The District covenants that it will promptly pay the principal of and amounts due from time to time under the (Reimbursements Agreement) at the place, on the dates and in the manner provided herein, in the Bonds, the Letter of Credit Note and the Reimbursement Agreement according to the true intent and meaning hereof and thereof. Such principal and interest, any such premium and amounts due under the Letter of Credit NOte and amounts due from time to time under the Reimbursement Agreement are limited obligations of the District payable solely from the Services Contract, the Revenues and the moneys from time to time deposited in the Pledged Funds, including the Qualified Investements in which such moneys are invested, which Revenues, Services Contracts, moneys and investments are hereby specifically pledged and assigned to the payment thereof in the manner and to the extent herein specified, subject, in the case of moneys deposited in the Pledged Funds, to the provisions hereof permitting the application of such moneys for the purposes set forth herein. The Bonds shall not constitute nor give rise to a general obligation or liability of the District or the State or any political subdivision or agency thereof or a charge against the general credit or taxing power of any of the foregoing and the District shall not be obligated to pay the same except from the Revenues and moneys pledged or assigned therefor or derived from the rights, title and interests pledged or assigned therefor.

SECTION 209. SUPPLEMENT TO SECTION 402 OF THE BOND RESOLUTION. Section 402 of the Bond Resolution is hereby supplemented to read as follows:

Limitation on District's Liability. Each of the covenants by the District with the Trustee and the holder of the Letter of Credit Note, Bondholders and the Bank set forth in this Article or elsewhere herein shall be subject to the provisions of Section 401 hereof with respect to the status of the Bonds, the

Letter of Credit Note and amounts due from time to time under the Reimbursement Agreement as limited obligations of the District and the limitations set forth in this Section 402. No breach by the District of any provision, condition or warranty of this Resolution shall impose any pecuniary liability upon the District or any charge upon its general credit. The liability of the District under this Resolution or any provision, condition or warranty herein included or for any breach or default by the District of any of the foregoing shall be limited solely and exclusively to the Trust Estate created hereby.

The District shall be entitled to the advice of counsel and shall be wholly protected as to action taken or omitted to be taken in good faith in reliance on such advice. The District may rely conclusively on any communication or other document furnished to it hereunder and reasonably believed to be genuine. The District shall not be liable for any action (a) taken by it in good faith and reasonably believed by it to be within the discretion or powers conferred upon it, or (b) in good faith omitted to be taken by it because reasonably believed to be beyond the discretion or powers conferred upon it, or (c) taken by it pursuant to any direction or instruction by which it is governed hereunder or (d) omitted to be taken by it by reason of the lack of any direction or instruction required hereunder for such action; nor shall it be responsible for the consequences or any error in judgment reasonably made by it. The District shall in no event by liable for theapplication or misapplication of funds, of for other acts or defaults, by any person except its own officers and employees and the Members of the Governing Authority. When any consent or other action by the District is called for herein, it may defer such action for a reasonable period of time pending such investigation or inquiry or receipt of such evidence (if any) as it may require in support thereof. No permissive right or power to act which the District may have shall be construed as a requirement to act; and no delay in the exercise of any such right or power shall effect the subsequent exercise of that right or power. No recourse shall be had by the Trustee, the Bank or any Bondholder for any claim based on this Resolution, the Letter of Credit Note, or the Bonds against any officer, employee or agent of the District of Member of the Governing Authority alleging personal liability on the part of such person unless such claim is based upon the willful dishonesty of or intentional violation of law by such person.

SECTION 210. SUPPLEMENT TO SECTION 404 OF THE BOND RESOLUTION. Section 404 of the Bond Resolution is hereby supplemented to read as follows:

Performance of Covenants by District. The District covenants that it will faithfully perform at all times any and all covenants, agreements, undertakings, stipulations and provisions contained in this Resolution, in any and every Bond executed and delivered hereunder and in the Letter of Credit Note and the Reimbursement Agreement, and in all proceedings of the District pertaining thereto. The District covenants that it is duly authorized under the Constitution and laws of the State to issue the Bonds which have been authorized hereby, to adopt this Resolution deliver the Letter of Credit Note, enter into the Reimbursement Agreement and to pledge and grant a security interest in the Service Contracts, Revenues and Pledged Funds in the manner and to the extent herein set forth.

SECTION 211. NEW SUPPLEMENTAL SECTION 410. The Bond Resolution is hereby supplemental by the addition of a new Section 410 to read as follows:

Amendments to Services Contracts. The Services Contracts may be amended from time to time in accordance with the terms thereof provided, however that so long as the Letter of Credit or the Letter of Credit Note is in full force and effect and the Bank is not wrongfully dishonoring any drawing thereunder any amendment may be made only with the consent of the Bank and further provided that any amendment may be made to the Services Contracts without the consent of the Trustee.

SECTION 212. NEW SUPPLEMENTAL SECTION 411. The Bond Resolution is hereby supplemented by the addition of a new Section 411 to read as follows:

So long as the letter of Credit is outstanding and the Bank is not wrongfully dishonoring a drawing thereunder, the District hereby covenants that prior to giving of any notice under Section 307 to the Trustee with respect to a redemption described in Section 301, the District shall deposit or cause to be deposited in the Redemption Fund amounts sufficient to pay the Bonds to be redeemed in accordance with such notice.

SECTION 213. AMENDMENT TO SUBSECTION 504(d) OF THE BOND RESOLUTION. Subsection 504(d) of the Bond Resolution is hereby amended to read as follows:

Subject to the next succeeding sentence the Trustee shall, from time to time, withdraw from the Debt Service Fund and within such fund from the appropriate Series Debt Service Account and (i) remit by mail to the Holder of each Bond the amount required to pay interest on such Bond as such interest becomes due and (ii) set aside in trust an amount equal to the amount of, and for the sole and exclusive purpose of paying, the principal of all Bonds, or portions thereof in the case of redemption by applicstion of sinking fund installments, as such principal becomes due at maturity or by reason of redemption by application of sinking fund installments. Notwithstanding the foregoing sentence, the Trustee shall in lieu of withdrawing moneys from the Series 1984 Debt Service Account of the Debt Service Fund for payment of principal of and interest on any Series 1984 Bonds of each maturity payable from aounts drawn under the Letter of Credit, withdraw moneys from the Letter of Credit Account, to the extent moneys are on deposit in such Letter of Credit Account, and apply the moneys so withdrawn to the payment of the principal of and the interest on the Series 1984 Bonds of such maturity. On the second Wednesday of each month, or if such Wednesday is not a Business Day on the next succeeding Business Day, the Trustee shall withdraw from the Series 1984 Debt Service Account and deposit into the Revenue Fund, the amount deposited therein pursuant to Section 503(b)(2) which has not been used to reimburse the Bank pursuant to Section 504 or to pay interest to the Series 1984 Bonds. In addition, at the written direction of the Bank prior to the Actual Commercial Operation Date, the Trustee shall transfer to the Bank from the Debt Service Fund the amount necessary to pay the Letter of Credit Fee.

SECTION 214. SUPPLEMENT TO SUBSECTION 505(c) OF THE BOND RESOLUTION. Subsection 505(c) of the Bond Resolution is hereby supplemented to read as follows:

Moneys deposited into a Series Redemption Account shall be used to redeem in whole or in part the Bonds of the related series Outstanding to the extent of such moneys so long as no Event of Default described in Section 901(a) or (b) has occurred and is continuing hereunder; provided, however that, in the case of the Series 1984 Redemption Account, moneys deposited therein shall, in lieu of such use, be used to pay the principal portion of the Letter of Credit Note, to the extent of such moneys, to reimburse the Bank for drawings, under the Letter of Credit, to pay the principal due on redemption prior to maturity (except for redemption pursuant to Section 303) of Series 1984 Bonds of each maturity which are payable from amounts drawn under the Letter of Credit by transfer of immediately available funds on the date of such drawing provided, however, that any calculation with respect to the Letter of Credit Note with respect to such payments shall be based upon written certification by the Bank and, in the absence of such certification on the next preceding certification by the Bank; and provided further, however, that as and when directed by the District in writing, so long as there shall remain in such Series Redemption Account moneys sufficient for the redemption of Bonds of the related Series called for redemption and not purchased by the Trustee pursuant to this Section, the Trustee shall use such moneys in such series Redemption Account to purchase (and in such event shall cancel) Bonds of the related series either (i) at a public or private sale, with or without advertisement, in such manner, from such person or presons, at such prices as the District shall direct in writing or (ii) pursuant to such other directions in writing as the District may in its discretion give the Trustee, but in either case only to the extent such moneys are in excess of the amount required for payment of the Bonds of the related series theretofore matured or called for redemption, the premium thereon, if any, and past due interest in all cases when Bonds of the related series have not been presented for payment. No redemption shall be required if the amount in the applicable Series Redemption Account shall be less than $100,000.

To the extent moneys have been paid into the Redemption Fund pursuant to Section 505(i) and notice of redemption shall not have been given pursuant to Section 307, money deposited therein shall be used to pay the Letter of Credit Note for drawings under the Letter of Credit, provided, however, that any calculation with respect to the Letter of Credit Note with respect to such payments shall be based upon written certification by the Bank and, in the absence of such certification on the next preceding certification by the Bank.

SECCTION 215. SUPPLEMENT TO SECTION 512 OF THE BOND RESOLUTION. Section 512 of the Bond Resolution is hereby supplemented to read as follows:

Repayment of Funds. After payment in full of the Bonds and any amounts due and owing under the Letter of Credit Note and the Reimbursement Agreement (the

calculation of such amounts due and owing being based upon written certification by an authorized officer of the Bank) and the fees, charges and expenses of the Trustee and any paying agents and all other amounts required to be paid under this Resolution any amount remaining in any of the funds held by the Trustee hereunder shall be paid to the District.

SECTION 216. SUPPLEMENT TO SECTION 701 OF THE BOND RESOLUTION. Section 701 of the Bond Resolution is hereby supplemented to read as follows:

Construction Fund Investments. Any moneys held in the various Construction Accounts shall be invested and reinvested by the Trustee, at the written direction of the District in specified Qualified Investments and so long as the Letter of Credit is in full force and effect and the Bank is not wrongfully dishonoring any drawing thereunder with the consent of the Bank (which consent will be deemed given as to any investment or reinvestment of moneys if no objection has been received by the Trustee from the Bank either in writing, by telecopy or telex or orally by telephone by the time such investments or reinvestments are to be made). Such investments shall be held by or under the control of the Trustee and shall be deemed at all times a part of the Construction Fund. The interest accruing thereon and any profit resulting therefrom prior to the Actual Commercial Operation Date shall be credited first to the Operating Fund to the extent necessary so that the amount of such interest and profit so credited to the Operating Fund equals the sum of (1) $1,200,000 plus (2) the amount of Letter of Credit Fees paid from the Operating Fund prior to delivery of the Bank Notice to the Trustee, and thereafter to be retained in the Construction Fund. Any such interest accruing and profit resulting therefrom after the Actual Commercial Operation Date shall be credited to the Revenue Fund. Such investments shall mature in such amounts and have maturity dates or be subject to redemption at the option of the holder thereof onor prior to the date on which the amounts so invested will be needed for the purposes of the various Construction Accounts. The Trustee is directed to sell and convert to cash a sufficient amount of such investments whenever the cash held in the Construction Fund is insufficient to pay a requisition when presented or to make a timely disbursement required to be made therefrom.

The District hereby covenants to provide the Bank with notification of any direction to the Trustee to invest Construction Fund moneys in the manner provided in the above paragraph, either in writing, by telecopy or telex or orally by telephone not less than thirty (30) minutes prior to any such investement or reinvestment.

SECTION 217. SUPPLEMENT TO SECTION 801 OF THE BOND RESOLUTION. Section 801 of the Bond Resolution is hereby supplemented to read as follows:

Discharge of the Lien of the Resolution. When all of the Bonds shall have been paid, or shall be deemed to have been paid as provided in Section 802 hereof, and all amounts due under the Letter of Credit Note and the Reimbursement Agreement have been paid as evidenced by a certificate of the Bank and if the District shall not then be in default under any of its other obligations under this Resolution, the Bonds, the Letter of Credit Note or the Reimbursement Agreement as evidenced by a certificate of the Bank, and if the District shall have caused to be paid all other sums of money due or to become due hereunder to the Trustee (or shall have made provision for such payment satisfactory to the Trustee), then the lien of this Resolution, these presents and the rights hereby granted shall cease, terminate and be void, and thereupon the Trustee shall, at the written direction of the District, cancel and discharge this Resolution and execute and deliver to the District such instruments in writing as shall be required by the Distrct to cancel and discharge this Resolution and assign and deliver to the District any property at the time subject to the Resolution which may be in its possession or subject to its control, except for moneys and obligations held in the Debt Service Fund, Debt Service Reserve Fund and Redemption Fund for the purpose of paying Bonds which have not yet been presented for payment.

SECTION 218. SUPPLEMENT TO SECTION 901 OF THE BOND RESOLUTION. Section 901 OF THE Bond Resolution is hereby supplemented to read as follows:

Defaults. The occurrence of any of the following events, subject to the provisions of Section 910 hereof, is hereby defined as and declared to be and to constitute an "Event of Default":

(a) Default in the payment of any interest on any Bond;

(b) Default in the due and punctual payment of the principal of or any premium on any Bond, whether at the stated maturity thereof, or upon sinking fund or other proceedings for redemption thereof, or upon the maturity thereof by declaration;

(c) Failure by the District to observe and perform any other covenant, condition or agreement on the part of the District in this Resolution or in the Bonds;

(d) Failure by the Bank to honor a proper draft under the Letter of Credit;

(e) Failure to make due and punctual payment of principal or interest under the Letter of Credit Note or an "Event of Default" under the Reimbursement Agreement".

SECTION 219. NEW SUPPLEMENTAL SECTION 905-A. The Bond Resolution is hereby supplemented by the addition of a new Section 905-A to read as follows:

Rights of Bank When There Are No Bondholders. In the event that there are no Bondholders within the meaning of the Resolution, and the obligations under the Letter of Credit Note or the Reimbursement Agreement remain outstanding, then the rights granted to "the holders of a majority of aggregate principal amount of Bonds then Outstanding" under Sections 904 and 905 hereof and to "the holders or owners of not less than twenty-five per cent (25%) in aggregate principal amount of Bonds then OUtstanding" under Section 908 hereof may be exercised by the Bank to the extent and in the manner such rights could have been exercised by such Bondholders under such Sections.

SECTION 220. SUPPLEMENT TO SECTION 906 OF THE BOND RESOLUTION. Section 906 of the Bond Resolution is hereby supplemented to read as follows:

Application of Moneys. All monesy received by the Trustee pursuant to any right given or action taken under the provisions of this Article shall, after payment of the costs and expenses of the proceedings resulting in the collection of such moneys and of the expenses, liabilities and advances incurred or made by the Trustee, be deposited into the Debt Service Fund and all moneys in the Debt Service Fund together with all moneys in the Revenue Fund, the Construction Fund, the Surplus Fund, the Redemption Fund and the Debt Service Reserve Fund shall be applied as follows:

(a) Unless the principal of all the Bonds shall have become or shall have been declared due and payable, all such moneys shall be applied:

First--To the payment to the persons entitled thereto of all installments of interest then due on the Bonds in the order of the maturity of the installments of such interest and, if the amount available shall not be sufficient to pay in full any particular installment, then to the payment ratably, according to the amount due on such installments, to the persons entitled thereto, without any discrimination or privilege; and

Second--To the payment to the persons entitled thereto of the unpaid principal of any of the Bonds which shall have beomce due (other than principal of Bonds with respect to the payment of which moneys are held pursuant to the provisions of this Resolution), in the order of their due dates, with interest on such Bonds from the respective dates upon which they or such principal became due and, if the amount available shall not be sufficient to pay in full Bonds or the principal thereof due on any particular date, together with such interest, then to the payment ratable, according to the amount of principal due on such date, to the persons entitled thereto without any discrimination or privilege.

Third--To the payment to the persons entitled thereto of all maounts of principal and interest due and owing under the Letter of Credit Note and all amounts due and owing under the Reimbursement Agreement.

(b) If the principal of all the Bonds shall have become due or shall have been declared due and payable, all such moneys shall be applied to the payment of the principal and interest then due and unpaid upon the Bonds without preference or priority of principal over interest or of interest over principal, or of any installment of interest over any other installment of interest, or of any Bond over any other Bond, ratably, according to the amounts due

respectively for principal and interest, to the persons entitled thereto without any discrimination or privilege and then to the payment to the persons entitled thereto of all amounts of principal and interest due under the Letter of Credit Note and all amounts due under the Reimbursement Agreement.

(c) If the principal of all the Bonds shall have been declared due and payable, and if such declaration shall thereafter have been rescinded and annulled under the provisions of this Article then, subject to the provisions of paragraph (b) of this Section in the event that the principal of all the Bonds shall later become due or be declared due and payable, the moneys shall be applied in accordance with the provisions of paragraph (a) of this Section.

Notwithstanding the foregoing provisions of this Section 906, any moneys derived from a drawing under the Letter of Credit may be used only to pay the unpaid principal of or interest on the Series 1984 Bonds then due.

Whenever moneys are to be applied pursuant to the provisions of this Section, such moneys shall be applied at such times, and from time to time, as the Trustee shall determine, having due regard to the amount of such moneys available for applicqtion and the likelihood of additional moneys becoming available for such application in the future. Whenever the Trustee shall apply such funds, it shall fix the date (which shall be an interest payment date unless it shall deem another date more suitable) upon which such application is to be made and upon such date interest on the amounts of principal to be paid on such dates on the amounts of principal to be paid onsuch dates shall cease to accrue. The Trustee shall give such notice as it may deem appropriate of the deposit with it of any such moneys and of the fixing of any such date, and shall not be required to make payment to the holder of any Bond until such Bond shall be presented to the Trustee for appropriate endorsement or for cancellation if paid in full.

Whenever all Bonds and premiums, if any, and interest thereon and all principal and interest due and owing under the Letter of Credit Note and all amounts due and owing under the Reimbursement Agreement have been paid under the provisions of this Section and all expenses and charges of the Trustee have been paid, any balance remaining in the Debt Service Fund shall be paid to the District.

SECTION 221. SUPPLEMENT TO SECTION 910 OF THE BOND RESOLUTION. Section 910 of the Bond Resolution is hereby supplemented to read as follows:

Waivers of Defaults. The Trustee may in its discretion waive any Event of Default hereunder and its consequences and rescind and annul any declaration of maturity of principal, and shall do so upon the written request of the holders of: (1) a majority in aggregate principal amount of all Bonds then Outstanding with respect to which a default in the payment of principal or interest on the Bonds exists in the case of a default in the payment of principal of or interest on the Bonds; or (2) a majority in aggregate principal amount of all Bonds then Outstanding in the case of any other default; provided, however, that there shall not be waived (a) any Event of Default respecting the payment of the principal of any Bond at its maturity date or redemption date prior to maturity, or (b) any Event of Default which resulted in a drawing under the Letter of Credit unless the stated amount thereof has been full reinstated, or (c) any Event of Default respecting the payment of the interest on any Bond (d) any Event of Default under (e) of Section 901 of this Resolution, unless prior to such waiver or rescission, all arrears of principal (due otherwise then by declaration) and interest, with interest (to the extent permitted by law) at the rate borne by the Bonds with respect to which such default shall have occurred on overdue installments of interest and all arrears of payments of principal when due, as the case may be, and all expenses of the Trustee in connection with such default, shall have been paid or provided for, and in the case of any such waiver or rescission or in case any proceeding(s) taken by the Trustee on account of any such default shall have been discontinued or abandoned or determined adversely, then and in every such case the District, the Trustee and the Bondholders shall be restored to their former positions and rights hereunder, respectively, but no such waiver or rescission shall extend to any subsequent or other default, or impair any right consequent thereon and further provided that so long as the Letter of Credit is in full force and effect and the Bank is not wrongfully dishonoring any drawing thereunder no default under Section 901(e) can be waived without the consent of the Bank.

SECTION 222. SUPPLEMENT TO SECTION 1001(C) OF THE BOND RESOLUTION. Section 1001(o) of the Bond Resolution is hereby amended to read as follows:

(o) With respect to the Bank, the Trustee undertakes to perform and observe only such of its covenants and obligations as are specifically set forth in this Resolution, and no implied covenants or obligations with respect to the Bank shall be read into this Resoltuion against the Trustee, and the Trustee shall not be deemed to own any fiduciary duty to the Bank in its capacity as such and shall have no obligation to enforce the Reimbursement Agreement.

SECTION 223. SUPPLEMENT TO SECTION 1506 OF THE BOND RESOLUTION. Section 1506 of the Bond Resoltuion is supplemented to read as follows:

Certain Provisions Relating to the Bank. Notwithstanding anything to the contrary herein, references to the Bank in this Resolution shall be deemed to be effective only during the period prior to the date the Series 1984 Bonds are no longer payable from the Letter of Credit and the Letter of Credit Note is outstanding and thereafter shall be of no further force or effect.

SECTION 224. SUPPLEMENT TO APPENDIX C OF THE BOND RESOLUTION. Appendix C of the Bond Resolution is hereby amended to read as follows:

ORDINANCE REQUIRING DELIVERY OF PROCESSIBLE
WASTE TO THE SOLID WASTE MANAGEMENT FACILITY

WHEREAS, the Davis County Solid Waste Management and Energy Recovery Special Service District (the "District") has determined that construction of a solid waste management facility (the "Facility") as defined in Section 2(2) of the Utah Solid Waste Management Act, chapter 32 of Title 26, Utah Code Annotated (1953), as amended, is necessary in Davis County in order to protect, preserve and enhance the environment within Davis County, and

WHEREAS, the District has entered into Davis Solid Waste Disposal Services Contracts with certain cities (the "Contracts") in Davis County pursuant to which Contracts the Cities have agreed to supervise and regulate the collection, transportation and disposition of all Processible Waste ("Processible Waste," constituting "Solid Waste" as defined in the Solid Waste Management Ace which is processible by the Facility) generated within their respective jurisdictions (including any territory annexed thereto in the future) asauthorized by the Solid Waste Management Act, and

WHEREAS, the Utah Solid Waste Management Act provides among other things, that the governing body of a public entity may

(1) regulate the collection, transportation and disposition of all Solid Waste within its jurisdiction;

(2) require that all such Solid Waste generated within its jurisdiction be delivered to a solid waste management facility;

(3) control the right to collect, transport, and dispose of all Solid Waste generated within its jurisdiction;

NOW, THEREFORE, BE IT ORDAINED by the Board of Commissioners of Davis County, Utah, acting as the governing authority of the District;

(1) All ordinances and resolutions or parts thereof in conflict herewith are hereby repealed to the extent of such conflict.

(2) Beginning on the date provided in the notice given by the owner of the Facility (referred to inthe preamble hereinabove) directly to any City for the commencement of delivery of Processible Waste to the Facility or in the NOtice given by the District as to the Effective Date for the commencement of delivery of Processible Waste to the Landfill (each as defined in Section 2.1 of the Contracts), all persons (including private collectors of Solid Waste operating within the jurisdiction of the District), except persons within Cities that have executed and delivered effective Contracts, shall deliver all Processible Waste (as defined in the preamble hereinabove) generated within the District and any territory annexed thereto in the future, to the Facility or the Landfill in accordance with the contract; provided, however, that in the event the Facility is operating at capacity or is Shutdown as provided in the Contracts referred to in the preamble hereinabove, such persons, including private collectors of Solid Waste operating within the jurisdiction of the District, shall, upon the direction of the owner of the Facility, deliver all Processible Waste to a landfill or landfills within Davis County.

(3) If any one or more of the provisions of this ordinance should be contrary to law, then such provisions shall be null and void and shall be deemed separable from the remaining provisions, and shall in no way affect the validity of any of the other provisions.

(4) This ordinance shall become effective as provided by law.

ARTICLE III
Miscellaneous

SECTION 301. OTHER PARAGRAPHS NOT EFFECTED. All paragraphs of the Bond Resolution, other than those referred to in Article II of this First Supplemental Resolution, are hereby ratified, confirmed and continued in their entirety and are not hereby amended or supplemented in any respect.

SECTION 302. EFFECTIVE DATE. This First Supplemental Resolution shall take effect immediately upon its adoption.

ADOPTED: July 22, 1985.

/s/ Harry B. Gerlach, Sr.
Chairman pro tem

ATTEST:

/s/ Michael G. Allphin
County Clerk

Appendix II – D

District Omnibus Certificate

$54,750,000
DAVIS COUNTY SOLID WASTE MANAGEMENT AND
ENERGY RECOVERY SPECIAL SERVICE DISTRICT,
SOLID WASTE
MANAGEMENT REVENUE BONDS, SERIES 1984

DATED: July 26, 1985

DISTRICT OMNIBUS CERTIFICATE

The undersigned, the duly authorized Chairman of the Administrative Control Board of the Davis County Solid Waste Management and Energy Recovery Special Service District, Utah (the "District"), hereby certifies as follows:

1. The Utah Special Service District Act, Chapter 23 of Title 11, Utah Code Annotated 1953, as amended, the Utah Solid Waste Management Act, Chapter 32 of Title 26, Utah Code Annotated 1953, as amended, the Utah Municipal Bond Act, Chapter 14 of Title 11, Utah Code Annotated 1953, as amended (collectively, the "Act") has not been modified, supplemented, amended or repealed in any way adversely affecting the organization of the District or its right to issue $54,750,000 Davis County Solid Waste Management and Energy Recovery Special Service District, Utah, Solid Waste Management Revenue Bonds, Series 1984 (the "Bonds"), and its right to make provision for the payment thereof in accordance with the laws pertaining thereto now in effect.

2. No forfeiture, dissolution or other proceedings or legislative measures adversely affecting the District have been instituted by the District or, to my knowledge, against it or on its behalf, and the District and its corporate privileges and franchises remain in good standing and the corporate and statutory power and authority of the District remain in full force and effect under the laws of the State of Utah.

3. The representations and warranties of the District contained in the Purchase Contract dated December 26, 1984 between the District and the Underwriters named therein (the "Purchase Contract"), with respect to the sale by the District of the Bonds, are true, complete and correct in all material respects on and as of the date hereof as if made on the date hereof.

4. Except for Wright, et al. v. Davis County, et al., Civil No. 36459, pending in the Second Judicial District Court of Davis County, Utah, to which reference is hereby made, no action, suit, proceeding, inquiry or investigation, at law or in equity, before or by any court, government agency or public board or body, is pending or, to the best of my knowledge, threatened, affecting the corporate existence of the District or the entitlement of the officers thereof to their respective offices or affecting or seeking to prohibit, restrain or enjoin the sale, issuance, or delivery of the Bonds or the collection of the revenues of the District pledged or to be pledged to pay the principal of and interest on the Bonds, or in any way contesting or affecting the validity or enforceability of the Bonds, the Bond Resolution or the Related Documents (as each is defined in the Purchase Contract) or the "First Supplemental Resolution to the Davis County Solid Waste Management and

Energy Recovery Special Service District Resolution Authorizing the Issuance of Solid Waste Management Revenue Bonds adopted on December 26, 1984" (the "Supplemental Resolution") amending the Bond Resolution or contesting the tax-exempt status of the interest on the Bonds as described in the Official Statement dated December 26, 1984 with respect to the Bonds (the "Official Statement"), or contesting in any way the completeness or accuracy of the Official Statement or any supplement or amendment thereto, or contesting the powers of the District or any other authority or proceedings for the issuance, sale or delivery of the Bonds, the adoption of the Bond Resolution, the Supplemental Resolution or the execution and delivery of the Related Documents or the performance of the District's obligations under the Bond Resolution, the Supplemental Resolution or the Related Documents, nor to the best of my knowledge, is there any basis therefor, wherein an unfavorable decision, ruling or finding would materially adversely affect the validity or enforceability of the Bonds, the Bond Resolution, the Supplemental Resolution the Related Documents or the Purchase Contract or would materially adversely affect the transactions contemplated by the Official Statement.

5. To the best of my knowledge, no event affecting the District or the transactions contemplated by the Official Statement has occurred since the date of the Official Statement which should have been disclosed in the Official Statement so that the Official Statement does not contain any untrue statement of a material fact or omit to state a material fact required to be stated therein or necessary to make the statements therein, in the light of the circumstances under which they were made, not misleading, and which had not been disclosed in a supplement or amendment to the Official Statement.

6. The District has complied with all the agreements and satisfied all the condition on its part to be performed or satisfied at or prior to the date hereof pursuant to the Purchase Contract.

7. All representations, warranties and recitals made or given by the District in the Related Documents are true, correct and complete on and as of the date hereof with the same force and effect as though the same had been made or given on and as of the date hereof. The Resolution of the District adopted on November 7, 1984, the Resolution Authorizing the Issuance of Solid Waste Management Revenue Bonds adopted by the District on December 26, 1984 (the "Bond Resolution"), the Supplemental Resolution and the Resolutions authorizing the execution and delivery of certain contracts, documents and certificates related hereto adopted on December 14, 1984 and December 26, 1984 have each been duly adopted by the District and each is in full force and effect on the date hereof, none (except as provided herein) have been amended, modified, repealed, revoked or rescinded in any manner or any extent and are valid and binding upon the District and enforceable in accordance with their terms.

8. The representations and warranties contained in Section 7.01 of the Reimbursement Agreement, dated as of December 1, 1984, as amended (the "Reimbursement Agreement") between the District and Banque Indosuez are true and correct on the date hereof as if made on such date and no condition or event with which the giving of notice or the lapse of time or both would become an Event of Default under the Reimbursement Agreement has occurred.

9. All agreements, obligations, duties and conditions to be performed or satisfied by the District on or before the date hereof have been duly performed and satisfied and there exists on the date hereof no condition, event or act which would constitute an event of default as defined in the Bond Resolution or the Supplemental

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Resolution, and no condition, event or act which, with notice or lapse of time, or both, would constitute such an event of default; nor is there existing on the date hereof, any breach or non-performance by the District of any term, provision or condition under any of the aforesaid Related Documents.

10. All of the terms, conditions and provisions of the Resolutions required for the issuance of the Bonds have, in all respects, been duly observed, satisfied, performed and complied with and the execution, issuance, delivery and sale of the Bonds will not in any manner contravene or conflict with any of the aforesaid provisions and conditions.

11. The execution and delivery of the Bonds, the adoption of the Resolutions, the adoption of the Supplemental Resolution and the compliance by the District with the provisions of each thereof, will not conflict with or constitute a breach of or a default under any applicable law or applicable regulation of the State of Utah or the United States or any applicable judgment or decree or any agreement or other instrument to which the District is a party or is otherwise subject.

12. As of the date hereof no change has occurred or will occur with respect to the boundaries of the District, as created on September 24, 1984.

13. The District has not pledged or hypothecated the Revenues (as defined in the Bond Resolution, as amended by the Supplemental Resolution) other than (i) to secure the punctual payment of the principal or, any premium, if any, and interest on the Bonds under the Bond Resolution, as amended by the Supplemental Resolution, (ii) under the Reimbursement Agreement, and (iii) pursuant to the Letter of Credit Note.

14. The Bonds are limited obligations of the District issued on the date hereof.

15. No writ of review has been filed pursuant to the provisions of Section 11-23-11(2), Utah Code Annotated 1953, as amended, with respect to the establishment of the District on September 24, 1984.

16. All capitalized terms employed herein which are not otherwise defined shall have the same meanings as in the Purchase Contract.

IN WITNESS WHEREOF we have hereunto set our hands as of the date set forth above.

DAVIS COUNTY SOLID WASTE
MANAGEMENT AND ENERGY
RECOVERY SPECIAL SERVICE DISTRICT

Robert Palmquist
Chairman,
Administrative Control Board

ATTEST

Glen E. Saunders
~~County Clerk~~ Secretary

[SEAL]

DT01590

SECTION ONE

INTRODUCTION

1.1 GENERAL DESCRIPTION

Wasatch Integrated Waste Management District's (WIWMD) Energy Recovery Facility (ERF) is a key component of the integrated Municipal Solid Waste (MSW) disposal system owned and operated by WIWMD.

The ERF consists of two (2) 210 ton/day refractory wall mass burn MSW incinerators. When operating at maximum continuous rating, each incinerator-boiler combination raises approximately 52,000 pounds per hour of 500 psig, 500°F steam. The facility combusts up to 140,000 tons per year of MSW, generates electricity mainly to operate the facility with a small amount of surplus electricity being sold to Utah Light & Power, and exports low pressure steam to Hill Air Force Base to replace steam that would otherwise be raised by on-base fossil fuel fired boilers. The non-hazardous combined ash residue from the facility is disposed of at Wasatch Integrated Waste Management District's landfill located in Layton, Utah approximately one mile east of the energy recovery facility.

The ERF operates 24 hours per day, seven days per week, 52 weeks per year. Downtime is experienced when the facility experiences whole-plant or partial outages to maintain the equipment. The combined hours of operation of the two combustors may not exceed 16,300 hours per year. MSW processed through the facility is reduced, approximately 70 percent by mass and 90 percent by volume, which substantially extends the life of the district's landfill.

1.2 LEGAL DESCRIPTION

Wasatch Integrated Waste Management District, formally known as Davis County Solid Waste Management and Energy Recovery Special Service District, dba. Wasatch Energy Systems, was

formed on September 24, 1984, by Resolution No. 84-200 adopted by the Board of County Commissioners of Davis County, Utah pursuant to the provisions of the Utah Special Service District Act. Under the special Service District Act WIWMD constitutes a separate body politic and corporate and quasi-municipal public corporation distinct from each county or municipality in which WIWMD is located. Following the establishment WIWMD, in accordance with the provisions of the Special Service District Act, the governing body of each of the cities now included within the boundaries of Davis and Morgan Counties adopted a resolution electing to be included in the District.

The Special Service District Act provides WIWMD may not be dissolved nor may any areas within the District be withdrawn from the District if any bonds, notes or other obligations of the District are outstanding and unpaid or if any contractual obligation of the District to provide services exists. The boundaries WIWMD include are all of the municipalities in Davis County (other than certain areas within the City of bountiful), the unincorporated area of Davis County, Morgan City and the unincorporated area of Morgan County, which lies immediately east of Davis County. The District's present boundaries encompass an area of approximately 268 square miles with an estimated current population of approximately 270,000 persons.

Pursuant to Resolution No. 84-200 and Resolution No. 87-130 adopted by the Board of County Commissioners of the County, the governance of and the exercise of the powers of the District were delegated to the Administrative Control Board. The Administrative Control Board is presently composed of nineteen members, including the three County commissioners of Davis County and one member from each of sixteen other political subdivisions of the State of Utah that are included within the District.

1.2.1 Proof of Ownership

Copies of the following documents are included in the Appendix to Part II as proof of ownership.

- Resolution No. 84-200, establishing the District
- First Supplemental Resolution, Resolution No. 85-150, authorizing issuance of revenue bonds.

- Commissioners' Minutes regarding the First Supplemental Resolution.
- Solid Waste Management revenue Bonds, Series 1984.

1.2.2 Location

The ERF is located at 3404 North 650 East in Layton, Utah.

Latitude	41° 06' 34" North
Longitude	111° 57' 16" West

The facility is located in the NW1/4 of the SE1/4 of Section 4 in Township 4 North, Range 1 West.

1.2.3 Surrounding Land Use

Hill Air Force Base is adjacent to the facility on the west. Properties adjacent to the south and southeast are commercial in nature. Land located to the north of the facility is farm ground and HAFB golf courses. Several residential subdivisions and one golf course are located within one mile of the facility to the east.

1.2.4 Types of Waste

The ERF is a mass burn incinerator specifically permitted to burn Municipal Solid Waste (MSW). The ERF is operated in conjunction with the Davis County Landfill, as such, the waste stream from the District is segregated to provide waste at the ERF which is most suited for incineration. This waste consists primarily of residential waste delivered by commercial haulers using side loading trucks. Other waste processed at the facility includes commercial front loaders and roll-off containers and wastes that are self-hauled by private citizens and commercial facilities. In general, waste loads that contain more than 60% unburnable materials are diverted to the landfill. In addition, the facility processes classified documents and similar materials requiring special handling and witnessing of destruction. The facility is prohibited from burning hazardous waste, radioactive waste and all wastes included in Section 2.2 of the EPA Guide for Infectious Waste Management.

Hazardous wastes are not accepted at the ERF or at the landfill site. WIWMD has posted rules and requires that generators and transporters agree to the rules as a condition of use of the ERF and landfill facilities. WIWMD routinely inspects waste loads to confirm users' adherence to the rules and to detect unacceptable wastes. Fines and exclusions from this captive area facility are penalties that can be imposed to ensure compliance. WIWMD further employs and trains full-time spotters at the tipping floor to catch and eliminate unacceptable wastes.

SECTION TWO

PLAN OF OPERATION

2.1 ON-SITE WASTE HANDLING PROCEDURE AND INSPECTION

2.1.1 Refuse Handling

Refer to Part III Section 1.3(1.3.14) "Refuse Handling System" of this permit for the procedure of weighing and processing waste upon receipt, tipping floor and placement into the furnace.

2.1.2 Inspection of Waste

The tipping floor attendant conducts waste characterization/inspection continually during the day. Inspection logs are completed randomly for at least one percent of all loads received during the day. Additional logs will be filled out if inspections identify special waste. Refer to the following page for a copy of the inspection log. If hazardous waste is identified it will be removed to a safe location and the hauler that brought it to the facility will be notified to retrieve it for proper disposal.

WASATCH INTEGRATED waste management district

Inspector Information

Name: Date: Time:

Area Inspection Conducted: ☐ LF-Face ☐ LF-Citizen Pad ☐ PLT-Tipping Floor ☐ Other (Specify)

Commercial

Company Name:

Vehicle Type: ☐ Semi-Truck ☐ Panel Truck ☐ Pick-up ☐ Front Loader ☐ Side Loader ☐ Roll-Off ☐ Other_____

Vehicle ID No.: _____ Route No.: _____ Ticket No.: _____ City:_____

License Plate No.:_____

Residential

Vehicle Type: ☐ (Circle) Car/Van/Truck ☐ Truck (w/trailer) ☐ Panel Truck ☐ Car (w/trailer) ☐ Other_____

Ticket No.: _____ City: _____

License Plate No.:_____

Signature

(Signature hereon denotes that operator of the vehicle being inspected was present during routine waste screening inspection and does not admit confirm or identify liability)

_____ _____

(PRINT) Operator's Signature Inspector's Signature

_____

(SIGN) Operator's Signature

CONTAINERS		Yes	No
Full	If YES #		
Partial	If YES #		
Empty	If YES #		
Crushed	If YES #		
End Removed	If YES #		
FREE LIQUID			
MEAT			
HAZ MTLS			
PCB			

	Yes	No
POWDERS/DUST		
Known		
Unknown		
BioMedical Waste		
Radioactive Waste		
Asbestos		
Ash		
Labeled Hazardous		
Unusual Odors		
Strong		
Faint		
This load is:		
Non-Hazardous		
Suspect		
Probable		
Confirmed		

	QUANTITY
Lead Acid Batts	
Tires	
Oil	
Metal	
Appliances	
CFC Applncs	
Paints	
HseHld Cleaners	
Fuels	
Sod/Soil/Grass	
Bldg. Matls.	
Cement/Rocks	
Animal	
Other:	

Wasatch Integrated Waste Management District
P.O. Box 900
650 East Highway 193
Layton, UT 8401-0900

FORM WS0407

Waste screening training is conducted at the facility following SWANA's training program.

2.2 CONTINGENCY PLANS

2.2.1 Emergency Situations

This emergency organization has been formed to respond to a variety of plant emergencies including fire, hurricane/tornado/windstorm, medical emergencies and other natural disasters. The operations supervisor on each shift will be responsible for the overall program coordination. Because of the small size of the work force on each shift, it is imperative that each employee be able to perform each of the activities required in the event of a fire.

A. Fire Response

There are 2 basic functions that must be performed in the event of a fire:

1) Squad Leader/ Notifier
2) Fire response/ sprinkler control person

B. Squad Leader/Notifier (Shift Supervisor)

The squad leader will make sure someone has notified the fire department by phone and then notify employees of the emergency. He will direct the employee closes to the scene of the fire to respond to the scene to perform first aid, fire fighting and to check any sprinkler control valves in the area to make sure they are performing properly. The squad leader should verify that the fire pump has started by checking the pump running light or water pressure gauge in the operations room. The fire response person verifying that the fire hose or sprinklers are delivering adequate water could also verify this. A person will be sent to meet the fire department to

direct them to the scene of the fire. If there is no one available to meet the fire department they will report to the control room to obtain direction from the control room operator. The firemen will be given a walkie-talkie so that they can communicate with the control room operator during the fire fighting activity.

C. Fire Response/Sprinkler Control Person

This employee will respond to the scene of the fire to perform first aid and fire fighting using hand held fire extinguishers or the 1-1/2 inch fire hoses. The only fire fighting performed by employees beyond the use of 1 1/2" hose will be by use of the water cannon controlled from the operations room (for fighting fires in the pit area only). This employee will also be responsible for checking the proper functioning of any sprinkler or automatic extinguishing system. He will make sure that the sprinkler control valves are open for any sprinklers system involved in the fire. This employee will shut off the sprinkler control valve only at the direction of the squad leader or fire department.

D. Salvage Operations

Immediately following any fire, the fire insurance carrier will be notified to report the incident. Information regarding the incident will be immediately referred to the Plant Manager and Safety Director. All fire protection systems will be reset and fused sprinkler heads replaced as soon as possible. Cleanup and salvage should be coordinated with the fire insurance carrier for the facility.

E. Windstorm/Tornado/Hurricane

In the event of severe weather conditions that could cause bodily injury or property damage, all employees will be notified to seek refuge inside and stay off of outside stairs. An all clear signal will be given when weather conditions improve.

F. Medical Emergency

There will be at least one first aid trained employee on each shift. In the event of a medical emergency, the first person to respond will first call an ambulance or paramedic and then contact the trained first aid provider to respond to the scene. Another person should be assigned the responsibility of meeting the ambulance to give them directions to the scene of the incident.

G. Training for Fire Response

On an annual basis, all employees will be given the following training by the local fire department or in-house certified personnel:

1) Use of portable fire extinguishers.
2) Use of a 1/2inch hand held hoses.

On an annual basis, all employees will be trained in how to operate all fire protection systems and how to manually start the fire pump.

Once a year, at plant shutdown, the control room operator should be trained in the use of the water cannon. At this time they should be given "hands-on" training in use of this device.

2.2.2 Ground Water Control

Refer to Part III Section 1.3(1.3.17) "Waste Water System" for all waste water processing at the facility.

The facility shall maintain the incinerator area where solid waste is charged into the incinerator and the area where ash is removed from the incinerator such that they are

protected from water run-on during rain events as well as protected from run-off of any leachate that has contacted the waste or ash during the wash down of the equipment and facility.

If contamination of the ground water pond occurred, proper measures for clean-up prior to discharge would occur. This water is discharged to the SE corner of the energy facility property which is used as a drying bed. Note, the pond water is no longer discharged to Kays Creek. Refer to Utah Division of Water Quality Permit UTR000000 SWPPP (May 11, 2007).

2.3 MAINTENANCE PROGRAM OF FACILITY EQUIPMENT

All facility equipment and machinery is contained in a computerized preventive maintenance program. The current software being used is MP2. All equipment is assigned regular maintenance schedules based upon manufacture recommendations or more often as required from facility history. All maintenance logs are printed automatically based upon their daily, weekly, monthly, etc. schedules. They are then distributed to the proper personnel for completion. Once completed the logs are returned and the information is input into MP2 for historical control. All input information is maintained for a minimum of 5 years.

MP2 is a complex software program, State or County review can be conducted at the ERF.

2.4 WASTE RECEIVING AREA/STORAGE CLEANING PLAN

The facility maintains two areas in which refuse is deposited. The commercial tipping floor accepts all commercial haulers. The refuse is deposited on the floor at which time the tipping floor attendant inspects the load. Any items that are unacceptable are removed and the remaining waste is pushed into the storage pit. The capacity of the storage pit is described in Part III Section One (1.3)(1.3.14)(B)(3) of this permit.

The second area is the public tipping floor, located next to the commercial area is an area in which only public (home) or small business type loads are accepted. This waste is again unload either on the floor or trench, inspected by the tipping floor attendant and then pushed into the same storage pit as the commercial waste.

The Household Hazardous Waste Facility is located at WIWMD Landfill. Here, households only (no commercial) can bring household hazardous wastes such as: paints, oils, fertilizers, etc. to the facility. These wastes are then reused, recycled, or properly disposed of by an outside contractor. Public bringing such items to the ERF will be directed to the landfill for proper disposal.

Recyclables are separated from the waste brought in by the public sector. These consist of metal, car batteries and carpet pad. These items are picked up on a weekly or as need basis.

Waste is not left on either tipping floor, but is pushed into the storage pit after it has been inspected. Once in the storage pit the waste is constantly being fed into the furnaces. At no time is waste stored on the tipping floors. Small piles of waste that collect in the corners of these floors are continually manually cleaned up throughout the day. At the closing of each day the floors are swept utilizing a rotating brush on a Bobcat.

By keeping the waste pushed into the storage pit and the tipping floors kept clean of waste, disease vectors are controlled.

If the storage pit capacity is met the incoming waste will be diverted to the county landfill thereby avoiding the need to store any waste on the tipping floors. One time during the year the furnaces are shut down for an extended maintenance outage. Several days prior to this time incoming waste is diverted to the landfill allowing the stockpiled waste in the pit to be burnt. Once empty the pit is cleaned and the drainage system is inspected.

If the facility is shut down for an extended length of time, waste from the storage pit can be removed via the overhead cranes, placed into trucks and taken to the landfill for disposal.

2.5 COMBINED ASH RESIDUE CHARACTERIZATION

Combined ash residue from the ERF has consistently been characterized as a RCRA non-hazardous waste. Combined ash residue from the RF will be characterized as per the revised Combined Ash Residue Characterization and Quality Assurance Plan (Rigo & Rigo Associates, September 2000) which has been prepared for the facility. Residue from the facility will be disposed of appropriately as determined through proper characterization. A copy of the Combined Ash Residue Characterization and Quality Assurance Plan is being submitted with this application.

2.6 GENERAL TRAINING AND SAFETY PLAN

Refer to the facility's training records and safety manual.

APPLICATION
FOR A PERMIT TO OPERATE
AN ENERGY RECOVERY FACILITY

DAVIS COUNTY ENERGY RECOVERY FACILITY

PART III – TECHNICAL REPORT

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PART III – TECHNICAL REPORT

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SECTION ONE

OVERALL SYSTEMS DESCRIPTION

1.1 PURPOSE

The furnaces perform the complete combustion of 420 tons/day of waste producing high temperature flue gas.

The boilers cool the flue gas to produce high-pressure steam. The Gas Suspension Absorbers (GSA) and Electrostatic Precipitators are installed to meet regulatory requirements regarding stack emissions.

The backpressure turbine converts high-pressure steam to low pressure steam to low pressure steam and extracts work in the form of electrical energy. This energy is used to run plant equipment and the remainder is sold to the local power company. The low-pressure steam is exported to Hill Air Force Base or condensed and re-entrained back to the boilers

1.2 GENERAL DESCRIPTION

1.2.1 **Major Process Plant Systems** (Sketch #1)

- Furnaces
- Boilers
- Gas Suspension Absorbers (GSA)
- Electrostatic Precipitators (ESP's)
- High Pressure & Low Pressure Steam Distribution
- Boiler Feedwater

The furnace burns waste at temperatures of approximately 1900 Deg. F and reduces waste volume 90% to an essentially inert ash. Flue gas is cooled by the boiler to about 350 Deg. F and flows through the GSA's and ESP's for removal of fly ash, acid gases, dioxin/furans and heavy metals.

Combustion air for the furnaces is drawn from the refuse pit using Forced Draft (F.D.) Fans. Flue gases are drawn from the boilers using Induced Draft (I.D.) Fans and are discharged to atmosphere through the stack.

Demineralized water and condensate are fed to the Deaerator for oxygen removal (oxygen oxidizes steel and shortens facility life). Steam sent to the Deaerator directly contacts the demineralized water, heating it to the boiling point and driving off dissolved oxygen. This oxygen, along with a small steam plume, is vented off the Deaerator.

The boiler Feed Pumps take suction from the Deaerator and feed the boiler steam drum. Steam leaves the Boiler, having been heated by the hot flue gases. Boiler feed water replaces the steam boiled off.

The high-pressure steam, which is generated, flows through the Turbogenerator and produces electricity for operating the plant with unused power going to the grid. Low-pressure steam from the Turbogenerator is sent through a pipeline to Hill Air Force Base. Steam that is not exported or used within the plant is condensed using the Air Cooled Condenser and recycled through the Demineralized Water Storage Tank back to the Deaerator.

1.2.2 **Heat Recovery** (Sketch #1B)

Flue gas from the furnace enters the "furnace Section" of the boiler. Water walls in the three passes (three flow direction changes) of the "Furnace Section" recover heat by boiling the feed water and thereby generating steam. The cooled flue gas then transfers heat to the "Superheater Section" and thereby raises the temperature of the steam from the steam drum significantly above the temperature of wet (saturated) steam. The flue gas then flows upwards and then downwards through the "convection section" of the boiler. As the flue gas cools, water percolates in the "convection section" tubes releasing steam to the steam drum for de-entrainment of water droplets. Finally, flue gas flows upwards past the economizer where boiler feed water is preheated prior to entering the steam drum(below the liquid level).

Water hammer is avoided by keeping the boiler feed water from boiling by bypassing feed water past the first section of the economizer.

Following is a performance summary for major equipment:

- Furnaces - 2-50% furnaces, each rated for burning 210 tons/day at MCR and 425 tons/day at peak.
- Boilers - 2-50% boilers, each rated to produce 51,344 lbs./hr. of steam at MCR and 59,454 lbs./hr. of steam at peak. The steam produced is 500 Deg. F and 500 PSIG.
- Back Pressure Steam Turbogenerator - One back-pressure turbine operating continuously and guaranteed to produce 1600 kW from 101,344 lbs./hr. of 500 Deg. F and 485 PSIG steam. Steam is exhausted at 365 Deg. F. and 150 PSIG. The power produced will be used for plant auxiliaries.

1.2.3 **Auxiliary Process Plant Systems**

- Refuse Handling
- Gas Suspension Absorbers (GSA)
- Ash Handling
- Chemical Feed

Regarding the Refuse Handling System, waste is delivered to the plant by truck and is deposited into the refuse storage pit which has an approximate five day storage capacity. From the pit the waste is loaded into the furnace charging hopper by an overhead crane.

Concerning the GSA System, flue gasses exiting the economizer and prior to the existing ESP will enter the Semi-Dry Scrubber. This scrubber, known as a Gas Suspension Absorber , utilizes hydrated lime (Ca(OH)2), as an alkali, introduced through an air atomizing nozzle into a fluidized bed reactor to remove acidic components (namely hydrochloric acid (HCL), hydrofluoric acid (HF) and sulfur dioxide (SO2)) from the flue gas passing through the reactor. A cyclonic collector, known as a cyclone, recovers the lime coated particulate matter exiting the reactor and recirculates the bulk of this material back to the reactor for reintroduction into the gas stream. This recirculation allows for the complete utilization of the available alkali achieving reduced lime consumption. Fresh lime is added, as required, from the Lime Storage and Preparation system. The fine particles of lime along with ash particles from the incineration process that are not collected by the cyclone exit to the existing ESP for fine particle separation and collection

As for the Ash Handling system, the major portion of the ash drops off the end of the grates into the ash extractor. Siftings, which fall between the grates, are fed into the ash extractor using a serious of vibrating conveyors. Soot (boiler ash) carried over from the furnace into the boiler is fed into the ash extractor using a series of screw conveyors.

Ash from these three sources is cooled via water addition and pushed by the ash extractor into the ash pit. Fly ash and neutral salts from the GSA's and ESP's are conveyed using a series of screw conveyors directly into the ash pit. A water spray is used at the fly ash inlet to the ash to minimize dusting.

Both furnace/boiler/ESO lines feed the ash pit. At the ash pit, ash cranes are used to properly mix ash from both units together and transfer into containers for removal to a landfill

Pertaining to the Chemical Feed System, acid-neutralizing morphaline is injected along with oxygen scavenger, sodium sulfite, into the deaerator surge tank. The morphaline keeps the boiler pH high enough to prevent acid corrosion of the boiler system. The oxygen scavenger removes oxygen not removed by the Deaerator. Phosphates (Monosodium, disodium and trisodium are injected into the boiler flash drum for boiler passivation against corrosion as well as scale prevention. (Reference: Sketch #1.)

Sodium sulfite is injected into the raw water feeding the Demineralizer for removal of chlorine. Excess chlorine will shorten the life of the ion exchange resins used in the demineralization exchangers

Following is performance summary for major auxiliary process plant equipment:

- Refuse Cranes - 2-100% cranes, one in service and the other on standby, each rated for 5.5 tons.
- Ash Cranes -2-1005 cranes, one in service and the other on standby, each rated for 5.5 tons.

#Because steam may contact food at Hill Air Force Base, the use of hydrazine is not allowed.

1.2.4 Critical Control Loops

LOOP
FIC 153 FUNCTION - HP Steam flow from Boiler Superheater Section to Turbine Generator.
LOOP DESCRIPTION – This loop works in conjunction with FIC-101, which controls the primary air fan. The output signal of FIC-153 will be a remote PV to the FIC-153 controller.

LOOP
FIC-101 FUNCTION – Primary air flow control.
LOOP DIESCRIPTION – Changes the output of the Primary Air Fan. The set point is coming from the underfire LCP and the PV is from the underfire flow transmitter

LOOP
LIC 155/ FUNCTION - Steam drum level and flow of boiler feed water from Deaerator to
FT 153 Economizer
FIC 151 LOOP DESCRPTION - Output of the level controller on the steam drum and steam flow out of the drum adjust the set point of the flow controller for feed water into the steam drum. As steam flow out of the drum increases and vice versa. The Level Controller corrects the water flow to hold a set level. The above is accomplished with a Three-Element Control System (Steam Flow (Demand), Feed Flow (Response) and Drum Level (Supervisory)).

LOOP
TIC 162/ FUNCTION - Temperature of water exiting Economizer plus override for temperature of
TIC 109/ flue gas exiting Economizer section
LOOP DESCRIPTION - Normally, boiler feed water temperature at the exit of the Economizer controls the feedwater bypass around the first section of

the Economizer. If the Boiler feed water temperature rises above the set point, the three-way valve will bypass additional water around the first section of the Economizer. This will lower the temperature of the feed water entering the boiler drum and will raise the temperature of the flue gas exiting the Economizer. However, if the flue gas temperature exiting the Economizer exceeds 430 Deg. F, a high temperature override will transfer control to TIC 109./.

LOOP

TIC-153 FUNCTION - Maintain temperature in 1st Pass of "Furnace Section" of Boiler
LOOP DESCRIPTION - Temperature of air entering the first pass of the "Furnace Section" of the Boiler controls the cycle time of the combustion grate. An increase in temperature of flue gas entering the 1st pass will cause the cycle time to increase, slowing the amount of strokes of the grates which will decrease the temperature.

PIC 350/ PT 306/ PIC 307 FUNCTION - maintain pressure of steam flowing to Steam Pipeline
LOOP DESCRIPTION - PIC 350 controls the pressure of the steam flowing to HAFB. If demand for steam exceeds supply from the Boiler, reduction in pressure of the LP Header will result. This can cause the Turbine to overspeed and trip. To prevent this, PIC 307 overrides PIC 350 and maintains backpressure control of the LP Header.

PT 306 PIC 306 FUNCTION - Maintain pressure of steam to Air-Cooled condenser
LOOP DESCRIPTION - PIC 306 controls the backpressure of steam flowing to the Air-Cooled Condenser. Steam flow from the Turbine or Turbine Bypass that exceeds HAFB demand, will cause an increase in the pressure of the LP Header. This will cause the valve to open and will result in the excess steam being condensed and recycled.

LIC 007 FUNCTION - Level Control of Deaerator Storage tank
LOOP DESCRIPTION - Level is maintained by controlling the flow of demineralized water from the Demineralizer Water Pumps (Via the Blowdown Heat Exchanger).

PIC 007 FUNCTION - Pressure Control of Deaerator
LOOP DESCRIPTION - Pressure is maintained by controlling the flow of steam to the Deaerator from the LP Steam Header. If the pressure gets too high, the Pressure Controller will open the vent valve.

LIC 332 FUNCTION - Level control of condensate in Air Cooled Condenser and Subcooler

LOOP DESCRIPTION - Level is maintained in the condensate Hotwell by controlling the flow of condensate to the Demin. Water Storage Tank.

PIC 320/ FUNCTION - Freeze protection and pressure control of the Air Cooled Condensers

TIC 327A LOOP DESCRIPTION During cold weather the low flow of steam to the Air-Cooled Condensers, the Pressure Controller will hold a 20 PSIG pressure using PCV 320. (PIC 306 will close the Main Dump Valve to maintain pressure in the LP Header.) TIC 327 A acts as an override on PIC 320 to maintain a 75 Deg. F condensate temperature and thereby avoid freezing the condensate. This allows the system to remain instantly available to receive maximum steam flow, regardless of air temperature.

1.2.5 **Utility Systems** (Sketches #2A, 2B, 2C & 2D)

- Raw Water and Demineralized Water
- Fire Protection
- Cooling Water
- Waste Water
- Fuel Oil
- Compressed Air for Instrument, GSA & Service Use
- Electrical Power Distribution

Regarding the Raw Water and Demineralized Water System, raw water from the county main feeds the raw water tank and the two fire water storage tanks. From the raw water tank, potable water is fed to the distribution header and to the Demineralizer. (Sulfite is added to the stream feeding the Demineralizer to dechlorinate the potable water). From the fire water tanks, water is pumped to the fire protection loop.

The Demineralizer removes hard water salts, such as calcium carbonate and magnesium carbonate, which cause boiler tube fouling (and loss of heat transfer) and can damage turbine blades and plug turbine steam injection nozzles.

Demineralized water from the Demineralizer flows to the Demineralized Water Tank where it mixes with recycled condensate from the Air Cooled Steam Condenser. The demineralized water/condensate is then pumped to the Deaerator. This water replaces that sent to Hill Air Force Base as steam and boiler blown down to the Waste System.

Concerning the Cooling Water System, a mixture consisting of 50 % water and 50 % ethylene glycol is circulated throughout the plant for cooling of various equipment items. An Air Cooled Heat Exchanger is used for heat removal. Level is maintained in the system by mixing glycol with water in the Cooling Water Head Tank.

The Waste Water System takes oily wastewater from the Hydraulic Unit and the elevator pit flows to Lift Station #2. Boiler blowdown from the Atmospheric Blow

Down Tanks flows to Lift Station #6. Water from the Ash Ramp, Furnace Area and ESP Area flows to Lift Stations #3, #5 and #4, respectively. These lift stations are then pumped to the two settling basins (the second one is used as a polishing and backup basin). Neutralized wastewater from the Demineralization Area, the acid/caustic retention basin and the Neutralization Tank flows to Lift Station #7 and is then taken into the neutralization tank. Water from the neutralization tank is taken directly out a pressurized sewer line to the city main.

Wastewater from the Turbine Generator Area flows to a surge tank (Lift Station #2). Water from the settling ponds flow to the surge tank (Lift Station #6). From there, all the wastewater flows to Lift Station #2 and is then pumped directly to a pressurized line to the city main or can also be pumped through the gravity fed sanitary sewer line.

The Fuel Oil System consists of two fuel tanks (both above ground), one is a 6000-gallon tank used for circulating fuel through the furnace start-up fuel oil burners (FOB) and the 2MWh backup generator used for emergency situations. The unused portion of fuel used for the FOB is sent back to the supply tank.(Reference: Sketch #2B). The other is a 1000 gallon tank used to supply fuel to the day tank which feeds the diesel-driven fire pump and is also used to fill heavy equipment (loader, bobcat, etc).

The Compressed Air System consists of four air compressors. The two compressors located in the Turbine Room feed a series of equipment, namely, a single air receiver, pre-filters, dryers and after filters. The clean, dry air feeds all instruments plus all plant air users. The other two compressors located in the GSA MCC are mainly used to supply dry air to the GSA system. This air is primarily use to atomize the lime slurry used in the reactors, but can also supplement the instrument air from the other tow compressors.

The Electrical Power Distribution System is fed from three sources: a 1600 kW steam driven turbogenerator, a 2 MWh diesel driven backup generator (used for emergency situations) and UP&L. All sources produce electricity at 480 volts.

Power is distributed to seven motor control centers and the electric motor-driven fire pump. (MCC #6 is fed off of the bus to MCC #5.)

Normally, plant power is supplied from the steam-driven turbogenerator. UP&L is used to run the plant under backup conditions as a co-gen operation and the 2MW diesel generator is use for emergency situations (most often black plant conditions).

1.3 SYSTEMS DETAILED DESCRIPTION

1.3.1 Compressed Air for Instrument and Service Use

A. Propose

The compressed air systems provides instrument and service air for the facility. The systems consist of the following major mechanical equipment and related piping and controls:

1. Air Compressors
2. Air Receiver
3. Air Dryer
4. Air Distribution System

B. Description

1. Air Compressors

Installed are four 100% capacity motor-driven rotor, oil-free, two stage air compressors. The two plant air machines are capable of an actual air delivery of 280 sfcm at a discharge pressure of 125 psig. The two GSA air machines are capable of an actual air delivery of 446 sfcm at a discharge pressure of 128 psig.

2. Air Receiver

The plant air system has one air receiver installed on the common discharge line from the two air compressors. The vessels have a 89 cu. Ft. capacity and has a 135 psig design pressure. The GSA air system has one air receiver installed on the common discharge line from the two compressors. The vessel has a 400 gallon capacity and a 200 psig design pressure.

3. Air Dryer

The dryer units for both the plant and GSA systems have two tower chambers, which are designed to have one chamber in service while the other is undergoing regeneration. The drying cycle automatically alternates from one chamber to another. In addition the plant air system has two pre-filters, one operating the other on standby and two after filters, one in operation and the other on standby are installed upstream and downstream of the chambers respectively. The GSA has only one pre-filter and one after filter.

4. Air Distribution System

Flow indicator FI-720 and pressure gauge PG-718 meter air leaving the air dryer. Should the pressure in the header be reduced, alarm PAL-717 will sound in the control room. A network of air piping delivers instrument and service air throughout the plant.

On the GSA air leaving the dryer is metered by pressure switch PSA-1117. Should the pressure in the header be reduced, alarm PAL-1 will sound in the

control room. A network of air piping delivers service air to the GSA lances. This air can also supplement or be used in place of the plant air for instrumentation .

References

EF-0100-E-018	Air Compressors, Air Receiver and Air Dryer
EF-0200-E-020	Plant Air Service Water and Potable Water Distribution

1.3.2 ASH HANDLING SYSTEM

A. Purpose

The ash handling system is designed to convey the ash formed in the grates, boilers, GSA, and the electrostatic precipitators to the ash pit. From the ash pit, it is loaded into a container and removed to a landfill. It is estimated that the ash is approximately 20% by weight of the total refuse.

The system consists of the following sub-systems, major equipment and related controls:

1. Grate Sifting Ash Handling System
2. Ash Extractor System
3. Boiler Ash Handling System
4. Fly Ash System
5. Ash Pit and Crane System

B. Description

1. Grate Sifting Ash Handling

A small portion, 1% to 3% of the total ash produced is small in size (fines) and thus sifts through the grate into one of the six hoppers along the length of the grate.

The ash from these hoppers travels on two sets of vibrating conveyors and is discharged into the ash extractor. An interlock is provided to insure that the conveyor closest to the ash extractor is in operation before the other conveyor can be started. The conveyors operate continuously. Vibration switches are provided to signal conveyor operation. Should the belt break, the vibration switch will cause an alarm to sound.

2. Ash Extractor

Approximately 80% of the ash produced in the combustion of the refuse is captured by this system. The major portion of this 80% of the ash travels the length of the grate and is discharged directly into the ash extractor.

The ash extractor performs two duties. It discharges ash into the ash pit and maintains a water level that forms a seal to prevent tramp air from entering the furnace and cools the ash from approximately 700 Deg. F to 210 Deg. F.

Removal of ash from the extractor is performed by an hydraulic ram that pushes the ash onto a vibrating conveyor that transfers it to the ash pit. The hydraulic ram operates on a timer that is controlled by the operator. Should the extractor stop working an alarm will sound.

The ash extractor has several access doors through which jams can be freed.

3. Boiler Ash Handling System

The boiler is designed so that the flue gas is forced to change flow directions several times along the furnace and the convection section. Approximately 4% by wt. Of total ash produced as a result of the flue gas direction change will be collected by two sets of 5 hoppers each located under each boiler.

Depending on the location of the hoppers, the ash is either directly discharged, or conveyed by conveyors to be discharged into the furnace burnout zone. An interlock is provided to insure that the conveyor adjacent to the furnace is in operation before the other (economizer) can be started. From there, ash is discharged either directly to the ash extractor, or through the grate sifting ash-handling system into the ash extractor.

The vibrating conveyors operate continuously. Vibration switches are provided to signal operation. Should the belt break, the vibration switch will cause an alarm to sound.

4. Fly Ash System

Fly ash is collected by both the GSA and ESP (approximately 16% by weight of the total ash production). The fly ash exits the boiler and passes through the GSA reactor where it is coated with lime slurry. This coated ash then proceeds to the cyclone which separates the heavy coated particles from the gas stream allowing the lighter particles to proceed to the electrostatic precipitators.

The heavier particles drop into the GSA cyclone and are transported to a feeder box from which it's re-entrained into the reactor gas stream where the unused lime on the particles can be utilized. These heavier particles, as they fill the feeder box are conveyed through a drag chain conveyor and join the ESP conveyor and transport the fly ash to the ash storage pits where it is mixed with the bottom ash.

The gas stream that by passes the cyclone proceeds onto the electrostatic precipitators where the finer fly ash is collected. This fly ash is then dropped into the bottom of the ESP that has three fly ash hoppers. Each set of hoppers discharge through a rotary valve which controls air leakage and drops its contents into a drag chain conveyor. This conveyor is the same that the GSA discharges into and transports the fly ash into the ash storage pits.

All of the drag chain conveyors and the rotary valves are operated continuously. An interlock is provided to insure that down stream equipment (discharged into) is in operation before the upstream ash handling equipment can be operated.

Should the conveyors fail, or, the hopper plug, level of ash in the hopper will rise and trigger a high level switch. The switch will activate an alarm in the control room.

Should this occur, an isolation gate valve at the discharge from each hopper is provided to allow the operator to close the valve and clear the ash built-up.

5. Ash Pit and Crane System

Each furnace/boiler system discharges all of its ash production into its own individual ash pit. Each of these ash pits are designed to store 12 hours worth of the ash produced when the units are operated at MCR condition.

Next to the ash pits, two ash bunkers are provided, each having a storage capacity of 24 hours worth of the ash produced by the units when operated at MCR condition.

Servicing the bunkers and the pits are two automated over-head cranes, one operating and the other on standby. The operating crane is programmed to unload the ash from the ash pits into the bunkers, and from the bunker into an ash container that will be trucked to the landfill.

The normal storage capacity is slightly more than 4 days of operation at the MCR condition.

References

EF-0100-E-013 Grate Sifting and Boiler Ash Handling System
EF-1411-E-019 Fly Ash System
Air Pol D-1-1

1.3.3 Air Pollution System

A. Purpose

The Air Pollution System is an air cleaning system using a Gas Suspension Absorper Scrubber (GSA) and an Electrostatic Precipitators (ESP's). The system scope initiates at the outlet of the Economizer Discharge Duct and at the outlets of the GSA feeder box and the ESP's three pyramidal hoppers.

The function of the GSA is to remove acid gases (HCl and SO2), Dioxins and Furans, heavy metals, fly ash, and cool the gas stream to approximately 320 to 350 deg F. The ESP then removes the finer particulate from flue gas discharging from the GSA. The fly ash discharges out of the GSA and bottom of three hoppers per ESP into the Fly Ash Drag Chain Conveyor System. Cleaned flue gas is drawn from the ESP outlet through the I.D. Fan and up the Stack.

The system consists of the following equipment and controls:

GSA:

1. Lime system (storage, slaker, slurry)
2. Reactor and Cyclone sections
3. Nozzle
4. Motor control center
5. Air compressors
6. Carbon feed system

ESP:

1. Single chamber electrostatic precipitator with pyramidal hoppers.
2. Pressurized penthouse covering the entire precipitator hot roof for housing of the high voltage insulators, bus bars, heaters and blowers.
3. Electric rapping system for the collecting plates, discharge electrodes and gas distribution plates with rapper panel.
4. Transformer rectifiers with digital control consoles.
5. Motor control center.
6. Inlet and outlet nozzles.

B. Description

1. GSA:

A variety of pollutants in the form of gases and solids are emitted into the atmosphere during the municipal incineration process. Exhaust gases exiting the economizer will contain particulate matter, heavy metals and acid gases which must be removed before discharging to the atmosphere. Flue gasses exiting the economizer and prior to the existing ESP will enter the Semi-Dry Scrubber. This scrubber, known as a Gas Suspension Absorber (GSA), utilizes hydrated lime, as a n alkali, introduced through an air atomizing nozzle into a fluidized bed reactor to remove acidic components form the flue gas passing through the reactor. A cyclonic collector, known as a cyclone, recovers the lime coated particulate matter exiting the reactor and recirculates the bulk of this material back to the reactor for reintroduction into the gas stream. This recirculation allows for the complete utilization of the available alkali achieving reduced lime consumption. Fresh lime is added, as required, from the Lime Storage and Preparation system. The fine particles of lime along with ash particles from the incineration process that are not collected by the cyclone exit to the existing ESP for fine particle separation and collection.

Also included in a Activated Carbon Delivery system used for the absorption of heavy metals contained in the exhaust flue gasses. Injection of activated carbon to ach GSA is achieved via dedicated blowers that pneumatically convey the powdered carbon to a specially designed nozzle located at the inlet to the reactor.

The cleaned gases exit through the cyclone outlet and are directed to the inlet of the ESP for fine particulate removal. The gases exit the ESP and are directed to the inlet of the ID Fan. Clean gases exiting the ID Fan are then directed to the atmosphere through the existing exhaust stack where the GSA system performance is monitored by the existing CEMS.

Also supplied are two dedicated air-cooled rotary screw type air compressors used to supply both GSA systems as well as the Lime and Carbon systems with the required air supply for operation. Operation is one air compressor on-line and the second acting as stand-by.

2. ESP:
A single chamber three (3) field Electrostatic Precipitator is provided for each of the two furnace/boilers.

The ESP provides an extremely efficient means for all separation and collection of suspended solids or liquids from gases. The ESP is designed to reduce the particulate loading of flue gas from 4.75 g/scfm to 0.025 g/scfm based on 12% carbon dioxide when passing 53,000acfm of gas through the precipitator. Percent removal is 99.65%.

The inlet nozzle has perforated plates to distribute gas across the face of the treatment zone. Each of the three hoppers is provided with high level alarms,

electric vibrators and electric resistance heating elements. Electric impact-type rappers located on the penthouse roof rap the collecting surfaces. A computerized power control protects the power supply and prevents formation of fused ash in a full hopper.

Each penthouse is pressurized by an independent forced air system to prevent the entrance of dust into the penthouse and ton continuously clean the inside surface of the support insulators. An automatic control amplifier in the Rectifier Control Console maintains the correct power input to the Precipitator. The Automatic Power Control uses operator selected secondary voltage and spark rate to control the power supplied to the Precipitator to obtain best collection efficiency. The Master Controller provides data acquisition, control functions and energy management. This program interfaces the Automatic Power Control with the Stack Opacity Monitor to hold a preset stack opacity at the lowers power input. The hopper heaters maintain 300 Deg. F in the lower portion of the hopper. Each hopper is furnished with an electric vibrator.

The applied voltage is the primary factor affecting collection efficiency. An increase in the moisture content of the flue gas increases electrical conductivity, with a resulting increase of sparkover voltage and increase in precipitator current. The presence of water vapor (within certain limits) improves precipitation. If other conditions are constant, an increase in gas temperature usually lowers sparkover voltage. An increase in concentration of dust decreases precipitating current, decreases sparkover voltage and increases collecting efficiency. However, a large increase in dust concentration above normal requires an increase in the frequency of the discharge electrode and collecting surface cleaning.

When dust build-up on the collecting surface becomes excessive, precipitation current is lowered and collecting efficiency decreases. Ultimately, there may be intermittent arcing, violent fluctuations of the millimeter. An overload protection relay is provided to trip off the transformer-rectifier in that situation.

References

EF-0100-E-005 Boiler No. 1 - Cooling air, Combustion Air and Boiler Flue Gas System

EF-0100-E-006 Boiler No. 2 - Cooling Air, Combustion Air and Boiler Flue gas System

EF-0100-E-019 Fly Ash System

GSA drawings (refer to operations manual Vol. 1)

1.3.4 BOILER SYSTEM

A. Purpose

The boilers each are designed to admit 1750 Deg. F furnace flue gas and produce at MCR, 51,344 lb/hr of steam at 500 Deg. F and 500 psig from incoming water at 299 Deg. F.

The boiler system consists of the following major components and related piping and controls:

1. Boiler feed water regulating valve and controls
2. Economizer and by-pass system
3. Three pass evaporative furnace
4. Superheater and desuperheater station
5. Boiler bank evaporative section
6. Soot blowers
7. Blow down system

B. Description

1. Boiler Feed Water Regulating Valve and Controls

The feed water regulating valves FCV151 & FCV251 modulates incoming water to the boilers from the boiler feed pump discharge. The control of the valve is performed by a three element control system which gets its inputs from; 1) total steam flow leaving the boiler, 2) steam drum water level, and 3) incoming water flow into the boiler. The objective is to keep the proper water level in the steam drum through the range of operation. The valve is interlocked to close when the water level in the steam drum is high-high, and also is designed to fail close on a loss of air or power.

b. Economizer and By Pass System

The duties of the economizer are to heat the incoming water to a temperature of 50 Deg. F less than the temperature of the saturated water in the steam drum. (This temperature differential is called the approach temperature.) and to cool the flue gas to a temperature of between 430 Deg. F and 350 Deg. F.

To ensure that these conditions are met, the economizer is constructed in two sections. Incoming water from the boiler-regulating valve enters a three-way temperature control valve. Under normal MCR boiler operation, flue gas temperature leaving the economizer is being maintained at the desired temperature between 350 Deg. F and 430 Deg. F, with an approach temperature of approximately 50 Deg. F and all of the water entering the first section.

During reduced load operation, approach temperature and flue gas temperature tends to decrease, consequently, the three way valve will maintain these set temperatures by by-passing water past the first section of the economizer. It should be noted that the 50 Deg. F. approach temperature is a conservative value. This set point may be reduced in the field provided water hammer is not being created in the economizer section.

3. Three Pass Evaporative Furnace

This portion of the boiler is designed to reduce the gas temperature leaving the furnace at 1740 Deg. F, to the gas temperature required at the entrance of the first stage superheater. The heat given off by the gases, is transferred by both radiation and convection to the water wall tubes, where the water is being evaporated.

In addition, the furnace is designed with three gas passes. This is done in order to change the direction of the flow of the flue gases. This flow direction change traps a portion of the particles in the bottom hoppers. This reduces solid carry-over to the superheater section and the balance of the boiler convection surfaces.

4. Superheater

The superheater surfaces are sized to generate 500 Deg. F and 500 psig superheated steam through a control range of between 75% of the rated MCR condition and the full load MCR condition even when the surfaces are fouled.

5. Boiler Bank Evaporating Section

This section absorbs heat from flue gas leaving the superheater by convection heat transfer. The change of flue gas flow direction assists in removing solid particles from the gases and thus, reduces their flow to the pollution control devices downstream.

6. Soot Blowers

Each boiler is equipped with 11 soot blowers, 10 that are rotary type and 1 is a retractable type. Retractable blowing is normally performed automatically through a pre-programmed controller, which sets the time interval between blowing and the blowing sequence.

The pressure and flow switches on the steam line feeding the blowers provides an input to an interlock which prevents the travelling of the retractable soot blowers in the event of lack of steam.

7. Blow Down System

The two boilers share one continuos blow down tank and one atmospheric blow down tank. The continuous blow down tank is designed to admit saturated liquid from the steam drum on a continuous basis. This prevents the build-up of solids in the boiler. It is expected that less than 3% of the rated feed water flow is sufficient blow down flow. A manually operated valve controls the flow into the tank. The optimum setting for this valve will be determined in the field on the basis of results from periodic steam and water samplings. The steam produced by the tank will be routed to the deaerator, and the water will be drained through a feed water heater into the atmospheric tank.

A level control valve modulates the drain from the continuous blow down tank. Water from the blow-down system is discharged into one of the lift stations.

The atmospheric blow-down tank is primarily used for draining of the boiler during start-up and for intermittent blow down of the mud drum.

References

EF-0100-003 Boiler No. 1 - Steam and water system
EF-0100-004 Boiler No. 2 - Steam and water system.

1.3.5 BOILER FEEDWATER SYSTEM

A. Purpose

The boiler feedwater system scope starts at the demineralized water pump discharge and terminates at the economizer inlet nozzles.

The functions of the boiler feedwater system are as follows:

- Heat the condensate
- To deaerate the condensate (remove oxygen)
- To store an adequate amount of feedwater and to supply feedwater to the boilers.
- To provide regenerative heating of feedwater using low pressure steam.

The boiler feedwater system consists of the following major mechanical equipment and related piping and controls:

1. Blow down heat exchanger
2. Deaerator and Deaerator Storage Tank
3. Boiler Feedwater Pumps

B. Description

1. Blow Down Heat Exchanger

   A shell and tube horizontal feed water preheater is provided to heat the feed water with hot drained water from the blow down tank. The flow of drained water is controlled by level controller LCV-031 which maintains level in the blow down tank located at the discharge from the heater and maintaining level in the blow down tank.

2. Deaerator and Deaerator Storage Tank

   A tray type deaerator, designed to operate at 50 psig will remove oxygen from the condensate. A pressure control valve located on the low-pressure steam supply line to the deaerator will control pressure in the deaerator. The deaerator storage tank is designed to store approximately 20 minutes based on maximum feedwater flow. Feedwater level in the deaertor storage tank will be level controlled by a level control valve located in the condensate supply line to the deaerator.

   When a deaerator storage tank high level condition develops, a level control valve located in the deaerator dump line will open and the excess feedwater will be drained to the waste water system.

3. Boiler Feedwater Pumps

   Three 50% capacity of the two boilers operating at MCR, multi stage, horizontal centrifugal pumps are provided to supply feedwater from the deaerator storage tank to the boiler.

   When the two boilers are in operation, the steam driven pump along with one of the motor driven pumps will be operating. The other motor driven pump will be on a stand-by (in the automatic mode).

   When one boiler is in operation, the steam driven pump will be operating, one motor driven pump will be on a stand-by (in the automatic mode), and the other motor driven pump will be off.

   The interlocks for the pumps are configured to automatically start the stand-by pump on a low pressure condition in the feedwater discharge header, and to automatically trip the operating pumps on a low-low level in the deaerator storage tank.

References

EF-0100-E-012 Deaerator & Boiler Feed Pumps

1.3.6 BUILDING RELATED

A. Purpose

This section addresses the HVAC, Elevator, Fire Protection, Plant Air and Potable Water Systems. HVAC is necessary to provide freeze protection for operating systems, for health and safety of operators and protection of heat sensitive electrical and computer equipment. The Elevator provides lift capacity for personnel and maintenance equipment. Fire Protection Systems are provided for personnel safety and property loss prevention. The Plant Air systems operate control valves and other pneumatic items plus provide air supplies for maintenance. The Potable Water System serves process users and provides water for safety showers and plumbing items.

B. Description

HVAC

Three packaged rooftop air conditioning units are supplied. These are:

Item No.	Service	ACFM	Ent. Air Deg. F DB	WB
V-105.3A	1st Floor Offices	4000	78.4	62
V-105.3B & V-105.3C	Control Rm & 2nd Floor Offices	3800	82	63.2
V-105.3D	Crane & Fan Control Rm.	9500	82.6	63.3

In addition, window type air conditioners, electric infrared humidifiers, electric duct heaters, fan and electric unit heaters are supplied.

Refer to Dwg. Nos. AC-0100-E-001 & AC-0100-E-002 for the HVAC Equipment Schedules.

Refer to Dwg. Nos. AC-0200-E-003 thru AC-0100-E-009 for plans, sections and details.

Refer to Dwg. Nos. AC-0100-E-010 & AC-0500-E-011 for control and flow diagrams that include the "Sequence of Operation."

Passenger/Freight Elevator

The Elevator, supplied by Otis, is located at Col R-9 on Dwg. No. AA-0100-E-003. A sectional view is on Dwg. No. AA-0400-E-014.

Fire Protection

Refer to Section II. M for the systems description for Plant Fire Protection.

Plant Air System

Clean, dry air from the Compressed Air System feeds all instruments plus all plant air users. On Dwg. No. EF-0100-E-020, the instrument air root valves (1") are designated "IA" and the utility air connections are shown as "A".

Potable Water System

From the Raw Water Tank, potable water is fed to the distribution header on Dwg. No. EF-0100-E-020 the utility water connections are designated as "W" and the safety showers are shown as "SS".

1.3.7 CHEMICAL FEED SYSTEM

A. Purpose

The system consists of four types of chemical controls: Amine feed for control of pH, oxygen scavenger feed for oxygen removal and phosphate feed for the two boilers, and sulfite feed to the demineralizer feed water.

The system consists of the following major subsystems:

1. Amine Feed
2. Oxygen Scavenger
3. Phosphate Injection
4. Sulfite Injection

B. Description

1. Amine Feed

The Amine Feed system consists of mixing tank, a mixer and two chemical feed pumps. Morphaline is injected to the deaerator storage for control of corrosion by pH adjustment. When steam is recycled through the air-cooled condenser, morphaline injection should be reduced or stopped. Injection is performed with one pump on and other on stand-by. The rate of injection is set by manually adjusting the stroke on the pump.

Low level in the mixing tank will trigger an alarm in the control room.

2. Oxygen Scavenger

This system consists of a mixing tank, a mixer and two chemical feed pumps. The oxygen scavenger, sodium sulfite is injected into the deaerator storage tank for the purpose of removing and oxygen remaining down stream of the deaerator. This protects the boiler during deaerator system malfunction.

Injection is performed with one pump on and the other pump on stand-by. The rate of injection is set by manually adjusting the stroke on the pumps.

Low level in the tank will be alarmed in the control room.

3. Phosphate Injection

The Phosphate Injection system consists of a mixing tank, a mixer and three chemical feed pumps - one phosphate pump is dedicated to serve one boiler and the remaining pump is on a stand-by. All pumps take suction from the same tank. The flow rate from each pump is controlled by a manually operated stroke adjuster on the pump.

4. Sulfite Feed

The Sulfite Feed system consists of a mixing tank, a mixer and two chemical feed pumps. The fluid is injected into the raw water entering the demineralizer. Both pumps take suction from the tank. The flow rate from each pump is controlled by manually operated stroke adjuster on the pump.

Low level in the tank will be alarmed in the control room.

Reference

EF-0100-E-022 Chemical Feed System

1.3.8 COOLING WATER SYSTEM

A. Purpose

The system is designed to reject the heat generated by auxiliaries such as the lube oil systems, and the turbine generator.

The cooling media used is a 50% glycol solution.

In order to perform these duties, the system consists of the following major equipment and related piping and controls:

1. Air Cooled Glycol Cooler
2. Cooling Water Pumps
3. Cooling Water Head Tank
4. Cooling Water Storage Tank and a Hand Pump

B. Description

1. Air Cooled Glycol Cooler

The cooler, is an outdoor located forced draft type heat exchanger capable of rejecting 1.7 x 106 BTU/hr with an ambient air temperature of 90 Deg. F.

The circulated coolant flows through the exchanger that is cooled by the air. Two variable speed air fans produce the flow of air. The speed of the fans and the position of the air dampers are controlled to maintain the desired temperature of cooling fluid. Increase in fluid temperature increases the speed of the fans and opens the dampers. A decrease in temperature decreases the speed of the fans, and the opening of the dampers.

2. Cooling Water Pumps

Circulation of the glycol solution is provided by two 200 GPM pumps. During most of the year, one pump is in operation and the other is on standby. However, when the ambient temperature is 90 Deg. F or higher, it is recommended that both pumps be in service. An interlock is provided to turn the stand-by pump on a low-pressure condition in the discharge header.

3. Cooling Water Head Tank

The tank is a 200-gallon tank, which provides for expansion and contraction of the hot water.

A level gauge is installed to enable the operator to insure that the proper level is maintained. Should the level in the tank be lower than allowed, a low-level switch will trigger an alarm in the control room.

This tank will be filled with 50% glycol solution through a glycol fill nozzle by a hand pump from the storage tank.

During an emergency when glycol solution is not available, water from the service water system can be used by opening the manually operated 2" service water gate valve.

4. Cooling Water Storage Tank and Hand Pump

This tank is a 250-gallon capacity tank, which is filled with glycol and water. The tank is marked to assist the operator in mixing the proper solution. A portable manual pump pumps glycol solution from this tank to the cooling water head tank.

References

EF-0100-E-016	Cooling Water Pumps and Air Cooled Glycol Cooler
EF-0100-E-017	Cooling Water Distribution System

1.3.9 ELECTRICAL POWER DISTRIBUTION & TRANSMISSION

A. Purpose

The scope of the electrical power distribution begins at the terminals of the steam turbine generator and ends at the individual electrical users. The system distributes power generated by the steam turbine within the facility for local consumption.

The main components of the distribution system are the following:

1. 480 V Switchgear Line-up
2. 480 V Motor Control Centers (6)
3. Steam Turbine Generator
4. UP&L

B. Description

1. 480 Volt Switch gear Line-up

The 480 volt Switchgear consists of a switchgear section with draw out breaker and fuse truck compartments, associated bus bars, instrument and control power transformers, instruments and supporting structures. Switchgear service is 3-phase, 3 wire, 480 wye volts, solidly grounded.

All circuit breakers are furnished with selectively coordinated trip devices. Service continuity is maintained for circuits except the faulted circuit. The breakers have a means for padlocking the breaker in its compartment in each position (connect-test-disconnect). The breakers are equipped with a means for manually closing and opening the contacts. The design includes red and green mechanical position indicators and manual trip buttons. Mechanical interlocks perform the following functions:

a. Prevent a closed circuit breaker being moved to or from any position.

b. Prevent the circuit breaker from being closed unless the primary disconnecting devices are either in full contact in the "operate" position or separated by a safe distance in the "test" position.

Feeder breakers are manually operated, draw-out air circuit type three pole, single throw, 600 volt, 60 hertz, with a minimum 50,000 amperes RMS symmetrical average. Feeder breakers are equipped with a stored energy type of mechanism for quick-make, quick-break operation and includes position indicator, manual trip button and manual operating handle. Each feeder breaker is equipped with the following:

a. One (1) current transformer
b. One (1) ammeter, 5 ampere for use with current transformer

The fuse truck assembly is furnished with fuses, coordinated with the system shown on Attachment "A". The 3200 amp fuse truck is fused at 2500 amps and the 1600 amp fuse truck at 800 amps. A means is provided for moving the truck assembly in and out of its compartment. The truck assembly is lockable in each position.

Each fuse truck installation is equipped with the following:

a. One (1) current transformer
b. One (1) ammeter, 5 ampere for use with current transformer
c. Interlocks between the fuse truck and the corresponding upstream breaker, controlled by a Kirk key system.

2. 480 Volt Motor Control Centers (6)

Motor control centers 1, 2, 3, & 4 are designed for indoor installation and MCC Nos. 5 & 6 are designed for outdoor installation. The MCC's are designed for 3 phase, 60 hertz, 480 volt service with 1200 or 800 ampere main horizontal bus and 600 ampere vertical bus. The control voltage is 120 volts provided by separate isolated winding control power transformers (CPT) in each individual unit.

The standard combination motor starter unit consists of a motor circuit protection breaker and a magnetic motor starter.

Units are of the draw-out type. Each door is interlocked with the associated circuit disconnect means so that the door may not be opened while the circuit disconnect device is in the closed position and the disconnecting device cannot be operated with the door open. A defeater means is available to permit a trained operator to by-pass each of the positions. The use of a screwdriver is required to obtain access into a unit with the disconnect closed. Means is provided for locking the circuit disconnect device in the open position when the door is closed. Overload relays are of the manual reset type from the front of the enclosure.

A circuit breaker feeder unit consists of a circuit breaker with integral current limiter device in a standard plug-in unit.

The Table below shows which systems are handled by which MCC.

TABLE

MCC SYSTEM	#1	#2	#3	#4	#5	#6	#7
Compressed Air			X	X			
Ash Handling	X	X					
ESP			X				
Boiler	X	X					
Boiler Feedwater	X	X					
Building Related			X	X			
Chemical Feed							
Cooling Water							
Electrical		X	X	X	X	X	
Furnace	X	X	X				
Fuel Oil							
Fire Protection						X	
GSA							X
Refuse Handling	X			X		X	
Steam			X				
Water			X		X	X	
Waste Water			X	X	X		

References

Dwgs. EF-0100-E-002 thru EF-0100-E-009
GSA drawings (refer to GSA operations manual Vol. 1)

Items included in the Electrical System are:

1) Standby power supplies
2) Heat tracing
3) Main breaker for Pump House MCC-6
4) Power Panel (in Maintenance Room) PP-1
5) Lighting Panel LP-1 & LP-2
6) Receptacle Panels RP-1 & Rp-2
7) Welding Receptacles WR-1, 2, 3, 4, 5, 6, 7, 8, 11, 13
8) Control Panel CP-1
9) Lighting Contractor
10) Instrument Panel ZP-1

Power is distributed to seven motor control centers and the electric motor-driven Fire Pump. (MCC #6 is fed off of the bus to MCC #5.)

3. Steam Turbine Generator

The steam-driven turbogenerator is rated is rated at 1600 kW, 1800 RPM, 480 volts, 3 phase, 60 Hertz at 0.8 powerfactor. Under normal plant operating conditions with both boilers delivering peak steam, the plant is expected to use 1290 kW. Under "dump conditions" (not exporting steam) total consumption is expected to be 1600 kW.

Normally, plant power is supplied from the steam-driven turbogenerator.

4. UP&L

Utah Power and Light 480V service is provided to Wasatch Energy Systems in a co-gen configuration. If the turbine-generator is providing full load the facility utilizes that power for operation and sends the excess to UP&L. If electricity being provided from the generator is less than required to operate the plant then UP&L provides the required make-up.

Reference Documents

Drawing No.	Rev. No.	Description
EE-0100-E-001	2	Electrical 480V AC One-Line Diagram
EE-0100-E-002	4	Electrical 480 V AC One-Line Diagram, MCC #1
EE-0100-E-003	3	Electrical 480V AC One-Line Diagram
EE-0100-E-004	4	Electrical 480V One-Line Diagram, MCC #3 Sht. 1 of 2
EE-0100-E-005	2	Electrical 480V One-Line Diagram, MCC #3 Sht. 2 of 2
EE-0100-E-006	3	Electrical 480V One-Line Diagram, MCC #4 Sht. 1 of 2
EE-0100-E-007	3	Electrical 480V One-Line Diagram, MCC #4 Sht. 2 of 2
EE-0100-E-008	4	Electrical 480V

EE-0100-E-009	4	One-Line Diagram, MCC #5 Electrical 480V One-Line Diagram, MCC #6

1.3.10 FURNACE SYSTEM

A. Purpose

The furnace system is designed to perform the complete combustion of 420 tons per day of refuse, while maintaining a furnace outlet temperature of 1750 Deg. F with a control range between 1700 Deg. F and 1800 Deg. F.

The system consists of the following major mechanical equipment and related controls:

1. Charging Hopper
2. Water Cooled Feed Chute
3. Feed Chute Cut Off Gate
4. Hydraulic Drive
5. Feeding Grate
6. Combustion Grates
7. Force Draft Fan (F.D. Fan)
8. Induced Draft Fan (I.D. Fan)
9. Furnace Roof Cooling Fan
10. Fuel Oil Start-Up Burners
11. Combustion Air and Refractory Cooled Ductwork System

B. Description

1. Charging Hopper
The Operator releases fuel from the refuse crane into the charging hopper. The hopper feeds the water-cooled feed chute. Refuse cannot be allowed to back-up from the chute into the hopper because the refuse would prevent the feed chute cut off gate from closing.

2. Feed Chute Cut-Off Gate

The feed chute cut off gate is used to separate the charging hopper from the feed chute. In the event of a backfire from the furnace into the feed chute the cut off gate is closed. This prevents the fire from spreading to the hopper. The cut off gate also is to be closed during a shutdown to keep gases from escaping local board or from the control room.

3. Water Cooled Feed Chute

The water-cooled feed chute feeds directly onto the feedgrate. Under normal operating conditions, 4 GPM of water from the cooling water system will keep the

chute cool. Cooling water is passed through pressure reducing stations PCV-116/216 through 1/2" lines and flow indicators FI-103/203 to the chute. The flow is adjusted automatically.

In the event of refuse bridging in the chute, the air void will allow fire from the combustion zone to penetrate into the feed chute. Fire in the feed chute will cause excessive heat that will raise the cooling water temperature leaving the chute. This will trigger high temperature alarm TDSH-105/205 and open a solenoid on/off diaphragm valve TV-105/205, to allow more water flow for cooling. The operator will close the cut off gate and free the refuse bridging by increasing the speed of the feed grate. If the chute is still jammed, the operator will have to physically clear the chute through the access door at the top of the chute.

The chute is equipped with a refuse low-level alarm LSL-101/102 to insure the furnace is receiving enough fuel.

4. The function of the hydraulic system is to supply oil of the proper pressure and flow to the cylinders in order to provide for the motion of the furnace grates and gates. Each furnace has a complete system.

   Because of the requirement for reliability, the system is configured with two piston type pumps, one is in service while the other is on stand-by. A set of accumulators us used to satisfy peak demand (the accumulators are also sized to be able to return the cylinders to their starting position in the event of a power failure). A by-pass system is used to return oil to the reservoir on low oil flow to the cylinders. Pressure reducing stations are provided to maintain the specified working pressure for the individual cylinders.

   Oil is admitted to and discharged from the cylinders through individual solenoid operated valves triggered by signals from the programmable controller. When demand for oil by the cylinders decreases, pressure at the pump discharge increases and pressure switch PSH-807-1/2 will trigger solenoid valve SV-809-1/2 to open. A circulating pump performs cooling of the oil and water-cooled cooler which is designed to reject 50,000 BTU/hr of heat.

5. Feeding Grates

   The feeding grate's function is to push refuse from the feed chute onto the combustion grates. The motion of the grate is achieved by two oil cylinders , which can be operated in either the automated mode, which responds to steam demand, or the manual remote mode that responds to an operator command.

   In the automated mode, the operator selects a desired number of strokes per grate cycle, and the duration of a cycle is controlled by steam demand, an increase in steam flow decreases the duration of a cycle. In the remote manual operating mode the operator selects the desired number of strokes per cycle and the duration for a

cycle. Limit switches control the motion limits and stroke length. In addition, the feeding grate is interlocked to not operate when the level of the water in the steam drum is low-low or the I.D. Fan is off.

6. Combustion Grates

The incoming refuse from the feed grate falls onto the combustion grate. Combustion along the grate is performed in three zones. The drying zone, the combustion zone and the burnout zone.

The drying zone consists of one 2 x 3 "standard elements". The combustion zone consists of two 2 x 3 "standard elements". The burnout zone consists of one 2 x 3 "standard element" and one 1 x 2 "end element". Ashes are discharged form the grate into the ash extractor.

Each "standard element' of the grate is composed of 6 rows of grate tiles, in sequence:

- sliding - tumbling - fixed - sliding - tumbling - fixed -

The "end element" has one additional row of sliding grate tiles followed by one additional row of fixed grate tiles.

With respect to the element's drive mechanism and drive motion, the standard and end elements are identical.

In each element:
- The sliding rows are activated by a common frame and level-arm system
- The tumbling rows are mechanically linked and activated by one level-arm system.

Hydraulic cylinders provide the driving action.

All cylinders are fed by one hydraulic pump-unit with a second pump-unit on stand-by.

Electromagnetic valves control the motion of the cylinders.
- Action stroke by activating the electromagnet
- Return stroke brining the electromagnet back into 0-position - spring loaded. Limit switches control the motion limits and stroke.

The action and return strokes of each cylinder can be controlled from Provox or from the field. The grate is either controlled in the automatic mode of operation, or in the manual remote mode of operation. In the automatic mode, the operator selects the number of strokes for both the tumbling and the sliding motions for each of the individual elements and the duration of the cycle is modulated automatically according to the steam flow from the boiler. In the manual remote mode, the

operator selects both the number of strokes and the duration of the cycle. In addition, the grate is interlocked not to operate when the level of water the steam drum is low-low or the I.D. fan is off.

7. Force Draft Fan (F.D.)

The F.D. Fan is a Robinson type 42" x 8 9/16" fan equipped with a variable speed motor. Expected unit operating speed is between 880 RPM and 1750. Combustion air is introduced from the refuse area through the fan suction duct and is discharged into three major distribution headers:

One Under-Fired Air Header
Two Over-Fired Air Headers

The total airflow through the fan is controlled by the operator via either one of the hand indicator controllers located both on a local panel or from the Provox in the control room.

Total airflow will be adjusted to maintain the proper excess air through the load range.

The split between over-flow air and under-fire air is controlled by modulating TCV 101 air damper to maintain furnace gas temperature outlet of 1750 Degrees F.

The distribution through the furnace will be manually adjusted during the start-up period to achieve complete combustion (maximum) burnout. Beyond that, only minor adjustments, possibly due to changes of fuel and/or ambient conditions, are expected.

For the protection of the boiler , the fan is interlocked to prevent it from running in the event of low-low level of water in the steam drum or when the I.D. Fan is not running.

8. Induced Draft Fan (I.D. Fan)

The I.D. Fan is a Robinson type 65" x 11 15/16" fan equipped with a variable speed motor. Expected during unit operating speed between 590 RPM and 1180. The fan speed is controlled to maintain a furnace draft via pressure controller PIC 101.

Hand indicator HIC 101 is located on a local panel for the operator to over-ride the automatic control.

9. Furnace Roof Cooling Fan

The fuel oil start-up burners are each rated at 5/5 x 10 6 BTU/hr and will be discussed in the fuel oil system description.

10. Combustion Air and Refractory Cooled Ductwork System

The combustion air and refractory cooled ductwork system routes the airflow from the various fans, to and from the furnace.

References

EF-0100-E-005 Boiler No. 1 - Cooling Air, Combustion Air and Boiler Flue Gas System
EF-0100-E-006 Boiler No. 2 - Cooling Air, Combustion Air and Boiler Flue Gas System
EF-0100-E-026 Furnace No. 1 - Hydraulic Oil System
EF-0100-E-027 Furnace No. 2 - Hydraulic Oil System

1.3.11 FUEL OIL SYSTEM

A. Purpose

The fuel oil system is designed to accept, store, and deliver fuel oil for the following plant operating conditions:

1. During a cold start-up the start-up burners will bring the furnace to a start up temperature and assist with the ignition of trash introduced.

2. In the event of a fire the diesel driven fire pump will run.

The system consists of the following major equipment and related piping and controls:

a. Fuel Oil Storage Tank
b. Fuel Oil Transfer Pumps
c. Fuel Oil Start-up Burners
d. Fuel Oil Day Tanks for the Diesel Engine

B. Description

1. Fuel Oil Tanks

There are two tanks. The 6000-gallon tank enables the continuous operation of the two start-up burners.

The 1000-gallon tank provides the fuel necessary to operate the diesel driven fire pump that provides fuel to all diesel driven heavy equipment.

2. Fuel Oil Transfer Pumps

The 6000-gallon system is provided with two 100% fuel oil transfer pumps. One is on stand-by, and the other is in operation. The pumps take suction from the tank through the duplex strainer M.140.2.1. A pressure differential switch across the strainer will trigger an alarm in the control room advising the operator to change the strainer.

The operating pump is controlled to maintain approximately 35 psig. On the discharge header by modulating the position of the by-pass control valve PVC-714. This pressure is required at the suction of the start-up burners atomizing pumps.

3. Fuel Oil Start-Up Burners

Each furnace is equipped with one fuel oil start-up burner. The burners are mechanically atomized backpressure return controlled design for a maximum heat release of 5,500,000 BTU/hr.

Approximately 40 GPH of fuel oil from the fuel oil transfer pump enters the suction side of a burner's fuel atomizing pump, which raises the fuel pressure to approximately 294 psig.

The firing rate is controlled by manually modulating the position of the burner's back pressure return control valve, which determines the amount of fuel that is returned to the tank. The balance is atomized and fired in the furnace. The burner's blower that operates continuously supplies combustion air. Air is modulated by an air damper, which is mechanically linked to the burner's backpressure return control valve.

Should the atomizing pressure decline below the level of safe operation (approximately 147 psig.), the solenoid valve will by-pass the oil supply to the start-up burner and allow the spring to close the burner tip.

Although not automatically interlocked, it is recommended that the furnace will be purged for 5 minutes before starting the burner.

4. Fuel Oil Day Tanks for the Diesel Engines

The diesel driven firewater pumps is provided with a day tank. The tank is supplied with low-level switches that trigger alarms in the control room. Spring closed hand operated valves are provided.

References

EF-0100-E-021 Fuel Oil System 7 Diesel Engine Details

1.3.12 PLANT FIRE PROTECTION SYSTEM

A. Purpose

The general area fire detection system will automatically initiate alarms but will not automatically initiate fire-extinguishing systems. The special hazard fire protection system will automatically initiate alarms and fire extinguishing systems. Located throughout the plant are fire hoses, portable fire extinguishers and manually initiated alarms. The fire control system is self monitoring and will provide warning of system in-operability or malfunction.

The system consists of the following major mechanical equipment and related piping and controls:

1. Fire Water Tanks
2. Fire Water Pumps
3. General Areas - Automatic Detection Systems
4. Special Hazard Areas-Automatic Detection and Protection Systems
5. Control Panels
6. Manually Operated Fire Protection Equipment
7. Refuse Pit Fire Cannon
8. Refuse Pit Deluge System

B. Description

1. Fire Water Tanks

Each fire water tank has a storage capacity of 100,000 gallons. In order to insure that the tanks are full, each tank is equipped with an assembly of one set of low and high level switches, one set of low-low and high-high level switches, and one level indicator, all mounted on a float. Also provided is one low-low level switch that is directly piped on the body of the tank.

During the initial operation, the tank should be filled with water to the high level mark, which is 22'-2" from the bottom of the tank. At this level, the high level switch will trigger the power operated valve LV-727/731 to close. When tank water is being consumed, the low-level switch, which is set 18 ft. from the bottom of the tank, will trigger the power operated valve to open.

However, if the pressure in the city line declines, the flow of water that is required to satisfy plant demand may exceed the water flow into the tank and the level in the tank will decline. When the level in the tank declines to 17.5 ft., which is the first low-low level, an alarm will sound in the control room and also in panel #1 of the fire protection control system.

The operator will be required to open the manual normally closed by-pass valve, which will decrease the pressure drop for filling. Another way to fill the tank is to connect a utility hose to the discharge side of the raw water pumps.

2. Fire Water Pumps

The plant is equipped with three firewater pumps. The jockey pump is a 20 GP< rated pump suitable for continuos operation to insure that the fire water system has header pressure at all times.

The controller on this pump is designed to automatically start the pump on low pressure and automatically stop on high pressure. The adjustable pressure switch for this controller is set for a range from 90 psig. To 150 psig. During normal mode of operation, the pumps selection switch is set on the automatic mode.

The diesel driven fire pump is 1500 GPM rated. The controller for this pump is set to automatically start the pump on low pressure. Once started, the pump will continue to run until manually turned off. The controller is also furnished with a timer that automatically provides a weekly run of 30 minutes duration. In case of fire this pump is on and the motor driven pump is on stand-by.

The motor driven fire pump is rated for 1500 GPM and is provided with an automatic controller capable of starting the pump on low pressure, and stopping the pump on high pressure. The adjustable range of the pressure switch is from 75 psig. To 125 psig. During normal plant operation, the pumps selector switch is set on the automatic mode.

3. General Areas- Automatic Detection Systems

This fire detection system will initiate alarms but will not automatically activate fire-extinguishing systems. This system is provided for: the maintenance shop (102), electrical equipment (209), mechanical room (23), electrical room (303), mechanical room (304), control room (402) and the following control room consoles - Provox consoles, soot blower consoles, and electrical metering consoles. Upon receipt of an indication of fire from any of these detectors, the control panel shall activate a fire alarm bell in the vicinity of the hazard, visible indicators will show on the panel designating which hazard initiated the alarm. In addition, the panel will monitor itself to insure the availability of each of the detection systems.

4. Special Hazard Areas-Automatic Detection & Protection System

The plant is protected by automatically activated devices in the following areas: office and personnel facilities, fire pump house and for the turbo-generator lube oil system.

The office and personnel facilities are protected by wet pipe sprinkler systems. These systems are provided with an automatically activated fire alarm, which will be annunciated by means of fire bells at the location of the problem.

In addition to monitoring fire conditions, the panels will monitor the conditions necessary to insure proper operation of the sprinkler systems.

The turbo-generator lube oil systems will be protected by fixed water spray systems. The fire detectors are thermostatic spot-type heat detectors with rate compensation. Upon receipt of an indication of fire, the panel shall annunciate a fire alarm by means of fire bell located near the area of the hazard, and shall automatically open the solenoid-operated deluge valve to the appropriate water spray system. In addition to monitoring for fire, condition, the controls will monitor the conditioning necessary to insure availability of the detection and water spray system.

5. Control Panels

The fire protection system is provided with two main panels. Panel #1 is located at the fire pump house, and panel #2 is located in the control room.

Panel #1 is designated to serve the respective area of protection as was described in the sections above. Panel #2 is provided to serve the areas listed in previous sections and to monitor and indicate the conditions in Panel #1.

6. Manually-Operated Fire Protection Equipment

For the plant yard, fire hydrants are strategically located approximately 250 feet apart. Water to these hydrants is supplied by the underground fire protection loop. Hose houses for the hydrants are provided with the required equipment to fight fires.

The manual fire protection for the building consists of a system of hose stations and portable fire extinguishers located throughout the plant for optimum fire fighting capabilities. Fire alarm pullout stations are also located throughout fire plant for use by plant personnel after a fire is detected. In all cases, when fire is detected, the operator should first annunciate the condition, and only then try to control the fire.

7. Refuse Pit Fire Cannon

The fire cannon is located above the refuse pit. The cannon can rotate and tilt to supply an adjustable spray (mist to stream) of water to any area of the pit. The cannon is hydraulically remote manual controlled from the control room by an operator. The cannon has a battery backup power supply capable of 2 hours of operation.

8. Refuse Pit Deluge System

The refuse pit deluge system is located over the refuse pit and control room crane area window. Automatically activated by temperature sensors in the roof of the refuse pit the system will open and disperse water to all of the charging floor including direct contact on the crane window.

References

EF-0100-E-014	Raw Water and Demineralized Water Storage Tanks & Pumps
EF-0100-E-024	Firewater Tanks, Pumps and Controllers
EF-0100-E-025	Firewater Loop and Distribution

1.3.13 GAS SUSPENSION ABSORBER (GSA)

(Refer to Section 1.3.3 – Air Pollution System)

1.3.14 REFUSE HANDLING SYSTEM

A. Purpose

The refuse handling system is designed to provide fuel for a 400-ton/day mass burn steam/electric plant.

The system consists of the following major equipment and related controls:

1. Truck Weigh Station
2. Refuse Crane
3. Refuse Pit
4. Oversize Item Hatch

B. Description

1. Truck Weigh Station

The truck weigh station consists of two (inbound and outbound) 11' x 80' scales each with a gross capacity of 100 tons and a tandem axle capacity of 27.5 tons. There is also a back-up 10' x 80' scale that maintains the same weight capacity and can be operated from the scale house. Scales have an attended during all refuse receiving hours.

When a truck is weighed in on the scale, the weighing system automatically captures the date, time and incoming weight of the truck. It also records the origin of the load, vehicle I.D. customer/s name and commodity type, and owner's name.

After the truck is unloaded and re-weighed, the weighing system automatically retrieves the truck's initial weight, calculates the net weight and then prints a weigh-ticket. All of the data is stored and protected so that it can be used in reports, invoices and transmitted to a central computer.

2. Refuse Crane

Two 100% capacity electric overhead traveling double girder refuse cranes are provided. One crane runs while the other crane is on standby. Both cranes can be operated simultaneously if required. Each crane has a 5.5-ton capacity.

The cranes are equipped with a 6-spade electric hydraulic orange peel grab.

The cranes may be operated in either the automatic or manual modes from the control room operator's chair. Two operator chairs are provided and usual operation is that one is in use and the other is in stand-by, but both cranes can be ran simultaneously.

The crane provides a signal to a control room weighing device that records the weight of each load placed in the charging hopper.

3. Refuse Pit

The refuse pit provides 5 bays for the dumping of refuse. In the event of plant shutdown the pit can hold 5 days of refuse.

To assure uniform refuse composition, the refuse crane is used to mix the refuse while it is in the pit.

1.3.15 HIGH AND LOW PRESSURE STEAM DISTRIBUTION SYSTEM

A. Purpose

The high pressure (HP) steam system scope initiates at the boiler superheater outlets and terminates at the back pressure steam turbine exhaust and the by-pass pressure reducing station valves outlet connections.

The low pressure (LP) steam system scope initiates at the back pressure turbine exhaust and the bypass steam pressure reducing control valves outlet connection, and terminates at the deaerator, air steam condenser steam inlet connections, and the process steam supply tie-in connection at the Hill Air Force Base.

The functions of the HP and LP steam systems are as follows:

- To supply steam to the back-pressure steam turbine for electrical power generation

- To supply steam to the deaerator for regenerative hating and deaerating of the condensate.
- To supply and condition the process steam in accordance with the requirements of the HAFB.

The system mainly consists of the following mechanical equipment and related piping and controls:

1. boilers
2. High Pressure Steam Header
3. Back Pressure Steam Turbine Generator
4. Bypass Steam Pressure Reducing Station
5. Low Pressure Steam System
6. Dump Steam Pressure Reducing Station
7. Boiler Feed Pump Turbine
8. Process Steam Pressure Reducing Station
9. Steam Delivery System to HAFB
10. Dump Air Cooled Condenser

B. Description

1. Boilers

Two (2) boilers, each designed to generate a peak steam flow of 59,454 lb/hr at 500 psig, 500 Deg. F. will normally be supplying steam to the back pressure turbine and the bypass steam control valves via the HP steam header. To establish and maintain steam flow through the boiler superheater during start-up, the superheater outlet header vent valve should remain open until the outlet steam has reached the required temperature and pressure.

2. High Pressure Steam Header

The two boilers will supply superheated steam to the high-pressure steam header. Since with mass burning boilers the response to fuel rate changes is slow, the HP (500 psig) steam header pressure will be controlled by the steam consumers, mainly the back pressure steam turbine generator and the by-pass steam valves.

3. Back Pressure Steam Turbine Generator

One (1) single stage, back pressure steam turbine generator capable of producing 1600 kW is designed to receive steam at 500 psig, 500 Deg. F. and to exhaust the steam at 150 psig. The turbine will normally produce power for the plant auxiliaries.

The steam turbine will be controlled automatically by the inlet nozzle assembly via the Electro-pneumatic control system. Steam flow through the turbine will be modulated to maintain the 500-psig pressure in the HP steam header.

If pressure in the HP steam header declines, and the flow through the by-pass pressure reducing station is zero, the turbine will reduce its power generator to raise the header pressure. This reduction in power generation may cause the activation of the emergency diesel generator.

If pressure in the HP steam header is increased and the main steam flow exceeds the turbine generator required for power, then the excess steam flow will be by-passed through the by-pass pressure reducing valves.

The turbine steam leak-off system is provided with two water ejectors. These ejectors service water, which are adjusted manually by the globe valves located on the inlet line to the ejectors.

4. By-pass Steam pressure Reducing Station

Two 50% capacity steam pressure reducing valves are provided to control the HP (500 psig) steam header pressure.

Most of the time the station will perform the limited duty of keeping the pressure in the HP header from rising when the main steam flow exceeds the turbine generator flow requirements for in house power. However, when the backpressure steam turbine generator is out of service, all of the boilers steam flow passes through this station.

During this mode of operation (by-pass of the Turbogenerator) the boilers still produce normal steam conditions of 500 Deg. F and 500 psig,. The temperature of the steam in the LP header will be 420 Deg. F, therefore, the steam delivered at the Air Force Base will be approximately 20 Deg. F. superheated. Since the steam contract calls for saturated steam, it is beneficial to produce the steam from the boiler at a lower temperature, perhaps 430 Deg. F. by increasing the flow through the desuperheaters. This will increase the total exported steam flow by approximately 400 lb/hr. In conclusion , if the turbo-generator is off for a long period of time, the operator should reduce the temperature of the superheated steam leaving the boiler in order to maximize the flow of exported steam.

The controls provided for the station are the split range type, which is designed to activate one valve for steam flows between 0% and 50% of the rated flow, and the two valves for flows between 50% and 100% of the rated flow.

In the event that one of the valves failed, the operator can isolate this valve and open the by-pass globe valve.

The flow through the by-pass valve will become the base flow and the other control valve will be modulating in order to maintain the pressure. To assist the operator in determining the flow through the by-pass valve, a pressure gauge is installed near-by, up stream of the station. It may be noted that hangers of plant operating condition may require re-adjustment of the position of the by-pass valve.

5. Low Pressure Steam System

The low-pressure (150 psig) steam header will be controlled by the steam dump pressure reducing control valves.

Under normal mode of operation, the steam produced will be exported to the Air Force Base while the excess steam in the header will be by-passed through the steam dump pressure reducing valves into the steam cooled air condenser. Likewise if the steam supply to the Air Force Base is interrupted, all of the steam will flow through the steam air condenser.

6. Dump Steam Pressure Reducing Station

As mentioned before, excess steam from the low pressure header will be by-passed through this station. The station is provided with three pressure reducing valves. Two main 6" valves, PCV-306 A & B, and one small valve PCV-327. The valves are controlled by a split range control system that is designed to activate the small valve for flows less than 8000 lbs./hr.. The other two valves will come on sequencing, one valve covering the flow up to approximately 50% and the two activated when flows are between approximately 50% to 100% of the flow.

During the summer, it is possible that the valves will not pass a complete dump flow to the condenser, if so, the operator will be required to open one of the by-pass 6" globe valves.

In the event that one of the valves fail the operator can isolate the valve and open the by-pass globe valve.

The flow through the by-pass valve will be the base flow and the other control valve will be modulating in order to maintain the pressure. To assist the operator in determining the flow through the by-pass valve, a pressure gauge is installed near-by, up stream of the station. It may be noted that changes of plan operating conditions may require re-adjustment of the position of the by-pass valve.

The steam leaving this station normally flows into the air cooled steam condenser but, in the event that the condenser is out of service during boiler start-up a manual by-pass vent valve is provided to exhaust the steam to the atmosphere.

7. Boiler Feed Pump Turbine

One (1) steam turbine is provided to drive one of the three boiler feed water pumps during normal operation and black out conditions. The turbine is designed to receive 150 psig, slightly superheater steam and exhaust the steam at 55 psig.

8. Process Steam Pressure Reducing Station

One 100% pressure reducing valve normally controlled to maintain the pressure down stream of the steam dryer at 115 psig and saturation temperature.

Should the demand for steam by the Air Force Base increase beyond the capabilities of the plant, the pressure in the LP header will tend to reduce, and may result in the over-speed of the turbo-generator. In order to prevent this from occurring, an interlock control system is provided to restrict the flow of exported steam, in favor of maintaining the pressure at the LP header.

9. Steam Delivery System to Hill Air Force Base

This section mainly consists of the following mechanical equipment and related piping; process steam pressure reducing valve, steam sampling station, steam dryers, steam exported metering stations, steam bent station, steam acceptance metering stations.

To ensure that steam supplied to the Hill Air Force Base does not contain condensate, two steam dryers are provided. The first, located at the plant will be drained through a restriction orifice to the deaerator, the other, located by the battery limit of HAFB will be drained through a steam trap assembly to an open hub.

Between the two steam dryers a pressure control vat station is provided. The station will be controlling the pressure at HAFB in the event and excess steam is developed in their system and the boilers were not able to handle the swing.

Also provided is a power operated shut off valve, remote manual controlled from HAFB to enable to stop the steam supply in the event of a failure in their system.

Installed are two metering stations, one up stream of the vent station, which we call steam exported metering station, and the other, down stream of the vent station, which we call the acceptance metering station. (The acceptance metering station are two stations in parallel one operating and the other is a stand-by)

Both stations measure flow rates, temperatures and pressures, information is used to determine the energy delivered.

The reason for the two metering stations is because HAFB may use the available steam, or vent all or part of it to the atmosphere.

Major differences in readings between the two metering stations will allow the operator to determine quickly that either HAFB is venting steam or that steam is lost due to a failure in the line.

When the ambient temperature is lower than 90 Deg. F, and/or the flow rate through the equipment is less than the 113,000 lb/hr design flow rate, the condensing pressures and condensate temperatures leaving the unit will decrease if the air flow rate through the fans remain the same.

To achieve the objective noted above, the control system will modulate the air flow so that at lower steam flow and/or reduced ambient temperatures, the air flow will be reduced to maintain approximately 140 psig at the condensing section inlet and a condensate temperature of 203 Deg. F leaving the Sub-cooler.

For protection against freezing, a 2 1/2" by-pass steam valve is installed. The valve will be modulated to ensure that the temperature of the condensate leaving the Sub-cooler will not drop below 60 Deg. F or the pressure in the tank is not less than 1 psig.

The equipment manufacturer predicted that when the ambient temperature is 10 Deg. F, no more than 2500 lb/hr of steam will be required to maintain 60 Deg. F at the outlet of the Sub-cooler.

10. Dump Air Cooled Condenser

This equipment is installed in order to allow the operation of the boilers at their rated MCR condition even in the event of a reduced or no sale of steam to the Air Force Base.

The system is composed of five major subsystems:

a. Air Cooled Steam Condenser: This section is a heat exchanger designed to condense 113,000 lb/hr of incoming steam at 150 psig and 366 Deg. F. Condensate leaving this section is at 147 psig and 361 Deg. F.

   Surface for this exchanger was sized for an ambient temperature of 90 Deg. F. and an air flow at 471,750 scfm. The temperature of the air leaving this section is 292 Deg. F and the heat duty is 97,100,000 BTU/her.

b. Condensate Hotwell Tank: this tank will collect condensate from the air cooled steam condenser and discharge it to the sub-cooled section. (3 minutes storage is provided)

c. Air Cooled Condensate Sub-Cooler: This section is a heat exchanger designed to cool 113,000 lb/hr of condensate form 361 Deg. F down to 203 Deg. F.

Surface for this exchanger was sized for an ambient temperature of 90 Deg F and an air flow of 137,200 scfm.

The temperature of the air leaving this section is 203 Deg. F and the heat duty is 18,200,000 BTU/hr.

For proper operation of this equipment, the control system is designed to accomplish the following:

- Maintain sufficient pressure to ensure flow of condensate through the system and into the demineralized water storage tank.
- Insure that the temperature of the condensate leaving the sub-cooler is high enough to prevent freezing, but not higher than 203 Deg. F. At the design point, all of these objectives are achieved via proper sizing of the heat exchanger surfaces to reject heat at pressures and temperatures noted above.

  When the ambient temperature is less than 32 Deg F and reduced steam flows through the unit, the pressure and the temperature of the water may reduce to levels with which the potential for freezing exists. In order to prevent such a condition from occurring, pCV-320 is installed to maintain a minimum operating pressure that is not less than 20 psig and a temperature of water leaving the unit that is not less than 60 Deg. F.

d. Condensate Discharge System: this sub-system controls the rate of condensate discharged from the Sub-cooler, which is achieved by controlling the level in the hotwell tank. Since the pressure of the condensate varies between 140 psig to 20 psig, at the lower range of pressures (perhaps under 30 psig) the pressure in the hotwell tank may not be sufficient to discharge the condensate into the demineralized tank.

   In order to be able to discharge water from the hotwell tank at low pressures, two 36 GPM and 70 ft. rated pump are installed on by-pass line around this check valve. The pumps are activated on a high level switch signal from the hotwell tank.

e. Vent: The vent system is located down stream of the dump steam pressure reducing station and is a manually operated system. The only times venting is performed is when the air cooled steam condenser is out of service, or on a start-up. During inch operation modes, the operator isolates the air cooled steam condenser, and opens the manual by-pass vent valve.

<u>References</u>

EF-0100-E-007 High and Low Pressure Steam Distribution

EF-0100-E-010 Air Cooled Steam Condenser

1.3.16 RAW AND DEMINERALIZED WATER SYSTEM

A. Purpose

The main purpose of this system is to accept raw water from a 20" main city water line, and treat it to the specified boiler feed water quality that is required by the boiler manufacturer.

In addition, raw water is supplied to the five water tanks, the portable water users, service water and cooling water make-up demand.

The system consists of the following major equipment and related piping and controls:

a. Main Water Supply Lines
b. Raw Water Storage Tank
c. Raw Water Pumps
d. Demineralizer
e. Demineralized Water Storage Tank
f. Demineralized Water Make-up Pumps

1. Main Water Supply Line

The plant main water supply line is tied to a 20" city water line that is operated at a pressure of approximately 28 psig.

Incoming water to the plant is measured by the Rockwell Turbometer flow totalizer, which provides readings of plant water consumption. Readings from this meter shall be taken and recorded every 24 hours of plant operation.

In addition to the supply of water to the water treatment facility, the system also provides water to the fire water storage tanks. (A detailed description of the fire water tanks is included in the fire protection system description)

2. Raw Water Storage Tank

The raw water storage tank has a storage capacity of 50,000 gallons. This capacity allows operation of the plant at it's MCR condition for approximately 1.5 hours during an interruption of the city water supply.

The operational objective is to keep the tank full so that maximum water is available upon interruption of city water service. The tank is equipped with an assembly of a set of low and high level switches, one set of low-low and high-high

level switches, and one level indicator, all mounted on a float. Also provided is one low-low level switch that is directly piped on the body of the tank.

During the initial operation, the tank should be filled with water to the high level mark, which is 22'-2" from the bottom of the tank. At this level, the high level switch will trigger the power operated valve LV-700 to close. When tank water is being consumed, the low level switch, which is set 18"-)" from the bottom of the tank, will trigger the power operated valve to open.

However, if the pressure in the city line declines, the flow of water that is required to satisfy plant demand may exceed the water flow into the tank and the level in the tank will decline. When the level in the tank declines to 17.5 ft., which is the first low-low level, an alarm will sound in the control room, and the operator will be required to check the water supply system, pressure in the main or operation of valve LV-700 and reduce plant load if required.

3. Raw Water Pumps

Installed are two raw water pumps each rated for 360 gpm, and 175 ft. head. One pump is on stand-by and the other is operating. Should the pressure in the discharge header decline, the low pressure switch PSL-702 will trigger an alarm in the control room, and start the stand-by pump.

Should a low-low level condition exist in the tank, LSLL_701 will shut off the operating pumps.

Minimum flow through the pumps is secured by the re-circulating valves on the pumps discharge header.

In addition to the water needed for the demineralizer, the raw water pumps provide water to the service water and the potable water distribution system.

4. Demineralizer

Incoming water from the raw water pumps discharge header enters the demineralizer through self-regulated pressure control valve PCV-500 which is designed to maintain the pressure of the water at 80 psig.

The demineralized water treatment facility consists of two 100% demineralizing trains, each consisting of: one weak acid cation exchanger; one strong acid cation exchanger and one strong base anion exchanger. One common decarbonator for the two trains with transfer pumps and blowers is provided. Also, an acid regeneration system caustic regeneration system, neutralizing system, and a PCL based control system are installed.

A complete system description is available in the Manufacturer's Operating Instruction Book.

5. Demineralizer Water Storage Tank

The demineralized water tank is provided with a storage capacity of 130,000 gallons. The total capacity allows operation of the plant at its MCR condition for approximately 5.5 hours when the water treatment facility is out of service.

The operational objective is to keep the tank full. The tank is equipped with an assembly of one set of low and high level switches, one set of low-low and high-high level switches, and one level indicator all mounted on a float. Also provided is one low-low level switch, which is directly piped on the body of the tank for the protection of the demineralized water pumps.

During initial plant operation the tank should be filled with water to its normal operating level which is 20 ft. from the bottom of the tank. Normally, this level is maintained by modulating the power operated tank inlet valve either automatically through a level controller, or by the operator through the manual remote control station. However, since the demineralizer's turndown is limited to 2:1 ratio, the power operated valve is equipped with a mechanical stop which prevents flow reduction below 50% of the rated capacity of the demineralizer level in the tank will rise and the high level switch will shut off the demineralizer. As water is being consumed the tank level will decline, and the low level switch which is set at 19 ft. from the bottom of the tank, will start the demineralizer. When either the high-high or the low-low switches, which are set at 22.5 ft and 17.5 ft from the bottom of the tank respectively, makes contact, an alarm in the control room will sound to indicate a failure.

6. Demineralized Water Make-up Pumps

Installed are two demineralized water pumps each rated for 140 GPM. One pump is on a stand-by, and the other is in operation. Should the pressure in the discharge header decline, the low pressure switch PSl-713 will trigger an alarm in the control room, and start the stand-by pump. Should low-low level exist in the tank, LSLL-712 will shut down the operating pumps.

Minimum flow through each pump is assured by the circulating valves on the pump discharge header.

References

EF-0100-E-014	Raw Water and Demineralized Water Storage Tanks and Pumps
EF-0100-E-015	Demineralizer

1.3.17 WASTE WATER SYSTEM

A. Purpose

The system is designed to collect all of the different streams of plant effluents, perform treatment and discharge the balance.

The system consists of the following major mechanical equipment and related piping and controls:

1. Lift Stations and Pumps
2. Oil/Water Separator
3. Neutralization Tank
4. Sanitary Sewer System
5. Storm Water Sewer System

B. Description

1. Lift Stations and Pumps
The plant is equipped with seven (7) lift stations and an elevator pit pump. The following pumps are furnished:

Lift Station #	Station Name	Fluids Handled	No. of Pumps	Pump Type
1	Hydraulic Unit & Equip. Drain	Oily Water	1	Submersible
2	Surge Tank	All	2	Vertical
3	Ash Loading	Ashy Water	1	Submersible
4	(Not In Use)			
5	Furnace Area	Ashy Water	1	Submersible
6	Blowdown	Hot "Muddy" Water	1	Vertical
7	Demineralizer	Neutralized	1	Self-Priming
		Acid & Caustic	1	Horizontal
N/A	Elevator Pit	Oily Water	1	Submersible

The single pump stations operate automatically using one level switch. Low level starts these pumps. High level stops these pumps.

The dual pump stations are operated automatically by two level switches set to maintain the desired level. Since the flows into the lift stations will raise their level. The first switch will make contact and one of these pumps will be triggered on. Normally, one pump is capable of handling the incoming flow and maintaining the level. In the event that the level is still rising, the second switch will make

contact and the second pump will be triggered on. When the incoming flow stops, the level is reduced and the pumps are turned off.

All lift stations (except the elevator pit) are equipped with high level alarms that trigger an alarm in the control room.

2. Plant Waste

All plant water waste except sewage and the neutralization tank are discharged to LS-2. This water is then pumped through a dedicated pressurized line to the county main. This discharge along with the neutralization tank discharge are tested by Davis County Sewer Department on a quarterly basis.

3. Oil/Water Separator

This equipment is fed from the overflow of Lift Station #2 (Surge Tank). The water from the separator is gravity fed to the sanitary sewer.

The equipment can accommodate an incoming flow of 200 GPM, (which is four times the maximum predicted flow) and perform separation of water from oil by its cylindrical gravity displacement type oil/water separator. The oil reservoir has a 70 gallon capacity, equipped with a high level switch set to alarm on high level. In the separation chamber, the oil rises, the solids settle and clean water passes from the separator through the effluent pipe. A 24" manhole is provided over the oil tank to enable removing the oil with a portable pump.

4. Neutralization Tank

Fluid discharged from the Demineralizer during regeneration and drains from the Demineralizer Area flow to this tank. Caustic and acid are used to neutralize this fluid while circulating pumps mix the solution. Circulation of 250 PM is continuous. Total regeneration time is governed by the strong base anion exchanger (SBA) Tank capacity is 43,000 gallons. Pump-out rate using the circulating pumps must be at least 43.4 GPM. The solution is pumped out a dedicated pressurized sewer line to the county main.

4. Sanitary Sewer System

The system is gravity drained and also carries all overflow wastes from the Surge Tank.

5. Storm Water Sewer System

The storm water drainage system terminates in a pond. A lift station is provided with one 650 GPM vertical pump. An automatic off-on switch is provided for level control of the pond (to prevent overflow onto the HAFB runway) A high level

alarm is provided which is used to advise the control room if the pond is overflowing.

References

EF-0100-E-023,	REV 1 - Waste Water System
EF-0100-E-015	REV 4 - Demineralizer with Neutralization Tank
UTR000000	Davis Energy Recovery Facility Storm Water Pollution Prevention Plan (SWPPP) – May 11, 2007

SECTION TWO

CLOSURE PLAN

2.1 GENERAL

It is currently estimated that WIWMD has a remaining useful life of approximately 20 years. At the end of the useful life of WIWMD it will most likely be converted into a transfer station. Wastes currently being incinerated will be transferred to trailers for transport to a yet to be determined location for final disposal.

2.2 CLOSURE STRATEGY

Closure of the DCERF will consist of the following activities:

2.2.1 Removal of Solid Waste

All solid waste remaining at the facility upon final shut down of WIWMD will be removed from the site for disposal. Any remaining solid waste will be removed from the storage pit and loaded into trucks for final disposal at the WIWMD Landfill. The storage pit will be washed out after final removal of waste. Wash water will be discharged to the sanitary sewer in accordance with the existing discharge permit.

2.2.2 Removal of Combined Ash Residue

All combined ash residue remaining at the facility upon final shut down of the DCERF will be removed from the site for disposal. Remaining combined ash residue will be removed from the ash bunkers and loaded into trucks for final disposal at the Davis County Landfill. The ash bunkers will be washed out after final removal of combined ash residue. Wash

water will be discharged to the sanitary sewer in accordance with the existing discharge permit.

2.2.3 Removal of Facilities

Three possibilities exist for end use of the facility upon final closure; 1) the furnaces and associated equipment will be removed and replaced with compaction equipment for use as a transfer station, 2) the facility will be moth balled as is, and 3) the facility will be sold at salvage value and dismantled. At this point in time the final disposition of the facility is speculation. Several (at least 3) permit renewals are anticipated before final closure of the facility is required and complete details will be provided for approval by the Division of Solid and Hazardous Waste before any closure activities take place.

2.3 CLOSURE SCHEDULE

A complete plan for closure of the facility will be prepared and submitted to the Division of Solid and Hazardous Waste prior to closure of the facility.

Implementation of the approved Closure Plan will begin within 30 days of last receipt of waste. Closure will be completed within 180 days of implementation of closure activities.

The Division of Solid and Hazardous Waste will be notified of plans to close the facility in writing at least 60 days before anticipated last receipt of waste.

2.4 CERTIFICATION

Upon completion of closure activities, a professional engineer registered in the state of Utah will submit certification that the facility was closed in accordance with the closure plan.

2.5 POST-CLOSURE PLAN

No post-closure care is planned.

COMBINED ASH RESIDUE CHARACTERIZATION AND QUALITY ASSURANCE PLAN

Wasatch Energy Systems
Layton, Utah

Revision No. 0
September 2000

Revision 0	Revision History
Recommended for Use H. Gregor Rigo 9/19/00 Rigo & Rigo Associates, Inc. date **Recommended for Use** Facility Environmental Engineer date **Approved for Use** Plant Manager date	**Rev. 0** – Conformed Issue (September 2000)

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INTRODUCTION AND PURPOSE

Municipal solid waste [MSW] is a highly variable material consisting of many waste components. These components contain virtually of the elements. In the combustion process, the organics and metals break down and combine with oxygen and other elements in the waste and air to form new compounds. Some of the resulting materials accumulate in the combined ash residues leaving the facility. These residues may or may not exhibit the characteristics of hazardous wastes.

Prudent environmental practice and regulatory compliance require that the toxicity characteristics of these residues be correctly determined. Following the Combined Ash Residue Characterization and Quality Assurance Plan provides assurance to staff, management and the public that the residues leaving the facility for disposal are properly characterized. This way, everyone can be confident that they are properly managed in an environmentally protective and legally correct manner.

The highly variable (heterogeneous) nature of combined ash residues makes the correct characterization of incinerator residues a difficult and exacting process. Accurate characterization begins with obtaining representative samples of the combined ash residues leaving the facility. It continues through preparation of representative laboratory sub-samples. Then, the laboratory procedures must follow the prescribed regulatory methods. Finally, the results must be correctly compared to the regulatory standards to determine the regulatory status of the residues.

Your enthusiastic and intelligent participation in this program is essential to the future of the Facility.

This QA plan is a living document. As you have questions or find ways to improve these procedures, please bring them to the Plant Environmental Engineer or Plant Manager for formal consideration and incorporation in the next revision.

FACILITY RESIDUE HANDLING

The Wasatch Energy Systems (WES) municipal waste combustion (MWC) facility in Layton, Utah incinerates up to 140,000 tons of municipal solid waste (MSW) per year to produce district-heating steam for Hill Air Force Base and electricity for Utah Power & Light. After utilization, approximately 37,000 tons per year of combined incinerator ash and air pollution control system (APCS) residue remain for disposal.

Bottom ash is extruded from water filled ram dischargers at the end of each incinerator's grate onto vibratory conveyors. As the ash moves the short distance to the bin, boiler and economizer ash is deposited on top of the bottom ash. APCS residue is moved from the hoppers to the bin in closed screw conveyors. The APCS residue is moistened prior to being discharged into the divided bin opposite the bottom ash from the same boiler. The residue streams are combined and accumulated in a concrete ash storage bin.

This ash storage bin is also called the ash bunker or ash pit. It has four separate segments. In the segmented bin, combined residues are mixed as they are moved from the first and third segments (A and C) where they are initially discharged to the central bin (B). Several times during each 12-hour shift, the residues are transferred from the central bin (B) to the larger end bin (D) for storage until it is loaded into covered trucks for disposal. All residue transfers and mixing are done using a clamshell grapple.

Residue dug out of bin D is discharged into trucks through a load-out hopper. After loading, the filled truck pulls forward, is covered and leaves the fully enclosed ash house. Residues are out-loaded 3 to 6 days per week, 6 to 12 hours per day. The frequency and duration of out-loading depends on the number of incinerators that are operating.

After weighing, the truck goes to the landfill and discharges its load. The residue is put to beneficial use as part of the daily cover. Research conducted at the Oak Ridge National Laboratory in the early 1980's demonstrated that using incinerator ash as daily cover reduces the strength and toxicity of the leachate compared to landfilling municipal solid waste alone. Field experience at WES and other landfills demonstrates that the residue is an effective vector barrier.

REGULATORY REQUIREMENTS

The Resource Recovery and Conservation Act and implementing regulations (40 CFR 262.11) require that the person who generates solid waste determine if that waste is a hazardous as defined in 40 CFR 261.20. That solid waste is to be managed in accordance with the regulatory determination.

For municipal solid waste combustors (incinerators), EPA had historically held that the residues derived from burning MSW were exempt from the requirement to characterize the waste. On May 2,1994, however, the Supreme Court held in City of Chicago v. EDF that EPA's determination that incinerator residues were exempt from RCRA management requirements was outside their legal authority and incinerators had to characterize their residue streams. Importantly, the court did not find that incinerator ash was hazardous; rather that the residue must be managed in accordance with its RCRA characteristics.

In response to this ruling, EPA issued guidance concerning the Sampling and Analysis of Municipal Refuse Incinerator Ash (EPA\530-R-95-036, June 1995) that provides some advice on the design of sampling plans beyond that contained in SW-846. The guidance also specifies that the 90 percent (one sided) statistical confidence level upper confidence limit for the sample increments is compared to the regulatory thresholds to determine waste characteristics and that good statistical practice be followed in making the comparison.

The point at which the in-plant residue stream became subject to RCRA classification (i.e., the point at which they should be sampled) was clarified by the February 3, 1995 (60 FR 6666) publication of "EPA policy interpretation of point at which RCRA Section 3001(i) jurisdiction begins for municipal waste combustion ash at waste-to-energy facilities' and distribution of the March 22, 1995 joint memorandum from the Assistant Administrators for the Office of Solid Waste and Emergency Response [OSWER] and Office for Enforcement and Compliance Assurance [OECA] to the Regional Administrators entitled "Revised implementation strategy for City of Chicago v. EDF municipal waste combustion (MWC) Ash Supreme Court Decision".

These documents make it clear that the residue becomes subject to RCRA sampling requirements

when it leaves the combustion facility and that the 14 samples suggested by the sampling guidance be taken on sequential residue removal days.

RESIDUE SAMPLING AND TESTING PROCEDURE

Representative combined ash samples generated at the Davis County Incinerator have consistently tested RCRA non-hazardous under the TCLP protocol[1].

Residue sampling and testing is to be done whenever a significant process change has occurred which can reasonably be expected to change the residue characteristics. Such changes might include upgrading the APCS (e.g., installing a gas suspension adsorber – GSA), using different APCS reagents, or replacing the incinerator with a different type of combustor.

Sampling begins in the middle of the month after the change is effective. The actual start date is set to accommodate scheduled plant maintenance outages and planned vacations.

During the characterization, combined ash is sampled as it is withdrawn from bin D for removal to the landfill. Daily sampling is separated into "morning" and "afternoon" hauling periods by dividing the number of hours residue hauling is expected to occur in half. Sample increments are taken every hour and composited to create two samples per residue hauling day. This is a periodic random sampling plan like those described in SW-846. It continues until seven sequential residue-hauling days have been sampled.

Each composite sample is reduced to pass a 9 mesh (nominal 3/8 inch) screen, thoroughly mixed and two nominal 1,000 g laboratory samples are extracted using a trier sampler made from 2", schedule 10 pipe. One of the composite samples is sent to the laboratory for analysis; the other sample is kept as a plant archive sample until the laboratory results have been supplied and reviewed.

The laboratory samples are sent to the laboratory, extracted and the extract is analyzed for all 8 TCLP metals. Because recent comparisons of various analytical methods indicate that lead and cadmium, the only metals consistently found above method detection limits, exhibit a very high bias when analyzed using ICP, if an IC-MS is available, extracts testing above the regulatory

[1] USEPA, Test Methods for Evaluating Solid Waste, SW-846, Third Edition, November 1986 (with 1996 revisions), Method 1311 (Revision 0, July 1992), Attachment 1.

limit using the comparatively inexpensive ICP should be reanalyzed using a IC-MS.

One randomly selected sample is subjected to zero head-space (ZHE) extraction to reconfirm that the organics are all at least a factor of 10 below the regulatory threshold. If higher results are encountered, all the samples need to be subjected to ZHE extraction and trace organics analysis.

Laboratory results are compared to the regulatory thresholds provided in 40 CFR 261.24 using the methods outlined in SECTION NINE of SW-846. As long as the 90 percent statistical confidence level (two sided) upper confidence level [UCL] for the data average is less than the regulatory threshold, the combined residue is RCRA non-hazardous[2].

Results are to be reported to the Plant Manager as quickly as practicable. Necessary documentation includes the sampling log, Chain of Custody forms, laboratory QA/QC documentation and statistical data reduction and interpretation. The results are to be accompanied by a certification statement signed by the individual(s) in responsible charge of sampling and data interpretation stating that "the results, after reasonable enquiry and to the best of my knowledge are representative, correct and accurate."

All deviations from this sampling plan and referenced EPA procedures are to be documented. The potential impact of each deviation is to be determined and described in the report. If the cause of the deviation was an error, the steps to be taken to prevent recurrence are to be described and implemented. If the cause is a change in facility design or operation, this sampling plan should be revised as appropriate to keep this living document accurate and representative.

The Plant Manager determines the regulatory status of the facility' combined residue stream based on the results of the sampling and analysis.

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[2] ibid and USEPA, Sampling and Analysis of Municipal Refuse Incinerator Ash, EPA53O-R-95-036, June 1995, Attachment 5.

COMBINED ASH SAMPLING

Combined ash is sampled from segment D of the ashbin, as it is ready to leave the facility. This residue is representative of the materials taken to the sanitary landfill for ultimate disposal.

The random sampling procedure to implement when a change in waste characteristics are suspected is as follows:

- Acquire and label 14, clean 5-gallon plastic pails with covers. Put these pails at a convenient location in the ash handling area making sure that they are kept covered and any fugitive dusts in the enclosed space is not allowed to accumulate in such a way that the dust will become commingled with the sample increments when the lid is opened or closed.

- Select a convenient day to begin sampling when experienced and qualified personnel are expected to be available to complete the sampling program without missing a scheduled residue-hauling day.

- Check with the residue-hauling contractor and determine how long he intends to remove ash each day. Divide the expected residue removal time in half to form two sampling periods for that day.

- Once each half hour, stop the grapple as it is traversing from the out-loading bin D to the discharge hopper at a safe location to remove a sample. Knock off any loose dirt from the sampling shovel and rinse it in a bucket of water filled from the source used to quench the ash.

- Because the clam shell closing action will cause fine material to sift and roll from the center of the residue pile as the grapple closes, use the cleaned shovel to remove the top 4 to 6 inches of the residue from the center of the grapple. Put this potentially non-representative material to the side of the grab. Then, extract a shovel full of residue from the center of the cleared area. Be careful to take as representative a sample as possible. Include oversized and bulky items. If a large item (i.e., a water heater, muffler, etc.) blocks the sampling area,

uncover an adjacent area to take the sample from.

- Put the shovel full of incremental sample into the correctly labeled container and cover.
- Repeat the previous step until all hourly increments have been accumulated.
- After all the periodic samples scheduled for accumulation have been put in the container, the 5-gallon bucket contains the morning or afternoon sub-sample for that sampling day.
- Continue sampling until a total of 14 samples, two per day, have been accumulated. Since the facility out-loads combined ash residue 3 to 6 days per week, this will require sampling on 8 to 16 calendar days in a row.

SAMPLE PREPARATION

Once a sub-sample has been obtained, it should be kept covered until prepared for shipment to the analytic laboratory. Preparation consists of reducing the entire sample to pass a No. 9 (nominal 3/8 inch) screen, thoroughly mixing the size-reduced sample and extracting representative laboratory and archive samples.

- Open the sample container, then:
- Either:
  - Pass all the samples through a 3/8' jaw crusher,
  - Or, alternately:
    - Pass the sample over a No. 9 sieve or screen made up out of ½ inch hardware cloth. Accumulate the fines on a sheet of heavy gage plastic. Set aside the underflow, this material passed the sieve.
    - Using a sledgehammer or other suitable device, reduce the nonmetallic oversized material so that it will fit into the jaw crusher. Accumulate all fines and add them to the material that originally passed the screen.
    - Irreducible metallic items are either described, weighed and discarded **or** reduced using shears and saws to a nominal 3/8-inch top size. If discarded, describe and record the weight of material separated.
    - Pass the remainder of the material through the jaw crusher. The jaws should be set to produce a 3/8-inch top size.
    - Recombine the fines, sheared metallic items and crushed material.

Then:

- Mix the combined, sized residue on a sheet of heavy gage plastic and then split using a nominal 2-inch splitter until the sample size is reduced to about 2 gallons.

- Rinse out the 5-gallon sampling container and put the split into it. Put the 5-gallon sample container into a rotary cement mixer and thoroughly mix the sub-sample for a minimum of 5 minutes.

- Stop the mixer and extract about 1 kg (1 quart) of mixed residue using a sampling thief made out of an appropriate length of nominal 1 1/2 inch, schedule 10 pipe split along the centerline. The thief should be slid along the bottom of the 5-gallon container and lifted straight up to obtain a representative sample. Alternatively, after rinsing, the splitter can be used repeatedly until an appropriately sized laboratory sample is obtained.

- Put the laboratory sample into a clean, borosilicate or polyethylene bottle with a Teflon lined cap. Attach an appropriate label identifying the sample, sample date, sampler and person preparing the laboratory sample.

- It is prudent to prepare at least one archived sample in case of damage in transit or additional material is needed for confirmatory analyses. To do this, repeat the sub-sampling process used to prepare the laboratory sample to prepare a facility archive sample.

- Once a practical shipment (usually all 14 samples) is prepared, arrange to send the samples to an experienced, Utah-certified laboratory for extraction and analysis. Notify the laboratory that the samples have been sent. Ask to be notified when the samples are received at the laboratory.

LABORATORY ANALYSIS

- Request the laboratory to perform TCLP extractions on all samples. Each extract should be analyzed for the complete list of TCLP metals using ICP. In the event that lead or cadmium are above regulatory limits, the analyses should be repeated using and IC-MS since ICP has a documented high bias for these metals.

- One sample is to be subjected to zero headspace extraction (ZHE) and analyzed for the complete list of RCRA organics. The ZHE sample is determined by starting at the beginning of the following table of random numbers between 1 and 14. Use the sixth sample the first time the analysis is requested. That number is already crossed-off in the table. For subsequent samplings, select the next unused random number. Cross off each sample number in the table as it us used.

Sampling	Sample to Analyze for ZHE organics	Sampling	Sample to Analyze for ZHE organics	Sampling	Sample to Analyze for ZHE organics
1	6	21	13	41	6
2	3	22	3	42	3
3	6	23	3	43	5
4	8	24	1	44	5
5	11	25	13	45	10
6	8	26	3	46	8
7	4	27	3	47	5
8	5	28	8	48	2
9	13	29	7	49	10
10	8	30	6	50	11
11	6	31	6	51	7
12	8	32	4	52	2
13	12	33	8	53	9
14	5	34	11	54	13
15	13	35	9	55	8
16	11	36	12	56	10
17	10	37	3	57	7
18	4	38	5	58	3
19	13	39	1	59	5
20	7	40	4	60	8

- Most combined ash samples require Extraction Fluid No. 1. Direct the laboratory to confirm any finding that Extraction Fluid No. 2 should be used by performing two additional determinations. Then, use the extraction fluid identified by at least two of the three determinations.

- Request the laboratory to retain all TCLP extracts until 14 calendar days after the results for all samples have been telefaxed or emailed to the facility.

- Require the Utah certified laboratory to provide a statement that the TCLP extraction was performed in strict accordance with Method 1311 and the analytic protocols in SW-846. The analytic report must be accompanied by a laboratory QA/QC report documenting blanks, calibrations, and matrix spikes, the completed Chain of Custody Forms, a discussion of any deviations and any other materials required by the most recent edition of SW-846.

INITIAL QUALITY CONTROL DATA SCREENING

- Upon receipt of the laboratory results, enter the results into a spreadsheet along with the extraction fluid number and final extract pH.

- Look at the data for any obviously high or low results. These might be typographical or transcription errors that can be corrected. If there is no data entry error, review the laboratory QA/QC report to make sure that the data has been properly transcribed from the back-up sheets to the laboratory summary report.

- Also, review the laboratory QA/QC reports for any notations that might indicate there is a problem with the analysis (interferences or sample compromised during laboratory processing).

- Prepare a plot of TCLP metal concentration versus pH for each metal. Put pH on the horizontal scale and concentration on the vertical scale. The vertical scale should be logarithmic. The data should fall in a relatively narrow band. The data range should be comparable to that shown in Figure 6.4 for lead and Figure 6.3 for cadmium (see attachments)[3]. If the results are outside these ranges, or other ranges developed using the historic plant data, then something has changed, either in the plant or at the laboratory. Investigate and find out what caused the change and include the finding in the summary report.

- Combined ash residue usually requires Extraction Fluid No. 1. Due to statistical change alone, one or two of the 14 samples might require that Extraction Fluid No. 2 be used. If more require that Extraction Fluid No. 2 be used, then it is imperative to find out why. At a minimum, submit the archived duplicate samples to another Utah-certified laboratory for Extraction Fluid determination. If the Extraction Fluid type is not confirmed, audit the original laboratory to determine what caused the finding. If the original findings are confirmed, investigate what occurred in the facility to cause the change.

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[3] The International Ash Working Group, An International Perspective on Characterization and Management of Residues from Municipal Solid Waste Incineration, Summary Report, December 1994, Attachment 8.

COMPARISON TO REGULATORY THRESHOLDS

Determination of regulatory status is done in accordance with SW-846 and EPA guidance on sampling and analysis of incinerator residues. These are provided in Appendices 2, 3, 4, 5 and 8 along with a paper[4] that consolidates the statistics and provides a conservative, upper bound estimate of the upper confidence limit.

Begin the analysis by assembling all the TCLP results into a spreadsheet. Record the sample identification, sampling date and time period, weight of total sample, weight and description of any rejected materials, final pH of the extraction fluid and the leachate concentrations. Add to the notes any deviations from accepted standards identified in the laboratory QA/QC report.

If the summary sheet identifies a result as not detected, record the detection limit as a negative number and display the result in ( ) notation. If the instrument scan sheet provides a positive value (that is, a result that does not meet laboratory detection or quantitation limit standards) record the measured value and flag the value as tentative [T] in the next column per ASTM convention instead of recording the detection limit; add the detection limit in notes at the bottom of the page. Use the tentative value in preference to half the detection limit in any subsequent mathematical procedures that require uncensored data.

Beginning with metals with 14 analytic results, the determination is made on a metal-by-metal basis as follows:

- Find the largest value. If this is less than the regulatory threshold, STOP. The material is RCRA non-hazardous for that constituent.

- Find the fourth largest value (assuming 14 samples have been analyzed). If this is less than the regulatory threshold, STOP. The material is RCRA non-hazardous for that constituent.

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[4] Rigo, H. G., Interpreting TCLP Results -- a Simplified Approach, Solid Waste Management, Thermal Treatment & Waste-to-Energy Conference, AWMA, April 17-21, 1995 and Docket Comments submitted on EPA53O-R-94-020 (see Appendix 2).

- Determine the type of data distribution using the methods in SW-846 and the Rigo paper. Compute the upper confidence limit [UCL] following the procedure. Make sure that appropriate corrections are used if there are any censored results (Below Detection Limits values). Compare the UCL to the regulatory threshold. If the UCL is below the regulatory threshold, the combined ash is RCRA non-hazardous.

- For metals with less than 14 samples analyzed, if the largest value of each of the 4 increments submitted for analysis of all RCRA metals is less than a third of the regulatory threshold, the maximum possible UCL is the regulatory threshold. The combined ash is RCRA non-hazardous for these metals. The UCL should be calculated using both normal and lognormal distribution assumptions and the higher value compared to the regulatory standard. In the event that all four results are below detection limits [BDL], then the combined ash residue is declared RCRA non-hazardous for that material[5].

If the value is above the regulatory threshold, then the material needs to be handled in an appropriate manner. The plant manager must be notified immediately and steps taken to either isolate the combined ash for future disposition or dispose of it in a RCRA compliant manner.

[5] If all results are BDL, the best that can be done is to substitute half the detection limit and calculate the mean, standard deviation and UCL. If the detection limit [DL] is the same for each sample, then the standard deviation will always calculate out to be zero; the UCL is then, by definition, equal to half the detection limit. Since SW-846 requires a maximum detection limit equal to 10 percent of the regulatory threshold, it is impossible for half the DL to exceed the regulatory threshold.

ROUTINE QUALITY ASSURANCE PROCEDURES

Providing assurance that the combined ash stream maintains its characteristics between formal sampling campaigns is important. Experience with combined ash streams indicates that changes manifest themselves as a significant increases or decreases in the relative weight of combined residue generated per ton of MSW burned (the MSW composition may have changed).

To detect changes in relative weight of combined residue generation the following routine QA/QC procedure is be followed:

- Establish 3-sigma control limits for normal residue generation by dividing the amount of residue removed each week by the amount of MSW combusted. The average is the center of the distribution and *99* percent of the time a week's generation is expected to reside within 3 standard deviations (sigma) of the mean.

- At the beginning of each week, calculate the relative residue generation and add it to the ongoing plot. If it is within the 3-sigma bounds, the plant is operating normally and no change in generation rate is indicated.

Paying attention to trends can yield important information. If 6 weeks in a row the weights increase, decrease, or remain on the same side of the long-term average, then something small may have changed. This is known as an out-of-control situation.

Identifying statistical out-of-control situations is very important. It provides a means of identifying when something has changed in the facility. Out-of-control does not mean that there is necessarily a problem or regulatory violation. Rather, it means that the cause of a difference can be identified and corrected, if necessary, before a violation occurs. It is important to determine the cause of such situations.

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1 Toxicity Characteristic Leaching Procedure (TCLP) – RCRA Method 1311

2 Statistical Tables and ways to establish regulatory status

3 EPA policy interpretation regarding point-of-sampling

4 EPA policy guidance implementing Supreme Court decision on MWC residues

5 EPA guidance on MWC residue testing plans

6 Section NINE of SW-846 regarding sampling plans for solid wastes

7 Excerpts from International Ash Working Group (IAG) report on MWC residues

8 Excerpts from RCRA regulations (40 CFR 262)

AVERY™ READY INDEX® INDEXING SYSTEM

1

METHOD 1311

TOXICITY CHARACTERISTIC LEACHING PROCEDURE

1.0 SCOPE AND APPLICATION

1.1 The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes.

1.2 If a total analysis of the waste demonstrates that individual analytes are not present in the waste, or that they are present but at such low concentrations that the appropriate regulatory levels could not possibly be exceeded, the TCLP need not be run.

1.3 If an analysis of any one of the liquid fractions of the TCLP extract indicates that a regulated compound is present at such high concentrations that, even after accounting for dilution from the other fractions of the extract, the concentration would be above the regulatory level for that compound, then the waste is hazardous and it is not necessary to analyze the remaining fractions of the extract.

1.4 If an analysis of extract obtained using a bottle extractor shows that the concentration of any regulated volatile analyte exceeds the regulatory level for that compound, then the waste is hazardous and extraction using the ZHE is not necessary. However, extract from a bottle extractor cannot be used to demonstrate that the concentration of volatile compounds is below the regulatory level.

2.0 SUMMARY OF METHOD

2.1 For liquid wastes (i.e., those containing less than 0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8 µm glass fiber filter, is defined as the TCLP extract.

2.2 For wastes containing greater than or equal to 0.5% solids, the liquid, if any, is separated from the solid phase and stored for later analysis; the particle size of the solid phase is reduced, if necessary. The solid phase is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. A special extractor vessel is used when testing for volatile analytes (see Table 1 for a list of volatile compounds). Following extraction, the liquid extract is separated from the solid phase by filtration through a 0.6 to 0.8 µm glass fiber filter.

2.3 If compatible (i.e., multiple phases will not form on combination), the initial liquid phase of the waste is added to the liquid extract, and these are analyzed together. If incompatible, the liquids are analyzed separately and the results are mathematically combined to yield a volume-weighted average concentration.

3.0 INTERFERENCES

3.1 Potential interferences that may be encountered during analysis are discussed in the individual analytical methods.

4.0 APPARATUS AND MATERIALS

4.1 Agitation apparatus: The agitation apparatus must be capable of rotating the extraction vessel in an end-over-end fashion (see Figure 1) at 30 ± 2 rpm. Suitable devices known to EPA are identified in Table 2.

4.2 Extraction Vessels

4.2.1 Zero-Headspace Extraction Vessel (ZHE). This device is for use only when the waste is being tested for the mobility of volatile analytes (i.e., those listed in Table 1). The ZHE (depicted in Figure 2) allows for liquid/solid separation within the device, and effectively precludes headspace. This type of vessel allows for initial liquid/solid separation, extraction, and final extract filtration without opening the vessel (see Section 4.3.1). The vessels shall have an internal volume of 500-600 mL, and be equipped to accommodate a 90-110 mm filter. The devices contain VITON®[1] O-rings which should be replaced frequently. Suitable ZHE devices known to EPA are identified in Table 3.

For the ZHE to be acceptable for use, the piston within the ZHE should be able to be moved with approximately 15 psi or less. If it takes more pressure to move the piston, the O-rings in the device should be replaced. If this does not solve the problem, the ZHE is unacceptable for TCLP analyses and the manufacturer should be contacted.

The ZHE should be checked for leaks after every extraction. If the device contains a built-in pressure gauge, pressurize the device to 50 psi, allow it to stand unattended for 1 hour, and recheck the pressure. If the device does not have a built-in pressure gauge, pressurize the device to 50 psi, submerge it in water, and check for the presence of air bubbles escaping from any of the fittings. If pressure is lost, check all fittings and inspect and replace O-rings, if necessary. Retest the device. If leakage problems cannot be solved, the manufacturer should be contacted.

Some ZHEs use gas pressure to actuate the ZHE piston, while others use mechanical pressure (see Table 3). Whereas the volatiles procedure (see Section 7.3) refers to pounds per square inch (psi), for the mechanically actuated piston, the pressure applied is measured in torque-inch-pounds. Refer to the manufacturer's instructions as to the proper conversion.

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[1] VITON® is a trademark of Du Pont.

4.2.2 Bottle Extraction Vessel. When the waste is being evaluated using the nonvolatile extraction, a jar with sufficient capacity to hold the sample and the extraction fluid is needed. Headspace is allowed in this vessel.

The extraction bottles may be constructed from various materials, depending on the analytes to be analyzed and the nature of the waste (see Section 4.3.3). It is recommended that borosilicate glass bottles be used instead of other types of glass, especially when inorganics are of concern. Plastic bottles, other than polytetrafluoroethylene, shall not be used if organics are to be investigated. Bottles are available from a number of laboratory suppliers. When this type of extraction vessel is used, the filtration device discussed in Section 4.3.2 is used for initial liquid/solid separation and final extract filtration.

4.3 Filtration Devices: It is recommended that all filtrations be performed in a hood.

4.3.1 Zero-Headspace Extractor Vessel (ZHE): When the waste is evaluated for volatiles, the zero-headspace extraction vessel described in Section 4.2.1 is used for filtration. The device shall be capable of supporting and keeping in place the glass fiber filter and be able to withstand the pressure needed to accomplish separation (50 psi).

NOTE: When it is suspected that the glass fiber filter has been ruptured, an in-line glass fiber filter may be used to filter the material within the ZHE.

4.3.2 Filter Holder: When the waste is evaluated for other than volatile analytes, any filter holder capable of supporting a glass fiber filter and able to withstand the pressure needed to accomplish separation may be used. Suitable filter holders range from simple vacuum units to relatively complex systems capable of exerting pressures of up to 50 psi or more. The type of filter holder used depends on the properties of the material to be filtered (see Section 4.3.3). These devices shall have a minimum internal volume of 300 mL and be equipped to accommodate a minimum filter size of 47 mm (filter holders having an internal capacity of 1.5 L or greater, and equipped to accommodate a 142 mm diameter filter, are recommended). Vacuum filtration can only be used for wastes with low solids content (<10%) and for highly granular, liquid-containing wastes. All other types of wastes should be filtered using positive pressure filtration. Suitable filter holders known to EPA are shown in Table 4.

4.3.3 Materials of Construction: Extraction vessels and filtration devices shall be made of inert materials which will not leach or absorb waste components. Glass, polytetrafluoroethylene (PTFE), or type 316 stainless steel equipment may be used when evaluating the mobility of both organic and inorganic components. Devices made of high density polyethylene (HDPE), polypropylene (PP), or polyvinyl chloride (PVC) may be used only when evaluating the mobility of metals. Borosili-

cate glass bottles are recommended for use over other types of glass bottles, especially when inorganics are analytes of concern.

4.4 Filters: Filters shall be made of borosilicate glass fiber, shall contain no binder materials, and shall have an effective pore size of 0.6 to 0.8 µm, or equivalent. Filters known to EPA which meet these specifications are identified in Table 5. Pre-filters must not be used. When evaluating the mobility of metals, filters shall be acid-washed prior to use by rinsing with 1N nitric acid followed by three consecutive rinses with deionized distilled water (a minimum of 1 L per rinse is recommended). Glass fiber filters are fragile and should be handled with care.

4.5 pH Meters: The meter should be accurate to ± 0.05 units at 25 °C.

4.6 ZHE Extract Collection Devices: TEDLAR®[2] bags or glass, stainless steel or PTFE gas-tight syringes are used to collect the initial liquid phase and the final extract of the waste when using the ZHE device. The devices listed are recommended for use under the following conditions:

4.6.1 If a waste contains an aqueous liquid phase or if a waste does not contain a significant amount of nonaqueous liquid (i.e., <1% of total waste), the TEDLAR® bag or a 600 mL syringe should be used to collect and combine the initial liquid and solid extract.

4.6.2 If a waste contains a significant amount of nonaqueous liquid in the initial liquid phase (i.e., >1% of total waste), the syringe or the TEDLAR® bag may be used for both the initial solid/liquid separation and the final extract filtration. However, analysts should use one or the other, not both.

4.6.3 If the waste contains no initial liquid phase (is 100% solid) or has no significant solid phase (is 100% liquid), either the TEDLAR® bag or the syringe may be used. If the syringe is used, discard the first 5 mL of liquid expressed from the device. The remaining aliquots are used for analysis.

4.7 ZHE Extraction Fluid Transfer Devices: Any device capable of transferring the extraction fluid into the ZHE without changing the nature of the extraction fluid is acceptable (e.g., a positive displacement or peristaltic pump, a gas tight syringe, pressure filtration unit (see Section 4.3.2), or other ZHE device).

4.8 Laboratory Balance: Any laboratory balance accurate to within ± 0.01 grams may be used (all weight measurements are to be within ± 0.1 grams).

4.9 Beaker or Erlenmeyer flask, glass, 500 mL.

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[2] TEDLAR® is a registered trademark of Du Pont.

4.10 Watchglass, appropriate diameter to cover beaker or Erlenmeyer flask.

4.11 Magnetic stirrer.

5.0 REAGENTS

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 Reagent Water. Reagent water is defined as water in which an interferant is not observed at or above the method's detection limit of the analyte(s) of interest. For nonvolatile extractions, ASTM Type II water or equivalent meets the definition of reagent water. For volatile extractions, it is recommended that reagent water be generated by any of the following methods. Reagent water should be monitored periodically for impurities.

5.2.1 Reagent water for volatile extractions may be generated by passing tap water through a carbon filter bed containing about 500 grams of activated carbon (Calgon Corp., Filtrasorb-300 or equivalent).

5.2.2 A water purification system (Millipore Super-Q or equivalent) may also be used to generate reagent water for volatile extractions.

5.2.3 Reagent water for volatile extractions may also be prepared by boiling water for 15 minutes. Subsequently, while maintaining the water temperature at 90 ± 5 degrees C, bubble a contaminant-free inert gas (e.g. nitrogen) through the water for 1 hour. While still hot, transfer the water to a narrow mouth screw-cap bottle under zero-headspace and seal with a Teflon-lined septum and cap.

5.3 Hydrochloric acid (1N), HCl, made from ACS reagent grade.

5.4 Nitric acid (1N), HNO_3, made from ACS reagent grade.

5.5 Sodium hydroxide (1N), NaOH, made from ACS reagent grade.

5.6 Glacial acetic acid, CH_3CH_2OOH, ACS reagent grade.

5.7 Extraction fluid.

5.7.1 Extraction fluid # 1: Add 5.7 mL glacial CH_3CH_2OOH to 500 mL of reagent water (See Section 5.2), add 64.3 mL of 1N NaOH, and dilute to a volume of 1 liter. When correctly prepared, the pH of this fluid will be 4.93 ± 0.05.

5.7.2 Extraction fluid # 2: Dilute 5.7 mL glacial CH_3CH_2OOH with reagent water (See Section 5.2) to a volume of 1 liter. When correctly prepared, the pH of this fluid will be 2.88 ± 0.05.

NOTE: These extraction fluids should be monitored frequently for impurities. The pH should be checked prior to use to ensure that these fluids are made up accurately. If impurities are found or the pH is not within the above specifications, the fluid shall be discarded and fresh extraction fluid prepared.

5.8 Analytical standards shall be prepared according to the appropriate analytical method.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples shall be collected using an appropriate sampling plan.

6.2 The TCLP may place requirements on the minimal size of the field sample, depending upon the physical state or states of the waste and the analytes of concern. An aliquot is needed for preliminary evaluation of which extraction fluid is to be used for the nonvolatile analyte extraction procedure. Another aliquot may be needed to actually conduct the nonvolatile extraction (see Section 1.4 concerning the use of this extract for volatile organics). If volatile organics are of concern, another aliquot may be needed. Quality control measures may require additional aliquots. Further, it is always wise to collect more sample just in case something goes wrong with the initial attempt to conduct the test.

6.3 Preservatives shall not be added to samples before extraction.

6.4 Samples may be refrigerated unless refrigeration results in irreversible physical change to the waste. If precipitation occurs, the entire sample (including precipitate) should be extracted.

6.5 When the waste is to be evaluated for volatile analytes, care shall be taken to minimize the loss of volatiles. Samples shall be collected and stored in a manner intended to prevent the loss of volatile analytes (e.g., samples should be collected in Teflon-lined septum capped vials and stored at 4 °C. Samples should be opened only immediately prior to extraction).

6.6 TCLP extracts should be prepared for analysis and analyzed as soon as possible following extraction. Extracts or portions of extracts for metallic analyte determinations must be acidified with nitric acid to a pH < 2, unless precipitation occurs (see Section 7.2.14 if precipitation occurs). Extracts should be preserved for other analytes according to the guidance given in the individual analysis methods. Extracts or portions of extracts for organic analyte determinations shall not be allowed to come into contact with the atmosphere (i.e., no headspace) to prevent losses. See Section 8.0 (QA requirements) for acceptable sample and extract holding times.

7.0 PROCEDURE

7.1 Preliminary Evaluations

Perform preliminary TCLP evaluations on a minimum 100 gram aliquot of waste. This aliquot may not actually undergo TCLP extraction. These preliminary evaluations include: (1) determination of the percent solids (Section 7.1.1); (2) determination of whether the waste contains insignificant solids and is, therefore, its own extract after filtration (Section 7.1.2); (3) determination of whether the solid portion of the waste requires particle size reduction (Section 7.1.3); and (4) determination of which of the two extraction fluids are to be used for the nonvolatile TCLP extraction of the waste (Section 7.1.4).

7.1.1 Preliminary determination of percent solids: Percent solids is defined as that fraction of a waste sample (as a percentage of the total sample) from which no liquid may be forced out by an applied pressure, as described below.

7.1.1.1 If the waste will obviously yield no liquid when subjected to pressure filtration (i.e., is 100% solids) proceed to Section 7.1.3.

7.1.1.2 If the sample is liquid or multiphasic, liquid/solid separation to make a preliminary determination of percent solids is required. This involves the filtration device described in Section 4.3.2 and is outlined in Sections 7.1.1.3 through 7.1.1.9.

7.1.1.3 Pre-weigh the filter and the container that will receive the filtrate.

7.1.1.4 Assemble the filter holder and filter following the manufacturer's instructions. Place the filter on the support screen and secure.

7.1.1.5 Weigh out a subsample of the waste (100 gram minimum) and record the weight.

7.1.1.6 Allow slurries to stand to permit the solid phase to settle. Wastes that settle slowly may be centrifuged prior to filtration. Centrifugation is to be used only as an aid to filtration. If used, the liquid should be decanted and filtered followed by filtration of the solid portion of the waste through the same filtration system.

7.1.1.7 Quantitatively transfer the waste sample to the filter holder (liquid and solid phases). Spread the waste sample evenly over the surface of the filter. If filtration of the waste at 4 °C reduces the amount of expressed liquid over what would be expressed at room temperature then allow the sample to warm up to room temperature in the device before filtering.

NOTE: If waste material (>1% of original sample weight) has obviously adhered to the container used to transfer the sample to the filtration apparatus, determine the weight of this residue and subtract it from the sample weight determined in Section 7.1.1.5 to determine the weight of the waste sample that will be filtered.

Gradually apply vacuum or gentle pressure of 1-10 psi, until air or pressurizing gas moves through the filter. If this point is not reached under 10 psi, and if no additional liquid has passed through the filter in any 2 minute interval, slowly increase the pressure in 10 psi increments to a maximum of 50 psi. After each incremental increase of 10 psi, if the pressurizing gas has not moved through the filter, and if no additional liquid has passed through the filter in any 2 minute interval, proceed to the next 10 psi increment. When the pressurizing gas begins to move through the filter, or when liquid flow has ceased at 50 psi (i.e., filtration does not result in any additional filtrate within any 2 minute period), stop the filtration.

NOTE: Instantaneous application of high pressure can degrade the glass fiber filter and may cause premature plugging.

7.1.1.8 The material in the filter holder is defined as the solid phase of the waste, and the filtrate is defined as the liquid phase.

NOTE: Some wastes, such as oily wastes and some paint wastes, will obviously contain some material that appears to be a liquid. Even after applying vacuum or pressure filtration, as outlined in Section 7.1.1.7, this material may not filter. If this is the case, the material within the filtration device is defined as a solid. Do not replace the original filter with a fresh filter under any circumstances. Use only one filter.

7.1.1.9 Determine the weight of the liquid phase by subtracting the weight of the filtrate container (see Section 7.1.1.3) from the total weight of the filtrate-filled container. Determine the weight of the solid phase of the waste sample by subtracting the weight of the liquid phase from the weight of the total waste sample, as determined in Section 7.1.1.5 or 7.1.1.7.

Record the weight of the liquid and solid phases. Calculate the percent solids as follows:

$$\text{Percent solids} = \frac{\text{Weight of solid (Section 7.1.1.9)}}{\text{Total weight of waste (Section 7.1.1.5 or 7.1.1.7)}} \times 100$$

7.1.2 If the percent solids determined in Section 7.1.1.9 is equal to or greater than 0.5%, then proceed either to Section 7.1.3 to

determine whether the solid material requires particle size reduction or to Section 7.1.2.1 if it is noticed that a small amount of the filtrate is entrained in wetting of the filter. If the percent solids determined in Section 7.1.1.9 is less than 0.5%, then proceed to Section 7.2.9 if the nonvolatile TCLP is to be performed and to Section 7.3 with a fresh portion of the waste if the volatile TCLP is to be performed.

7.1.2.1 Remove the solid phase and filter from the filtration apparatus.

7.1.2.2 Dry the filter and solid phase at 100 ± 20 °C until two successive weighing yield the same value within ± 1%. Record the final weight.

NOTE: Caution should be taken to ensure that the subject solid will not flash upon heating. It is recommended that the drying oven be vented to a hood or other appropriate device.

7.1.2.3 Calculate the percent dry solids as follows:

$$\text{Percent dry solids} = \frac{\text{(Wt. of dry waste + filter) - tared wt. of filter}}{\text{Initial wt. of waste (Section 7.1.1.5 or 7.1.1.7)}} \times 100$$

7.1.2.4 If the percent dry solids is less than 0.5%, then proceed to Section 7.2.9 if the nonvolatile TCLP is to be performed, and to Section 7.3 if the volatile TCLP is to be performed. If the percent dry solids is greater than or equal to 0.5%, and if the nonvolatile TCLP is to be performed, return to the beginning of this Section (7.1) and, with a fresh portion of waste, determine whether particle size reduction is necessary (Section 7.1.3) and determine the appropriate extraction fluid (Section 7.1.4). If only the volatile TCLP is to be performed, see the note in Section 7.1.4.

7.1.3 Determination of whether the waste requires particle size reduction (particle size is reduced during this step): Using the solid portion of the waste, evaluate the solid for particle size. Particle size reduction is required, unless the solid has a surface area per gram of material equal to or greater than 3.1 cm^2, or is smaller than 1 cm in its narrowest dimension (i.e., is capable of passing through a 9.5 mm (0.375 inch) standard sieve). If the surface area is smaller or the particle size larger than described above, prepare the solid portion of the waste for extraction by crushing, cutting, or grinding the waste to a surface area or particle size as described above. If the solids are prepared for organic volatiles extraction, special precautions must be taken (see Section 7.3.6).

NOTE: Surface area criteria are meant for filamentous (e.g., paper, cloth, and similar) waste materials. Actual measurement of surface area is not required, nor is it recommended. For materials that do not obviously meet

the criteria, sample specific methods would need to be developed and employed to measure the surface area. Such methodology is currently not available.

7.1.4 Determination of appropriate extraction fluid: If the solid content of the waste is greater than or equal to 0.5% and if the sample will be extracted for nonvolatile constituents (Section 7.2), determine the appropriate fluid (Section 5.7) for the nonvolatiles extraction as follows:

NOTE: TCLP extraction for volatile constituents uses only extraction fluid #1 (Section 5.7.1). Therefore, if TCLP extraction for nonvolatiles is not required, proceed to Section 7.3.

7.1.4.1 Weigh out a small subsample of the solid phase of the waste, reduce the solid (if necessary) to a particle size of approximately 1 mm in diameter or less, and transfer 5.0 grams of the solid phase of the waste to a 500 mL beaker or Erlenmeyer flask.

7.1.4.2 Add 96.5 mL of reagent water to the beaker, cover with a watchglass, and stir vigorously for 5 minutes using a magnetic stirrer. Measure and record the pH. If the pH is <5.0, use extraction fluid #1. Proceed to Section 7.2.

7.1.4.3 If the pH from Section 7.1.4.2 is >5.0, add 3.5 mL 1N HCl, slurry briefly, cover with a watchglass, heat to 50 °C, and hold at 50 °C for 10 minutes.

7.1.4.4 Let the solution cool to room temperature and record the pH. If the pH is <5.0, use extraction fluid #1. If the pH is >5.0, use extraction fluid #2. Proceed to Section 7.2.

7.1.5 If the aliquot of the waste used for the preliminary evaluation (Sections 7.1.1 - 7.1.4) was determined to be 100% solid at Section 7.1.1.1, then it can be used for the Section 7.2 extraction (assuming at least 100 grams remain), and the Section 7.3 extraction (assuming at least 25 grams remain). If the aliquot was subjected to the procedure in Section 7.1.1.7, then another aliquot shall be used for the volatile extraction procedure in Section 7.3. The aliquot of the waste subjected to the procedure in Section 7.1.1.7 might be appropriate for use for the Section 7.2 extraction if an adequate amount of solid (as determined by Section 7.1.1.9) was obtained. The amount of solid necessary is dependent upon whether a sufficient amount of extract will be produced to support the analyses. If an adequate amount of solid remains, proceed to Section 7.2.10 of the nonvolatile TCLP extraction.

7.2 Procedure When Volatiles are not Involved

A minimum sample size of 100 grams (solid and liquid phases) is recommended. In some cases, a larger sample size may be appropriate, depending on the

solids content of the waste sample (percent solids, See Section 7.1.1), whether the initial liquid phase of the waste will be miscible with the aqueous extract of the solid, and whether inorganics, semivolatile organics, pesticides, and herbicides are all analytes of concern. Enough solids should be generated for extraction such that the volume of TCLP extract will be sufficient to support all of the analyses required. If the amount of extract generated by a single TCLP extraction will not be sufficient to perform all of the analyses, more than one extraction may be performed and the extracts from each combined and aliquoted for analysis.

7.2.1 If the waste will obviously yield no liquid when subjected to pressure filtration (i.e., is 100% solid, see Section 7.1.1), weigh out a subsample of the waste (100 gram minimum) and proceed to Section 7.2.9.

7.2.2 If the sample is liquid or multiphasic, liquid/solid separation is required. This involves the filtration device described in Section 4.3.2 and is outlined in Sections 7.2.3 to 7.2.8.

7.2.3 Pre-weigh the container that will receive the filtrate.

7.2.4 Assemble the filter holder and filter following the manufacturer's instructions. Place the filter on the support screen and secure. Acid wash the filter if evaluating the mobility of metals (see Section 4.4).

NOTE: Acid washed filters may be used for all nonvolatile extractions even when metals are not of concern.

7.2.5 Weigh out a subsample of the waste (100 gram minimum) and record the weight. If the waste contains <0.5% dry solids (Section 7.1.2), the liquid portion of the waste, after filtration, is defined as the TCLP extract. Therefore, enough of the sample should be filtered so that the amount of filtered liquid will support all of the analyses required of the TCLP extract. For wastes containing >0.5% dry solids (Sections 7.1.1 or 7.1.2), use the percent solids information obtained in Section 7.1.1 to determine the optimum sample size (100 gram minimum) for filtration. Enough solids should be generated by filtration to support the analyses to be performed on the TCLP extract.

7.2.6 Allow slurries to stand to permit the solid phase to settle. Wastes that settle slowly may be centrifuged prior to filtration. Use centrifugation only as an aid to filtration. If the waste is centrifuged, the liquid should be decanted and filtered followed by filtration of the solid portion of the waste through the same filtration system.

7.2.7 Quantitatively transfer the waste sample (liquid and solid phases) to the filter holder (see Section 4.3.2). Spread the waste sample evenly over the surface of the filter. If filtration of the waste at 4 °C reduces the amount of expressed liquid over what would be expressed at

room temperature, then allow the sample to warm up to room temperature in the device before filtering.

NOTE: If waste material (>1% of the original sample weight) has obviously adhered to the container used to transfer the sample to the filtration apparatus, determine the weight of this residue and subtract it from the sample weight determined in Section 7.2.5, to determine the weight of the waste sample that will be filtered.

Gradually apply vacuum or gentle pressure of 1-10 psi, until air or pressurizing gas moves through the filter. If this point is not reached under 10 psi, and if no additional liquid has passed through the filter in any 2 minute interval, slowly increase the pressure in 10 psi increments to a maximum of 50 psi. After each incremental increase of 10 psi, if the pressurizing gas has not moved through the filter, and if no additional liquid has passed through the filter in any 2 minute interval, proceed to the next 10 psi increment. When the pressurizing gas begins to move through the filter, or when the liquid flow has ceased at 50 psi (i.e., filtration does not result in any additional filtrate within a 2 minute period), stop the filtration.

NOTE: Instantaneous application of high pressure can degrade the glass fiber filter and may cause premature plugging.

7.2.8 The material in the filter holder is defined as the solid phase of the waste, and the filtrate is defined as the liquid phase. Weigh the filtrate. The liquid phase may now be either analyzed (See Section 7.2.12) or stored at 4 °C until time of analysis.

NOTE: Some wastes, such as oily wastes and some paint wastes, will obviously contain some material that appears to be a liquid. Even after applying vacuum or pressure filtration, as outlined in Section 7.2.7, this material may not filter. If this is the case, the material within the filtration device is defined as a solid and is carried through the extraction as a solid. Do not replace the original filter with a fresh filter under any circumstances. Use only one filter.

7.2.9 If the waste contains <0.5% dry solids (see Section 7.1.2), proceed to Section 7.2.13. If the waste contains >0.5% dry solids (see Section 7.1.1 or 7.1.2), and if particle size reduction of the solid was needed in Section 7.1.3, proceed to Section 7.2.10. If the waste as received passes a 9.5 mm sieve, quantitatively transfer the solid material into the extractor bottle along with the filter used to separate the initial liquid from the solid phase, and proceed to Section 7.2.11.

7.2.10 Prepare the solid portion of the waste for extraction by crushing, cutting, or grinding the waste to a surface area or particle size as described in Section 7.1.3. When the surface area or particle size has been appropriately altered, quantitatively transfer the solid

material into an extractor bottle. Include the filter used to separate the initial liquid from the solid phase.

NOTE: Sieving of the waste is not normally required. Surface area requirements are meant for filamentous (e.g., paper, cloth) and similar waste materials. Actual measurement of surface area is not recommended. If sieving is necessary, a Teflon coated sieve should be used to avoid contamination of the sample.

7.2.11 Determine the amount of extraction fluid to add to the extractor vessel as follows:

$$\text{Weight of extraction fluid} = \frac{20 \times \text{percent solids (Section 7.1.1)} \times \text{weight of waste filtered (Section 7.2.5 or 7.2.7)}}{100}$$

Slowly add this amount of appropriate extraction fluid (see Section 7.1.4) to the extractor vessel. Close the extractor bottle tightly (it is recommended that Teflon tape be used to ensure a tight seal), secure in rotary agitation device, and rotate at 30 ± 2 rpm for 18 ± 2 hours. Ambient temperature (i.e., temperature of room in which extraction takes place) shall be maintained at 23 ± 2 °C during the extraction period.

NOTE: As agitation continues, pressure may build up within the extractor bottle for some types of wastes (e.g., limed or calcium carbonate containing waste may evolve gases such as carbon dioxide). To relieve excess pressure, the extractor bottle may be periodically opened (e.g., after 15 minutes, 30 minutes, and 1 hour) and vented into a hood.

7.2.12 Following the 18 ± 2 hour extraction, separate the material in the extractor vessel into its component liquid and solid phases by filtering through a new glass fiber filter, as outlined in Section 7.2.7. For final filtration of the TCLP extract, the glass fiber filter may be changed, if necessary, to facilitate filtration. Filter(s) shall be acid-washed (see Section 4.4) if evaluating the mobility of metals.

7.2.13 Prepare the TCLP extract as follows:

7.2.13.1 If the waste contained no initial liquid phase, the filtered liquid material obtained from Section 7.2.12 is defined as the TCLP extract. Proceed to Section 7.2.14.

7.2.13.2 If compatible (e.g., multiple phases will not result on combination), combine the filtered liquid resulting from Section 7.2.12 with the initial liquid phase of the waste obtained in Section 7.2.7. This combined liquid is defined as the TCLP extract. Proceed to Section 7.2.14.

7.2.13.3 If the initial liquid phase of the waste, as obtained from Section 7.2.7, is not or may not be compatible with the filtered liquid resulting from Section 7.2.12, do not combine these liquids. Analyze these liquids, collectively defined as the TCLP extract, and combine the results mathematically, as described in Section 7.2.14.

7.2.14 Following collection of the TCLP extract, the pH of the extract should be recorded. Immediately aliquot and preserve the extract for analysis. Metals aliquots must be acidified with nitric acid to pH <2. If precipitation is observed upon addition of nitric acid to a small aliquot of the extract, then the remaining portion of the extract for metals analyses shall not be acidified and the extract shall be analyzed as soon as possible. All other aliquots must be stored under refrigeration (4 °C) until analyzed. The TCLP extract shall be prepared and analyzed according to appropriate analytical methods. TCLP extracts to be analyzed for metals shall be acid digested except in those instances where digestion causes loss of metallic analytes. If an analysis of the undigested extract shows that the concentration of any regulated metallic analyte exceeds the regulatory level, then the waste is hazardous and digestion of the extract is not necessary. However, data on undigested extracts alone cannot be used to demonstrate that the waste is not hazardous. If the individual phases are to be analyzed separately, determine the volume of the individual phases (to ± 0.5%), conduct the appropriate analyses, and combine the results mathematically by using a simple volume-weighted average:

$$\text{Final Analyte Concentration} = \frac{(V_1)\ (C_1) + (V_2)\ (C_2)}{V_1 + V_2}$$

where:

V_1 = The volume of the first phase (L).
C_1 = The concentration of the analyte of concern in the first phase (mg/L).
V_2 = The volume of the second phase (L).
C_2 = The concentration of the analyte of concern in the second phase (mg/L).

7.2.15 Compare the analyte concentrations in the TCLP extract with the levels identified in the appropriate regulations. Refer to Section 8.0 for quality assurance requirements.

7.3 Procedure When Volatiles are Involved

Use the ZHE device to obtain TCLP extract for analysis of volatile compounds only. Extract resulting from the use of the ZHE shall not be used to evaluate the mobility of nonvolatile analytes (e.g., metals, pesticides, etc.).

The ZHE device has approximately a 500 mL internal capacity. The ZHE can thus accommodate a maximum of 25 grams of solid (defined as that fraction of a

sample from which no additional liquid may be forced out by an applied pressure of 50 psi), due to the need to add an amount of extraction fluid equal to 20 times the weight of the solid phase.

Charge the ZHE with sample only once and do not open the device until the final extract (of the solid) has been collected. Repeated filling of the ZHE to obtain 25 grams of solid is not permitted.

Do not allow the waste, the initial liquid phase, or the extract to be exposed to the atmosphere for any more time than is absolutely necessary. Any manipulation of these materials should be done when cold (4 °C) to minimize loss of volatiles.

7.3.1 Pre-weigh the (evacuated) filtrate collection container (See Section 4.6) and set aside. If using a TEDLAR® bag, express all liquid from the ZHE device into the bag, whether for the initial or final liquid/solid separation, and take an aliquot from the liquid in the bag for analysis. The containers listed in Section 4.6 are recommended for use under the conditions stated in Sections 4.6.1 - 4.6.3.

7.3.2 Place the ZHE piston within the body of the ZHE (it may be helpful first to moisten the piston O-rings slightly with extraction fluid). Adjust the piston within the ZHE body to a height that will minimize the distance the piston will have to move once the ZHE is charged with sample (based upon sample size requirements determined from Section 7.3, Section 7.1.1 and/or 7.1.2). Secure the gas inlet/outlet flange (bottom flange) onto the ZHE body in accordance with the manufacturer's instructions. Secure the glass fiber filter between the support screens and set aside. Set liquid inlet/outlet flange (top flange) aside.

7.3.3 If the waste is 100% solid (see Section 7.1.1), weigh out a subsample (25 gram maximum) of the waste, record weight, and proceed to Section 7.3.5.

7.3.4 If the waste contains < 0.5% dry solids (Section 7.1.2), the liquid portion of waste, after filtration, is defined as the TCLP extract. Filter enough of the sample so that the amount of filtered liquid will support all of the volatile analyses required. For wastes containing ≥ 0.5% dry solids (Sections 7.1.1 and/or 7.1.2), use the percent solids information obtained in Section 7.1.1 to determine the optimum sample size to charge into the ZHE. The recommended sample size is as follows:

7.3.4.1 For wastes containing < 5% solids (see Section 7.1.1), weigh out a 500 gram subsample of waste and record the weight.

7.3.4.2 For wastes containing ≥ 5% solids (see Section 7.1.1), determine the amount of waste to charge into the ZHE as follows:

$$\text{Weight of waste to charge ZHE} = \frac{25}{\text{percent solids (Section 7.1.1)}} \times 100$$

Weigh out a subsample of the waste of the appropriate size and record the weight.

7.3.5 If particle size reduction of the solid portion of the waste was required in Section 7.1.3, proceed to Section 7.3.6. If particle size reduction was not required in Section 7.1.3, proceed to Section 7.3.7.

7.3.6 Prepare the waste for extraction by crushing, cutting, or grinding the solid portion of the waste to a surface area or particle size as described in Section 7.1.3. Wastes and appropriate reduction equipment should be refrigerated, if possible, to 4 °C prior to particle size reduction. The means used to effect particle size reduction must not generate heat in and of itself. If reduction of the solid phase of the waste is necessary, exposure of the waste to the atmosphere should be avoided to the extent possible.

NOTE: Sieving of the waste is not recommended due to the possibility that volatiles may be lost. The use of an appropriately graduated ruler is recommended as an acceptable alternative. Surface area requirements are meant for filamentous (e.g., paper, cloth) and similar waste materials. Actual measurement of surface area is not recommended.

When the surface area or particle size has been appropriately altered, proceed to Section 7.3.7.

7.3.7 Waste slurries need not be allowed to stand to permit the solid phase to settle. Do not centrifuge wastes prior to filtration.

7.3.8 Quantitatively transfer the entire sample (liquid and solid phases) quickly to the ZHE. Secure the filter and support screens onto the top flange of the device and secure the top flange to the ZHE body in accordance with the manufacturer's instructions. Tighten all ZHE fittings and place the device in the vertical position (gas inlet/outlet flange on the bottom). Do not attach the extract collection device to the top plate.

NOTE: If waste material (>1% of original sample weight) has obviously adhered to the container used to transfer the sample to the ZHE, determine the weight of this residue and subtract it from the sample weight determined in Section 7.3.4 to determine the weight of the waste sample that will be filtered.

Attach a gas line to the gas inlet/outlet valve (bottom flange) and, with the liquid inlet/outlet valve (top flange) open, begin applying gentle pressure of 1-10 psi (or more if necessary) to force all headspace

slowly out of the ZHE device into a hood. At the first appearance of liquid from the liquid inlet/outlet valve, quickly close the valve and discontinue pressure. If filtration of the waste at 4 °C reduces the amount of expressed liquid over what would be expressed at room temperature, then allow the sample to warm up to room temperature in the device before filtering. If the waste is 100% solid (see Section 7.1.1), slowly increase the pressure to a maximum of 50 psi to force most of the headspace out of the device and proceed to Section 7.3.12.

7.3.9 Attach the evacuated pre-weighed filtrate collection container to the liquid inlet/outlet valve and open the valve. Begin applying gentle pressure of 1-10 psi to force the liquid phase of the sample into the filtrate collection container. If no additional liquid has passed through the filter in any 2 minute interval, slowly increase the pressure in 10 psi increments to a maximum of 50 psi. After each incremental increase of 10 psi, if no additional liquid has passed through the filter in any 2 minute interval, proceed to the next 10 psi increment. When liquid flow has ceased such that continued pressure filtration at 50 psi does not result in any additional filtrate within a 2 minute period, stop the filtration. Close the liquid inlet/outlet valve, discontinue pressure to the piston, and disconnect and weigh the filtrate collection container.

NOTE: Instantaneous application of high pressure can degrade the glass fiber filter and may cause premature plugging.

7.3.10 The material in the ZHE is defined as the solid phase of the waste and the filtrate is defined as the liquid phase.

NOTE: Some wastes, such as oily wastes and some paint wastes, will obviously contain some material that appears to be a liquid. Even after applying pressure filtration, this material will not filter. If this is the case, the material within the filtration device is defined as a solid and is carried through the TCLP extraction as a solid.

If the original waste contained <0.5% dry solids (see Section 7.1.2), this filtrate is defined as the TCLP extract and is analyzed directly. Proceed to Section 7.3.15.

7.3.11 The liquid phase may now be either analyzed immediately (See Sections 7.3.13 through 7.3.15) or stored at 4 °C under minimal headspace conditions until time of analysis. Determine the weight of extraction fluid #1 to add to the ZHE as follows:

$$\text{Weight of extraction fluid} = \frac{20 \times \text{percent solids (Section 7.1.1)} \times \text{weight of waste filtered (Section 7.3.4 or 7.3.8)}}{100}$$

7.3.12 The following Sections detail how to add the appropriate amount of extraction fluid to the solid material within the ZHE and agitation of the ZHE vessel. Extraction fluid #1 is used in all cases (See Section 5.7).

7.3.12.1 With the ZHE in the vertical position, attach a line from the extraction fluid reservoir to the liquid inlet/outlet valve. The line used shall contain fresh extraction fluid and should be preflushed with fluid to eliminate any air pockets in the line. Release gas pressure on the ZHE piston (from the gas inlet/outlet valve), open the liquid inlet/outlet valve, and begin transferring extraction fluid (by pumping or similar means) into the ZHE. Continue pumping extraction fluid into the ZHE until the appropriate amount of fluid has been introduced into the device.

7.3.12.2 After the extraction fluid has been added, immediately close the liquid inlet/outlet valve and disconnect the extraction fluid line. Check the ZHE to ensure that all valves are in their closed positions. Manually rotate the device in an end-over-end fashion 2 or 3 times. Reposition the ZHE in the vertical position with the liquid inlet/outlet valve on top. Pressurize the ZHE to 5-10 psi (if necessary) and slowly open the liquid inlet/outlet valve to bleed out any headspace (into a hood) that may have been introduced due to the addition of extraction fluid. This bleeding shall be done quickly and shall be stopped at the first appearance of liquid from the valve. Re-pressurize the ZHE with 5-10 psi and check all ZHE fittings to ensure that they are closed.

7.3.12.3 Place the ZHE in the rotary agitation apparatus (if it is not already there) and rotate at 30 ± 2 rpm for 18 ± 2 hours. Ambient temperature (i.e., temperature of room in which extraction occurs) shall be maintained at 23 ± 2 °C during agitation.

7.3.13 Following the 18 ± 2 hour agitation period, check the pressure behind the ZHE piston by quickly opening and closing the gas inlet/outlet valve and noting the escape of gas. If the pressure has not been maintained (i.e., no gas release observed), the device is leaking. Check the ZHE for leaking as specified in Section 4.2.1, and perform the extraction again with a new sample of waste. If the pressure within the device has been maintained, the material in the extractor vessel is once again separated into its component liquid and solid phases. If the waste contained an initial liquid phase, the liquid may be filtered directly into the same filtrate collection container (i.e., TEDLAR® bag) holding the initial liquid phase of the waste. A separate filtrate collection container must be used if combining would create multiple phases, or there is not enough volume left within the filtrate collection container. Filter through the glass fiber filter, using the ZHE device as discussed in Section 7.3.9. All extract shall be filtered and collected if the

TEDLAR® bag is used, if the extract is multiphasic, or if the waste contained an initial liquid phase (see Sections 4.6 and 7.3.1).

NOTE: An in-line glass fiber filter may be used to filter the material within the ZHE if it is suspected that the glass fiber filter has been ruptured.

7.3.14 If the original waste contained no initial liquid phase, the filtered liquid material obtained from Section 7.3.13 is defined as the TCLP extract. If the waste contained an initial liquid phase, the filtered liquid material obtained from Section 7.3.13 and the initial liquid phase (Section 7.3.9) are collectively defined as the TCLP extract.

7.3.15 Following collection of the TCLP extract, immediately prepare the extract for analysis and store with minimal headspace at 4 °C until analyzed. Analyze the TCLP extract according to the appropriate analytical methods. If the individual phases are to be analyzed separately (i.e., are not miscible), determine the volume of the individual phases (to 0.5%), conduct the appropriate analyses, and combine the results mathematically by using a simple volume-weighted average:

$$\text{Final Analyte Concentration} = \frac{(V_1)\ (C_1) + (V_2)\ (C_2)}{V_1 + V_2}$$

where:

V_1 = The volume of the first phases (L).
C_1 = The concentration of the analyte of concern in the first phase (mg/L).
V_2 = The volume of the second phase (L).
C_2 = The concentration of the analyte of concern in the second phase (mg/L).

7.3.16 Compare the analyte concentrations in the TCLP extract with the levels identified in the appropriate regulations. Refer to Section 8.0 for quality assurance requirements.

8.0 QUALITY ASSURANCE

8.1 A minimum of one blank (using the same extraction fluid as used for the samples) must be analyzed for every 20 extractions that have been conducted in an extraction vessel.

8.2 A matrix spike shall be performed for each waste type (e.g., wastewater treatment sludge, contaminated soil, etc.) unless the result exceeds the regulatory level and the data are being used solely to demonstrate that the waste property exceeds the regulatory level. A minimum of one matrix spike must be analyzed for each analytical batch. As a minimum, follow the matrix spike addition guidance provided in each analytical method.

8.2.1 Matrix spikes are to be added after filtration of the TCLP extract and before preservation. Matrix spikes should not be added prior to TCLP extraction of the sample.

8.2.2 In most cases, matrix spikes should be added at a concentration equivalent to the corresponding regulatory level. If the analyte concentration is less than one half the regulatory level, the spike concentration may be as low as one half of the analyte concentration, but may not be not less than five times the method detection limit. In order to avoid differences in matrix effects, the matrix spikes must be added to the same nominal volume of TCLP extract as that which was analyzed for the unspiked sample.

8.2.3 The purpose of the matrix spike is to monitor the performance of the analytical methods used, and to determine whether matrix interferences exist. Use of other internal calibration methods, modification of the analytical methods, or use of alternate analytical methods may be needed to accurately measure the analyte concentration in the TCLP extract when the recovery of the matrix spike is below the expected analytical method performance.

8.2.4 Matrix spike recoveries are calculated by the following formula:

$$\%R\ (\%\text{Recovery}) = 100\ (X_s - X_u)/K$$

where:
X_s = measured value for the spiked sample,
X_u = measured value for the unspiked sample, and
K = known value of the spike in the sample.

8.3 All quality control measures described in the appropriate analytical methods shall be followed.

8.4 The use of internal calibration quantitation methods shall be employed for a metallic contaminant if: (1) Recovery of the contaminant from the TCLP extract is not at least 50% and the concentration does not exceed the regulatory level, and (2) The concentration of the contaminant measured in the extract is within 20% of the appropriate regulatory level.

8.4.1. The method of standard additions shall be employed as the internal calibration quantitation method for each metallic contaminant.

8.4.2 The method of standard additions requires preparing calibration standards in the sample matrix rather than reagent water or blank solution. It requires taking four identical aliquots of the solution and adding known amounts of standard to three of these aliquots. The forth aliquot is the unknown. Preferably, the first addition should be prepared so that the resulting concentration is approximately 50% of the expected concentration of the sample. The second and third additions should be prepared so that the concentrations are approximately 100% and

150% of the expected concentration of the sample. All four aliquots are maintained at the same final volume by adding reagent water or a blank solution, and may need dilution adjustment to maintain the signals in the linear range of the instrument technique. All four aliquots are analyzed.

8.4.3 Prepare a plot, or subject data to linear regression, of instrument signals or external-calibration-derived concentrations as the dependant variable (y-axis) versus concentrations of the additions of standard as the independent variable (x-axis). Solve for the intercept of the abscissa (the independent variable, x-axis) which is the concentration in the unknown.

8.4.4 Alternately, subtract the instrumental signal or external-calibration-derived concentration of the unknown (unspiked) sample from the instrumental signals or external-calibration-derived concentrations of the standard additions. Plot or subject to linear regression of the corrected instrument signals or external-calibration-derived concentrations as the dependant variable versus the independent variable. Derive concentrations for unknowns using the internal calibration curve as if it were an external calibration curve.

8.5 Samples must undergo TCLP extraction within the following time periods:

SAMPLE MAXIMUM HOLDING TIMES [DAYS]				
	From: Field collection To: TCLP extraction	From: TCLP extraction To: Preparative extraction	From: Preparative extraction To: Determinative analysis	Total elapsed time
Volatiles	14	NA	14	28
Semi-volatiles	14	7	40	61
Mercury	28	NA	28	56
Metals, except mercury	180	NA	180	360

NA = Not applicable

If sample holding times are exceeded, the values obtained will be considered minimal concentrations. Exceeding the holding time is not acceptable in establishing that a waste does not exceed the regulatory level. Exceeding the holding time will not invalidate characterization if the waste exceeds the regulatory level.

9.0 METHOD PERFORMANCE

9.1 Ruggedness. Two ruggedness studies have been performed to determine the effect of various perturbations on specific elements of the TCLP protocol. Ruggedness testing determines the sensitivity of small procedural variations which might be expected to occur during routine laboratory application.

9.1.1 Metals - The following conditions were used when leaching a waste for metals analysis:

Varying Conditions	
Liquid/Solid ratio	19:1 vs. 21:1
Extraction time	16 hours vs. 18 hours
Headspace	20% vs. 60%
Buffer #2 acidity	190 meq vs. 210 meq
Acid-washed filters	yes vs. no
Filter type	0.7 µm glass fiber vs. 0.45 µm vs. polycarbonate
Bottle type	borosilicate vs. flint glass

Of the seven method variations examined, acidity of the extraction fluid had the greatest impact on the results. Four of 13 metals from an API separator sludge/electroplating waste (API/EW) mixture and two of three metals from an ammonia lime still bottom waste were extracted at higher levels by the more acidic buffer. Because of the sensitivity to pH changes, the method requires that the extraction fluids be prepared so that the final pH is within ± 0.05 units as specified.

9.1.2 Volatile Organic Compounds - The following conditions were used when leaching a waste for VOC analysis:

Varying Conditions	
Liquid/Solid ratio	19:1 vs. 21:1
Headspace	0% vs. 5%
Buffer #1 acidity	60 meq vs. 80 meq
Method of storing extract	Syringe vs. Tedlar® bag
Aliquotting	yes vs. no
Pressure behind piston	0 psi vs. 20 psi

None of the parameters had a significant effect on the results of the ruggedness test.

9.2 Precision. Many TCLP precision (reproducibility) studies have been performed, and have shown that, in general, the precision of the TCLP is comparable to or exceeds that of the EP toxicity test and that method precision is adequate. One of the more significant contributions to poor precision appears to be related to sample homogeneity and inter-laboratory variation (due to the nature of waste materials).

9.2.1 Metals - The results of a multi-laboratory study are shown in Table 6, and indicate that a single analysis of a waste may not be adequate for waste characterization and identification requirements.

9.2.2 Semi-Volatile Organic Compounds - The results of two studies are shown in Tables 7 and 8. Single laboratory precision was excellent with greater than 90 percent of the results exhibiting an RSD less than 25 percent. Over 85 percent of all individual compounds in the multi-laboratory study fell in the RSD range of 20 - 120 percent. Both studies concluded that the TCLP provides adequate precision. It was also determined that the high acetate content of the extraction fluid did not present problems (i.e., column degradation of the gas chromatograph) for the analytical conditions used.

9.2.3 Volatile Organic Compounds - Eleven laboratories participated in a collaborative study of the use of the ZHE with two waste types which were fortified with a mixture of VOCs. The results of the collaborative study are shown in Table 9. Precision results for VOCs tend to occur over a considerable range. However, the range and mean RSD compared very closely to the same collaborative study metals results in Table 6. Blackburn and Show concluded that at the 95% level of significance: 1) recoveries among laboratories were statistically similar, 2) recoveries did not vary significantly between the two sample types, and 3) each laboratory showed the same pattern of recovery for each of the two samples.

10.0 REFERENCES

1. Blackburn, W.B. and Show, I. "Collaborative Study of the Toxicity Characteristics Leaching Procedure (TCLP)." Draft Final Report, Contract No. 68-03-1958, S-Cubed, November 1986.

2. Newcomer, L.R., Blackburn, W.B., Kimmell, T.A. "Performance of the Toxicity Characteristic Leaching Procedure." Wilson Laboratories, S-Cubed, U.S. EPA, December 1986.

3. Williams, L.R., Francis, C.W.; Maskarinec, M.P., Taylor D.R., and Rothman, N. "Single-Laboratory Evaluation of Mobility Procedure for Solid Waste." EMSL, ORNL, S-Cubed, ENSECO.

Table 1.
Volatile Analytes[1,2]

Compound	CAS No.
Acetone	67-64-1
Benzene	71-43-2
n-Butyl alcohol	71-36-3
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	67-66-3
1,2-Dichloroethane	107-06-2
1,1-Dichloroethylene	75-35-4
Ethyl acetate	141-78-6
Ethyl benzene	100-41-4
Ethyl ether	60-29-7
Isobutanol	78-83-1
Methanol	67-56-1
Methylene chloride	75-09-2
Methyl ethyl ketone	78-93-3
Methyl isobutyl ketone	108-10-1
Tetrachloroethylene	127-18-4
Toluene	108-88-3
1,1,1,-Trichloroethane	71-55-6
Trichloroethylene	79-01-6
Trichlorofluoromethane	75-69-4
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
Vinyl chloride	75-01-4
Xylene	1330-20-7

[1] When testing for any or all of these analytes, the zero-headspace extractor vessel shall be used instead of the bottle extractor.

[2] Benzene, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichloroethane, 1,1-dichloroethylene, methyl ethyl ketone, tetrachloroethylene, and vinyl chloride are toxicity characteristic constituents.

Table 2.
Suitable Rotary Agitation Apparatus[1]

Company	Location	Model No.
Analytical Testing and Consulting Services, Inc.	Warrington, PA (215) 343-4490	4-vessel extractor (DC20S) 8-vessel extractor (DC20) 12-vessel extractor (DC20B) 24-vessel extractor (DC24C)
Associated Design and Manufacturing Company	Alexandria, VA (703) 549-5999	2-vessel (3740-2-BRE) 4-vessel (3740-4-BRE) 6-vessel (3740-6-BRE) 8-vessel (3740-8-BRE) 12-vessel (3740-12-BRE) 24-vessel (3740-24-BRE)
Environmental Machine and Design, Inc.	Lynchburg, VA (804) 845-6424	8-vessel (08-00-00) 4-vessel (04-00-00)
IRA Machine Shop and Laboratory	Santurce, PR (809) 752-4004	8-vessel (011001)
Lars Lande Manufacturing	Whitmore Lake, MI (313) 449-4116	10-vessel (10VRE) 5-vessel (5VRE) 6-vessel (6VRE)
Millipore Corp.	Bedford, MA (800) 225-3384	4-ZHE or 4 2-liter bottle extractor (YT310RAHW)

[1] Any device that rotates the extraction vessel in an end-over-end fashion at 30 ± 2 rpm is acceptable.

Table 3.
Suitable Zero-Headspace Extractor Vessels[1]

Company	Location	Model No.
Analytical Testing & Consulting Services, Inc.	Warrington, PA (215) 343-4490	C102, Mechanical Pressure Device
Associated Design and Manufacturing Company	Alexandria, VA (703) 549-5999	3745-ZHE, Gas Pressure Device
Lars Lande Manufacturing[2]	Whitmore Lake, MI (313) 449-4116	ZHE-11, Gas Pressure Device
Millipore Corporation	Bedford, MA (800) 225-3384	YT30090HW, Gas Pressure Device
Environmental Machine and Design, Inc.	Lynchburg, VA (804) 845-6424	VOLA-TOX1, Gas Pressure Device
Gelman Science	Ann Arbor, MI (800) 521-1520	15400 Gas Pressure Device

[1] Any device that meets the specifications listed in Section 4.2.1 of the method is suitable.

[2] This device uses a 110 mm filter.

Table 4.
Suitable Filter Holders[1]

Company	Location	Model/ Catalogue No.	Size
Nucleopore Corporation	Pleasanton, CA (800) 882-7711	425910 410400	142 mm 47 mm
Micro Filtration Systems	Dublin, CA (800) 334-7132 (415) 828-6010	302400 311400	142 mm 47 mm
Millipore Corporation	Bedford, MA (800) 225-3384	YT30142HW XX1004700	142 mm 47 mm

[1] Any device capable of separating the liquid from the solid phase of the waste is suitable, providing that it is chemically compatible with the waste and the constituents to be analyzed. Plastic devices (not listed above) may be used when only inorganic analytes are of concern. The 142 mm size filter holder is recommended.

Table 5.
Suitable Filter Media[1]

Company	Location	Model	Pore Size (µm)
Millipore Corporation	Bedford, MA (800) 225-3384	AP40	0.7
Nucleopore Corporation	Pleasanton, CA (415) 463-2530	211625	0.7
Whatman Laboratory Products, Inc.	Clifton, NJ (201) 773-5800	GFF	0.7
Micro Filtration Systems	Dublin, CA (800) 334-7132 (415) 828-6010	GF75	0.7
Gelman Science	Ann Arbor, MI (800) 521-1520	66256 (90mm) 66257 (142mm)	0.7

[1] Any filter that meets the specifications in Section 4.4 of the Method is suitable.

Table 6. Multi-Laboratory TCLP Metals, Precision

Waste	Extraction Fluid	Metal	$\bar{X}$	S	%RSD
Ammonia Lime Still Bottoms	#1	Cadmium	0.053	0.031	60
	#2		0.023	0.017	76
	#1	Chromium	0.015	0.0014	93
	#2		0.0032	0.0037	118
	#1	Lead	0.0030	0.0027	90
	#2		0.0032	0.0028	87
API/EW Mixture	#1	Cadmium	0.0046	0.0028	61
	#2		0.0005	0.0004	77
	#1	Chromium	0.0561	0.0227	40
	#2		0.105	0.018	17
	#1	Lead	0.0031	0.0031	100
	#2		0.0124	0.0136	110
Fossil Fuel Fly Ash	#1	Cadmium	0.080	0.069	86
	#2		0.093	0.067	72
	#1	Chromium	0.017	0.014	85
	#2		0.070	0.040	57
	#1	Lead	0.0087	0.0074	85
	#2		0.0457	0.0083	18
				%RSD Range = 17 - 118 Mean %RSD = 74	

NOTE: $\bar{X}$ = Mean results from 6 - 12 different laboratories
Units = mg/L
Extraction Fluid #1 = pH 4.9
#2 = pH 2.9

Table 7. Single-Laboratory Semi-Volatiles, Precision

Waste	Compound	Extraction Fluid	$\bar{X}$	S	%RSD
Ammonia Lime Still Bottoms	Phenol	#1	19000	2230	11.6
		#2	19400	929	4.8
	2-Methylphenol	#1	2000	297	14.9
		#2	1860	52.9	2.8
	4-Methylphenol	#1	7940	1380	17.4
		#2	7490	200	2.7
	2,4-Dimethylphenol	#1	321	46.8	14.6
		#2	307	45.8	14.9
	Naphthalene	#1	3920	413	10.5
		#2	3827	176	4.6
	2-Methylnaphthalene	#1	290	44.8	15.5
		#2	273	19.3	7.1
	Dibenzofuran	#1	187	22.7	12.1
		#2	187	7.2	3.9
	Acenaphthylene	#1	703	89.2	12.7
		#2	663	20.1	3.0
	Fluorene	#1	151	17.6	11.7
		#2	156	2.1	1.3
	Phenanthrene	#1	241	22.7	9.4
		#2	243	7.9	3.3
	Anthracene	#1	33.2	6.19	18.6
		#2	34.6	1.55	4.5
	Fluoranthrene	#1	25.3	1.8	7.1
		#2	26.0	1.8	7.1
API/EW Mixture	Phenol	#1	40.7	13.5	33.0
		#2	19.0	1.76	9.3
	2,4-Dimethylphenol	#1	33.0	9.35	28.3
		#2	43.3	8.61	19.9
	Naphthalene	#1	185	29.4	15.8
		#2	165	24.8	15.0
	2-Methylnaphthalene	#1	265	61.2	23.1
		#2	200	18.9	9.5
				%RSD Range = 1 - 33 Mean %RSD = 12	

NOTE: Units = µg/L
Extractions were performed in triplicate
All results were at least 2x the detection limit
Extraction Fluid #1 = pH 4.9
#2 = pH 2.9

Table 8. Multi-Laboratory Semi-Volatiles, Precision

Waste	Compound	Extraction Fluid	$\bar{X}$	S	%RSD
Ammonia Lime	BNAs	#1	10043	7680	76.5
Still Bottoms (A)		#2	10376	6552	63.1
API/EW	BNAs	#1	1624	675	41.6
Mixture (B)		#2	2074	1463	70.5
Fossil Fuel	BNAs	#1	750	175	23.4
Fly Ash (C)		#2	739	342	46.3
					Mean %RSD = 54

NOTE: Units = µg/L
X = Mean results from 3 - 10 labs
Extraction Fluid #1 = pH 4.9
#2 = pH 2.9

%RSD Range for Individual Compounds

A. #1	0 - 113
A. #2	28 - 108
B. #1	20 - 156
B. #2	49 - 128
C. #1	36 - 143
C. #2	61 - 164

Table 9. Multi-Laboratory (11 Labs) VOCs, Precision

Waste	Compound	$\bar{X}$	S	%RSD
Mine Tailings	Vinyl chloride	6.36	6.36	100
	Methylene chloride	12.1	11.8	98
	Carbon disulfide	5.57	2.83	51
	1,1-Dichloroethene	21.9	27.7	127
	1,1-Dichloroethane	31.4	25.4	81
	Chloroform	46.6	29.2	63
	1,2-Dichloroethane	47.8	33.6	70
	2-Butanone	43.5	36.9	85
	1,1,1-Trichloroethane	20.9	20.9	100
	Carbon tetrachloride	12.0	8.2	68
	Trichloroethene	24.7	21.2	86
	1,1,2-Trichloroethene	19.6	10.9	56
	Benzene	37.9	28.7	76
	1,1,2,2-Tetrachloroethane	34.9	25.6	73
	Toluene	29.3	11.2	38
	Chlorobenzene	35.6	19.3	54
	Ethylbenzene	4.27	2.80	66
	Trichlorofluoromethane	3.82	4.40	115
	Acrylonitrile	76.7	110.8	144
Ammonia Lime Still Bottoms	Vinyl chloride	5.00	4.71	94
	Methylene chloride	14.3	13.1	92
	Carbon disulfide	3.37	2.07	61
	1,1-Dichloroethene	52.1	38.8	75
	1,1-Dichloroethane	52.8	25.6	49
	Chloroform	64.7	28.4	44
	1,2-Dichloroethane	43.1	31.5	73
	2-Butanone	59.0	39.6	67
	1,1,1-Trichloroethane	53.6	40.9	76
	Carbon tetrachloride	7.10	6.1	86
	Trichloroethene	57.3	34.2	60
	1,1,2-Trichloroethene	6.7	4.7	70
	Benzene	61.3	26.8	44
	1,1,2,2-Tetrachloroethane	3.16	2.1	66
	Toluene	69.0	18.5	27
	Chlorobenzene	71.8	12.0	17
	Ethylbenzene	3.70	2.2	58
	Trichlorofluoromethane	4.05	4.8	119
	Acrylonitrile	29.4	34.8	118
			%RSD Range = 17 - 144 Mean %RSD = 75	

NOTE: Units = µg/L

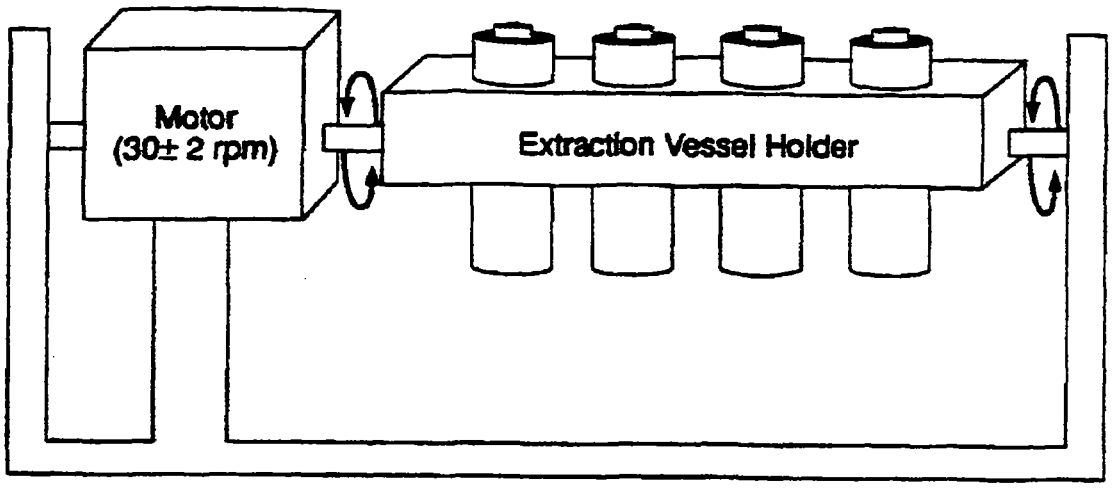


Figure 1. Rotary Agitation Apparatus

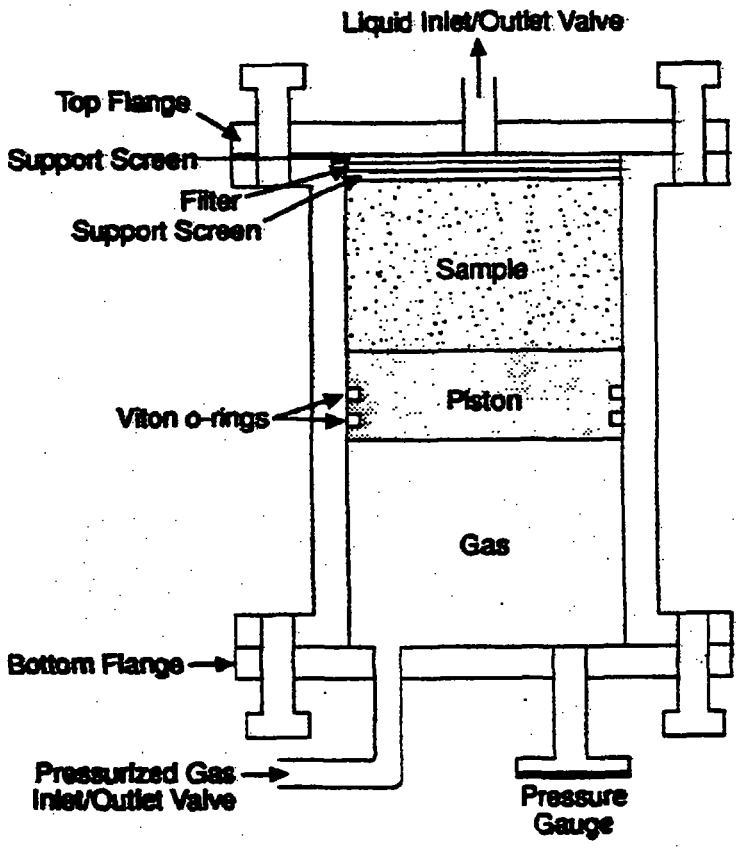
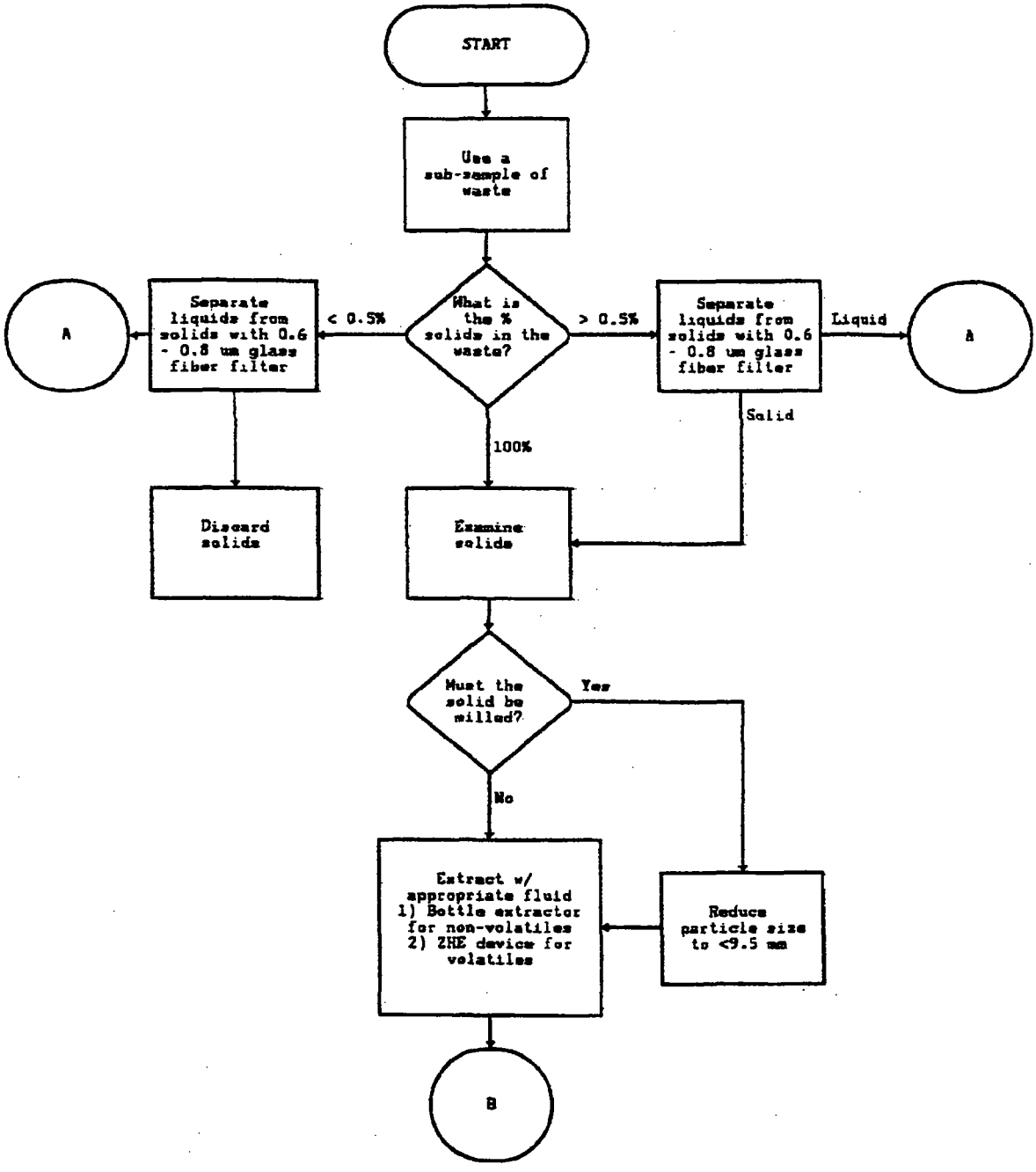


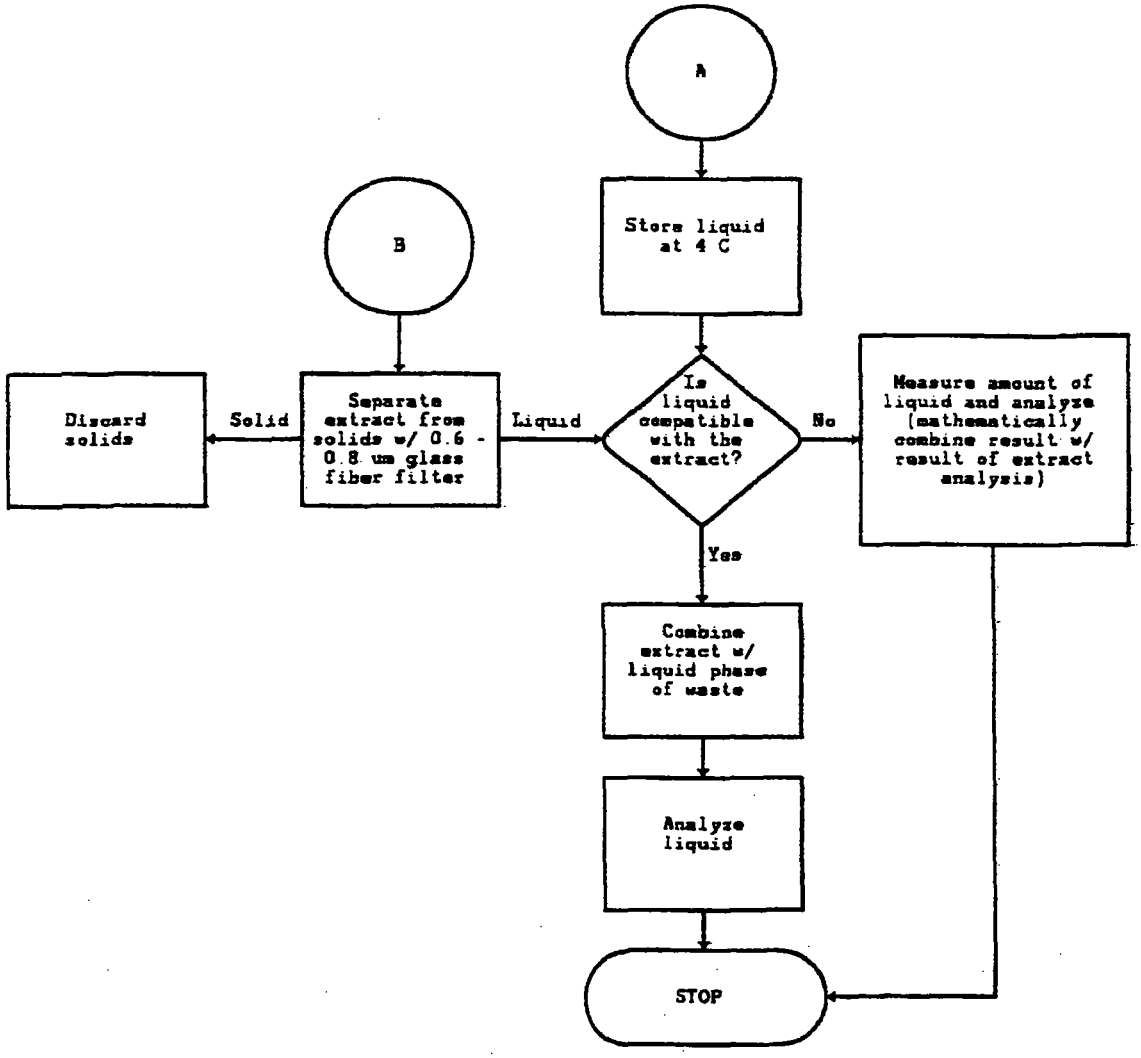
Figure 2. Zero-Headspace Extractor (ZHE)

METHOD 1311

TOXICITY CHARACTERISTIC LEACHATE PROCEDURE



TOXICITY CHARACTERISTIC LEACHATE PROCEDURE



2

Number of Samples	Degrees of Freedom	Tabulated "t" value one-tailed 90%	Standard Deviation Multiplier for Upper Confidence Limit	95% Coverage Upper Tolerance Limit K-Factor 95% Statistical Confidence	non-Parametric Upper 90% Confidence Limit (Rank from Largest)	Tabulated Chi Squared value 90%
2	1	3.078	2.176	26.260	-	0.0158
3	2	1.886	1.089	7.656	-	0.2107
4	3	1.638	0.819	5.144	-	0.5844
5	4	1.533	0.686	4.203	-	1.0636
6	5	1.476	0.603	3.708	1	1.6103
7	6	1.440	0.544	3.398	1	2.2041
8	7	1.415	0.500	3.187	2	2.8331
9	8	1.397	0.466	3.031	2	3.4895
10	9	1.393	0.441	2.911	3	4.1682
11	10	1.372	0.414	2.815	3	4.8652
12	11	1.363	0.393	2.736	3	5.5778
13	12	1.356	0.376	2.670	4	6.3038
14	13	1.360	0.363	2.614	4	7.0415
15	14	1.345	0.347	2.566	5	7.7895
16	15	1.341	0.335	2.524	5	8.8468
17	16	1.337	0.324	2.486	5	9.3122
18	17	1.333	0.314	2.458	6	10.0852
19	18	1.330	0.305	2.423	6	10.8649
20	19	1.328	0.297	2.396	6	11.6509
21	20	1.325	0.289	2.371	7	12.4426
22	21	1.323	0.282	2.349	7	13.2396
23	22	1.321	0.275	2.328	7	14.0415
24	23	1.319	0.269	2.303	8	14.8479
25	24	1.318	0.264	2.292	9	15.6587
26	25	1.316	0.258		9	16.4734
27	26	1.315	0.253		9	17.2919
28	27	1.314	0.248		10	18.1138
29	28	1.313	0.244		10	18.9392
30	29	1.311	0.239		11	19.7677
31	30	1.310	0.235		11	20.5992
41	40	1.303	0.203		15	29.0505
61	60	1.296	0.166		23	46.4589
121	120	1.289	0.117			
infinity	infinity	1.282	0.000			

PRESENTED AT THE AWMA'S SOLID WASTE MANAGEMENT
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INTERPRETING TCLP RESULTS -- A SIMPLIFIED APPROACH

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ABSTRACT

Correctly concluding that a residue is RCRA nonhazardous requires a finding that the 90 percent upper confidence limit [UCL] for the average TCLP contaminant concentration is less than the regulatory threshold. A correct characterization requires proper analysis of representative samples and statistically valid TCLP data interpretation. Statistically valid TCLP data interpretation is very tedious when the data is not normally distributed, as assumed in EPA's draft guidance for Sampling and Analysis of Municipal Refuse Incinerator Ash (1994), but warned against in SW-846, Test Methods for Evaluating Solid Waste (1986).

Tremendous statistical simplification can be achieved if the rank ordered result which bounds the UCL is used to make an initial determinant. If this value is less than the regulatory threshold, the residue is non-hazardous. If it is larger, then a representative distribution must be found and the inherently tighter UCL calculated using distributional assumptions in accordance with good statistical practice and 40 CFR 261 referenced SW-846.

INTRODUCTION

On May 2, 1994, the Supreme Court decided in the City of Chicago v. EDF that residues generated at municipal waste combustors [MWC] were not exempt from the requirements of RCRA Section 3001(i). The ruling effectively states that contrary to previous EPA guidance and determinations, combustion residues are only exempt from regulation if they do not exhibit hazardous characteristics.

Quarterly testing to assess the TCLP characteristics of residues is recommended in EPA's May 1994 draft guidance. EPA suggests that 14 samples be collected, extracted and analyzed using the Toxic Characteristic Leaching Procedure [TCLP], and the results compared to regulatory thresholds according to procedures outlined in Chapter NINE of SW-846. While a portion of SW-846 Table 9-1 is reproduced in the guidance, the equations needed to deal with nonnormal distributions are missing. Furthermore, SW-846 Section NINE text warning about nonnormality and methods of addressing this the problem are also missing.

When dealing with single industrial process waste streams, TCLP results are frequently normally distributed and data nonnormality does not present a concern. Residues from combustion processes, however, rarely meet the statistical requirements outlined in Chapter NINE of SW-846 for use of normal statistics. This is particularly true of TCLP lead and cadmium results. For nonnormal data sets, Chapter NINE recommends that the data be mathematically transformed to achieve normalcy and the comparison to regulatory standards be performed in the transformed plane. For example, if the data are square-root distributed and the regulatory threshold is 4, then the square-roots of the data are taken, summary statistics (average and standard deviations)

determined, the 90 percent statistical confidence level upper confidence limit [UCL] for the mean calculated, and finally the UCL is compared to 2--the square root of 4.

The correct normalizing transformation based on firm statistical grounds can be found by using methods and procedures employed by the Office of Solid Waste (EPA, 1989 & 1992) to analyze ground-water monitoring data at RCRA facilities. These procedures provide scientifically and statistically correct answers. But, these methods are sufficiently tedious that a staged approach which avoids them--while conservatively comparing TCLP characteristics to regulatory thresholds--is an economic and efficient way to analyze the data.

Nonparametric, distribution free approaches based on the rank ordered TCLP results provide an appropriate first stage. This approach inherently produces bounds which are broader than limits developed using distributional assumptions that take full advantage of the information in the data. Consequently, if the nonparametric statistics based conclusion is that the TCLP results are below the regulatory threshold, a more sophisticated statistical approach will not find an exceedance. On the other hand, finding an apparent exceedance using nonparametric statistics does not necessarily mean that the waste stream is hazardous. Rather, it points out the need for the following additional steps: establish a plausible underlying distribution for the data, correctly calculate the UCL and compare that result to the regulatory threshold.

The following three-step procedure is a practical, economical way to determine TCLP regulatory status of specific contaminant concentrations:

- Are all results less than the regulatory threshold? Stop, the waste is RCRA nonhazardous for that contaminant.
- Is the nth largest value (from Table 1) less than the regulatory threshold? Stop, the waste is RCRA nonhazardous for that contaminant.
- Establish an acceptable underlying distribution and calculate the 90 percent statistical confidence level upper confidence limit for the average. If the UCL is less than the regulatory threshold, the waste is RCRA nonhazardous. Otherwise, conclude that the waste exhibits toxicity leaching characteristics for the contaminant investigated.

The first step is justified and methods and tables needed to implement steps two and three follow.

NONPARAMETRIC DETERMINATION OF THE UCL

Nonparametric statistics do not require the analyst to make any assumptions about the underlying distribution of the data. Instead, key summary statistics, like the 90 percent statistical confidence level upper confidence limit used to compare the TCLP subsample to regulatory thresholds, are based on the rank ordered results.

Extensive nonparametric UCL tables and the mathematics underlying them are provided in Hahn & Meeker (1991). A simplified equation for determining the rank ordered result which corresponds to the 90 percent UCL is provided in EPA (1989). The equation is as follows:

$$R = \frac{1}{2}\{N - Z_p(N)^{\frac{1}{2}}\}$$

where:

- R is the rank of the nth largest result corresponding to the 90% UCL.
- N is the number of TCLP results, and
- Z_p is 1.282, the standard normal distribution value corresponding to the 90 percent statistical confidence level.

Table 1 includes the values of R beginning with 2 samples. The results demonstrate that for any characterization program with 6 or more TCLP results and the largest value for any pollutant less than the regulatory threshold, the 90 percent UCL is also less than the regulatory threshold. Hence, the guidance provided in Step 1: if all TCLP results are less than the regulatory thresholds, then there is no benefit to doing additional data reduction since the calculated UCL will be less than the nonparametric UCL. The 4th largest value is compared to the regulatory threshold if the sampling program produced 14 TCLP results as recommended by EPA (1994) draft ash sampling guidance to MWCs.

Table 2 provides lead and cadmium TCLP results for 14 MWC combined ash subsamples. Sampling was divided into morning and afternoon campaigns throughout a 7 day period. Each subsample was made up from a number of systematic random sample increments collected as the residue left the facility.

Each subsample was passed over a No. 9 (3/8 inch) screen. The friable overs were crushed to minus 3/8 inch in a jaw crusher. The irreducible malleable materials were separated and described. After recombining all the minus 3/8 inch material, the total subsample quantity was reduced using a splitter. Approximately 10 kg of sized material was then mixed in a small batch concrete mixer. Nominal 1 kg samples were separated across the full width of the batch mixer using a trier sampler made from nominal 2 inch, schedule 40 pipe.

The subsamples were sent to the lab. At the laboratory, the leaching fluid for each subsample was determined, 100 g aliquots were extracted and the leachates were analyzed using ICP for TCLP metals. Chain of custody was documented along with any deviations from both the facility's and laboratory's Quality Assurance Plans. Full SW-846 chemical analysis QA/QC requirements were followed.

The date in Table 2 contains below detection limits [BDL] results--shown in parentheses. Since the BDL results are all less than the detected values, a particularly nice feature of nonparametric UCL estimation comes into play. When the data are rank-ordered, the BDL results contribute information about position, but no special treatment is required to accurately estimate the mean, standard deviation and UCL of the detection limit censored data. As long as there are as many quantified results as are needed to provide a value for the Rth TCLP, the UCL result is uniquely determined. If the Rth value is BDL, then the UCL is no greater than the detection limit.

Since there are 14 subsamples used to characterize the waste in Table 2, the 4th largest value is the nonparametric UCL. Inspection of Table 2 indicates that there are occasional subsample results that exceed the regulatory threshold. The 4th largest result for cadmium (1.02 mg/l) is more than the 1.0 mg/l regulatory threshold while lead (2.1 mg/l) is below the 5.0 mg/l regulatory threshold. More detailed analysis of the cadmium data is indicated. The nonparametric UCL indicates that the waste stream is RCRA nonhazardous for lead and further analysis is not necessary. However, the detailed statistical analysis of lead will continue to be used to illustrate techniques, even though it is unnecessary.

PARAMETRIC DETERMINATION OF THE UCL

Parametric statistics require the analyst to determine an appropriate distribution to describe the data before the UCL can be calculated. The draft residue sampling guidelines (EPA, 1994) assume that the TCLP metal results are normally distributed. The UCL is calculated using the following formula:

$$UCL = \langle X \rangle + S\, t_{(1-\alpha)} N^{-\frac{1}{2}}$$

where:

$\langle X \rangle$	is the average of the data,
S	is the standard deviation of the data,
$t_{(1-\alpha)}$	is the t-statistic for N-1 degrees and the 1-α statistical confidence level, and
N	is the number of sample data points

If the normal distribution assumption is incorrect, then the calculated limit will be incorrect as well because "the validity of a CI (UCL) for the true mean concentration... ...(is) based on the assumption that individual concentrations of a contaminant exhibit a normal distribution." (SW-846, NINE-10).

The validity of the normal distribution assumption can be tested in a number of ways. One of the easiest was suggested by Filliben (1975) and is utilized by EPA'S Office of Solid Waste for making RCRA ground-water contamination data distribution determinations.

A quantile-quantile [Q-Q] plot of the data is prepared by plotting the (transformed) data against corresponding standard normal deviates[1] for the median percentage rank[2] of each data point. The linear regression line describing the contaminant concentration is calculated. If the correlation coefficient for the regression is less than the value in Table 3 associated with the selected statistical significance level, then the assumed distribution does not adequately describe the data. Since many commercial spreadsheets automatically generate r^2, Table 3 has a second set of columns providing critical values of r^2.

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[1]These can be found using a table of Standard Normal Deviates found in most Statistics texts. Alternatively, they can be calculated using the following rational approximation (Abramowitz & Stegun, 1965):

$$Z_f = \tau - (a_0 + a_1\tau + a_2\tau^2)/(1 + b_1\tau + b_2\tau^2 + b_3\tau^3)$$

where: $\tau = (-2\ln f)^{1/2}$ for $f \leq 0.5$ and
$= (-2\ln(1-f))^{1/2}$ for $f > 0.5$

$a_0 = 2.515517$ $b_1 = 1.432788$
$a_1 = 0.802853$ $b_2 = 0.189269$
$a_2 = 0.010328$ $b_3 = 0.001308$

[2]Median ranks can be found in tables in some statistics texts and they can be computed using the following formula (Blom, 1958):

$$f = (r-0.375)/(N+0.25)$$

where:

r = rank of the data point
N = number of data points in the set

It is imperative to recognize that statistics argues by double negatives. That is, statistics can never prove that a distribution assumption is correct; rather they are used to demonstrate that an assumed distribution is unlikely to describe the data under consideration.

Figures 1 and 2 are normal and lognormal quantile-quantile plots of the lead and cadmium data in Table 2. The correlation coefficient for the normal distribution regression in Figure 1 is 0.821. This value is substantially less than the critical value of 0.924 from Table 3 for the 8 above detection limits data points. There is less than a 90 percent chance (10 percent statistical significance level) that the data is normally distributed. When the log transformed data is analyzed, the correlation coefficient is 0.984. The normal distribution assumption is therefore inappropriate and parametric comparison of the results to the regulatory threshold should be done using lognormal statistics.

Figure 2 presents an interesting additional twist. If the regression is simply run through all 9 data points, neither the normal nor the lognormal transformation are adequate. Inspection of the plots reveals that the data is from a multinormal or multilognormal distribution; that is, there is a distinct kink in the best fit line. The data is described by two different distributions. Since regulatory status is determined by the upper confidence limit, the upper part of the curve is fit. When this is done, both the normal ($r = 0.981$) and lognormal ($r = 0.994$) adequately describe the data. Hahn and Shapiro (1967) and Shumway et al. (1989) have shown that when an analyst is unsure of the correct distribution to use, making the transformation is usually helpful and at worst harmless. Working with the log transformed data is therefore indicated to minimize the number of different computational procedures needed.

In order to make the comparison in the log-plane, the summary statistics ($<X>$ and S) are computed using the natural logarithms of the data rather than the untransformed data. SW-846 suggests that the comparisons be made in the transformed plane; however, it is usually easier to understand the comparison if the UCL is calculated in the log-plane, the transformation inversed and the result expressed in normal units. In the case of the log, this is done by taking the exponential of the log-plane UCL.

40 CFR 261, as interpreted by SW-846, implies (but does not state) that the upper confidence limit of the <u>average</u> should be less than the regulatory limit. Looking at the log-plane mean of lognormal data illustrates the problem. The mean of the log transformed data is the data's geometric mean. Hence, the log transformed UCL is about the <u>median</u> of the untransformed data, not the average. The transformed plane UCL is less than the UCL for the average of log transformed data and similarly understates the toxicity characteristic for other nonnormal distributions.

Instead of simply transforming the data and computing the UCL, it is more conservative and potentially more in line with the regulatory intent to calculate the UCL of the average. The UCL of the average is then compared to the regulatory limit.

Determining the UCL of the average of nonnormal data is a daunting task. Land (1975) developed a method for determining the UCL of the expected value (EV or arithmetic average in the normal plane)[3] for lognormally distributed data and several

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3 $EV = \exp(<y> + \frac{1}{2}S_y^2)$

where: $y = \ln(X)$,

$<y>$ = arithmetic average of y, and

other distributions[4]. The following focuses on determining the UCL for the average of lognormally distributed data. Interested readers are referred to Land to determine the UCL for other distributions.

After calculating the mean and standard deviation of the log transformed data, the UCL is:

$$UCL = \exp\{<y> + \tfrac{1}{2}S_y^2 + CS_y/(N-1)^{\frac{1}{2}}\}$$

where: C is taken from Table 4.

Rigo (1993) derived an equivalent formulation that can be programmed into a spreadsheet. The derivation follows Land's Taylor series expansion approach, but employs coefficients that can be calculated using t and chi square statistics provided in Table 1 or the asymptotic expansions for the functions found in Abramowitz & Stegun (1965):

$$UCL = \exp\{<y> + \tfrac{1}{2}S_y^2 + (t_{(N-1,\alpha)}^2/N^{\frac{1}{2}}S_y^2 + [\tfrac{1}{2}S_y^2\{(N-1)/X^2_{(N-1,1-\alpha)}-1\}]^2)^{\frac{1}{2}}\}$$

where: $X^2_{(N-1,1-\alpha)}$ is the chi squared statistic.

Using the average and standard deviation of the log-transformed data--the constant and slope in the linear regression of the quantile-quantile plot--the UCL of the average is 1.2 mg/l for lead and 0.9 mg/l for cadmium. Both contaminants are below the regulatory threshold, so the waste stream should be classified as RCRA nonhazardous.

There are many approaches to determining the average and standard deviation of censored data. Ad hoc substitution schemes involve simply removing the BDLs or substituting 0, ½DL or DL. A mathematical approach that develops a maximum likelihood estimate of the true mean and standard deviation of the transformed data starting with the censoring level (detection limit), fraction nondetects and detected data average and standard deviation has been developed by Cohen (1979, 1961 and 1959)[5].

The graphical, curve fit method using Q-Q plots is usually better than the substitution schemes and at least as good as any other method that makes maximum use of the information contained within the data (Berthouex & Brown, 1994). The detection

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S_y = Standard deviation of y

[4]For the square root distribution, $EX = <z>^2+S_z^2$ and for the arcsine distribution, $EX = \tfrac{1}{2}[1-\cos(2<w>)\exp(-2S_w^2)]$
where: z is the square root of X, and
w is the arcsin of the square root of X with S_z and S_w defined consistently.

[5]
avg $= <y> - L(<y>-y_c)$, and
stddev $= (s^2 + L(<y>-y_c)\}^{\frac{1}{2}}$
where: $\ln(L) = 0.182344 -0.03756/(\beta+1) +0.10018\beta +0.78079\delta -0.00581\beta^2 - 0.06642\delta^2 -0.0234\beta\delta +0.000174\beta^3 +0.001663\beta^2\delta -0.00086\beta\delta^2 -0.00653\delta^3$
$\beta = s^2/(<y>-y_c)^2$
$\delta = \ln[h/(1-h)]$, and
h = fraction BDL results
y_c = censoring level (detection limit)

limit based substitution schemes produce biased estimates of the mean and standard deviation; hence the UCLs are also biased. Cohen's method, like the Q-Q plot method, assumes that the hidden, censored part of the distribution is a continuation of the visible portion. It results in the best estimates for situations where this assumption is true and biased estimates where it is false. The Q-Q plot allows identification and characterization of multinormal distributions like that which describes the cadmium data in Table 2.

SUMMARY

Correctly calculating the UCL for TCLP data and making valid comparisons to regulatory thresholds is a tedious task that can be avoided in many cases. Nonparametric UCL estimates based on the rank ordered data provide a conservative bound that will not be exceeded by correctly calculated limits. Since nonparametric UCLs are inherently higher than parametrically calculated UCLs, identification of a reasonable distribution assumption and calculation of a parametric UCL is indicated before concluding that a waste stream exceeds the regulatory limit.

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Table 1. Tabulated statistical parameters used to determine UCL's.

Number of Samples	Degrees of Freedom	Tabulated "t" value one-tailed 90%	non-Parametric Upper 90% Confidence Limit (Rank from Largest)	Tabulated Chi Squared value 90%
2	1	3.078	-	0.0158
3	2	1.886	-	0.2107
4	3	1.638	-	0.5844
5	4	1.533	-	1.0636
6	5	1.476	1	1.6103
7	6	1.440	1	2.2041
8	7	1.415	2	2.8331
9	8	1.397	2	3.4895
10	9	1.393	3	4.1682
11	10	1.372	3	4.8652
12	11	1.363	3	5.5778
13	12	1.356	4	6.3038
14	13	1.360	4	7.0415
15	14	1.345	5	7.7895
16	15	1.341	5	8.8468
17	16	1.337	5	9.3122
18	17	1.333	6	10.0852
19	18	1.330	6	10.8649
20	19	1.328	6	11.6509
21	20	1.325	7	12.4426
22	21	1.323	7	13.2396
23	22	1.321	7	14.0415
24	23	1.319	8	14.8479
25	24	1.318	9	15.6587
26	25	1.316	9	16.4734
27	26	1.315	9	17.2919
28	27	1.314	10	18.1138
29	28	1.313	10	18.9392
30	29	1.311	11	19.7677
31	30	1.310	11	20.5992
41	40	1.303	15	29.0505
61	60	1.296	23	46.4589
121	120	1.289		
infinity	infinity	1.282		

Table 2. Lead and cadmium TCLP concentrations from a MWC.

REGULATORY THRESHOLD SUBSAMPLE I.D.	CONTAMINANT			
	1.0 mg/l CADMIUM		5.0 mg/l LEAD	
	mg/l	RANK	mg/l	RANK
C-1	0.85	6	1.28	5
C-2	0.24	9	(0.50)	12
C-3	(0.10)	10	(0.50)	13
C-4	(0.10)	11	(0.50)	14
C-5	1.63	1	6.05	2
C-6	1.07	3	2.10	4
C-7	0.95	5	10.45	1
C-8	0.48	8	0.95	6
C-9	(0.10)	13	(0.50)	10
C-10	1.02	4	0.79	7
C-11	(0.10)	14	(0.50)	11
C-12	(0.10)	12	(0.50)	9
C-13	1.28	2	2.12	3
C-14	0.80	7	0.71	8

Table 3. Percentage points of the normal probability plot correlation coefficient (r) and coefficient squared.

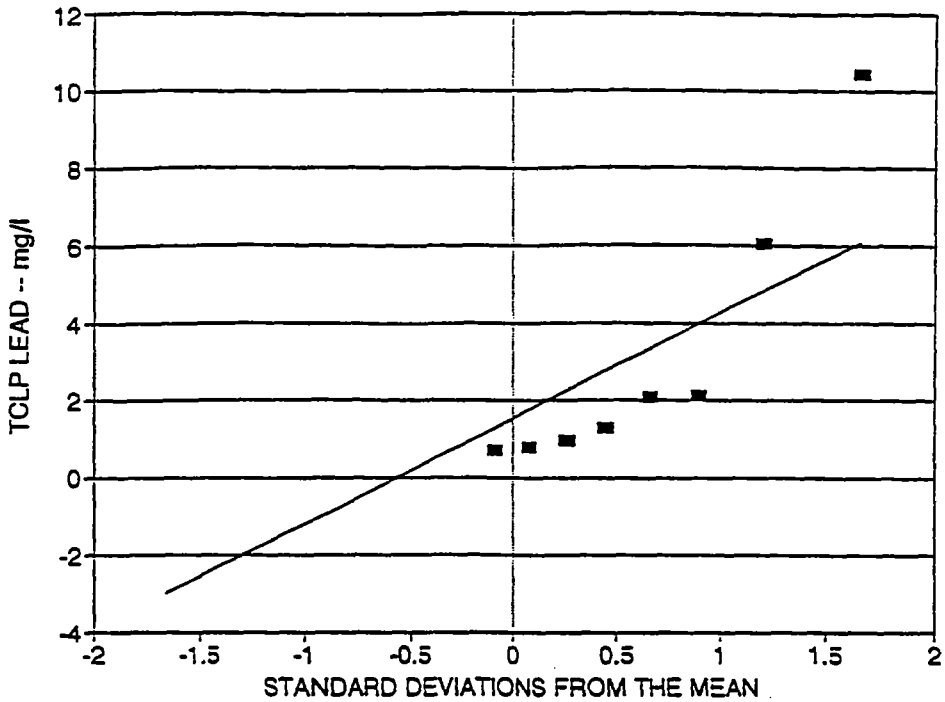
significance	r			r squared		
N	0.1	0.05	0.01	0.1	0.05	0.01
3	0.891	0.879	0.869	0.794	0.773	0.755
4	0.894	0.868	0.922	0.799	0.753	0.850
5	0.902	0.879	0.922	0.814	0.773	0.850
6	0.911	0.890	0.935	0.830	0.792	0.874
7	0.916	0.899	0.847	0.839	0.808	0.717
8	0.924	0.905	0.859	0.854	0.819	0.738
9	0.929	0.912	0.868	0.863	0.832	0.753
10	0.934	0.917	0.876	0.872	0.841	0.767
11	0.938	0.922	0.883	0.880	0.850	0.780
12	0.941	0.926	0.889	0.885	0.857	0.790
13	0.944	0.931	0.895	0.891	0.867	0.801
14	0.947	0.934	0.901	0.897	0.872	0.812
15	0.950	0.937	0.907	0.903	0.878	0.823
16	0.952	0.940	0.912	0.906	0.884	0.832
17	0.954	0.942	0.916	0.910	0.887	0.839
18	0.956	0.945	0.919	0.914	0.893	0.845
19	0.958	0.947	0.923	0.918	0.897	0.852
20	0.960	0.950	0.925	0.922	0.903	0.856
21	0.961	0.952	0.928	0.924	0.906	0.861
22	0.962	0.954	0.930	0.925	0.910	0.865
23	0.964	0.955	0.933	0.929	0.912	0.870
24	0.965	0.957	0.936	0.931	0.916	0.876
25	0.966	0.958	0.937	0.933	0.918	0.878
26	0.967	0.959	0.939	0.935	0.920	0.882
27	0.968	0.960	0.941	0.937	0.922	0.885
28	0.969	0.962	0.943	0.939	0.925	0.889
29	0.969	0.962	0.945	0.939	0.925	0.893
30	0.970	0.964	0.947	0.941	0.929	0.897
40	0.977	0.972	0.958	0.955	0.945	0.918
60	0.983	0.980	0.970	0.966	0.960	0.941
100	0.989	0.987	0.981	0.978	0.974	0.962

after Filliben (1975)

Table 4. Values of C to determine UCL of lognormal data.

Sy	number of data points -- N												
	3	4	5	6	7	8	9	10	11	12	13	14	15
0.10	1.689	1.506	1.438	1.403	1.381	1.367	1.356	1.349	1.344	1.338	1.334	1.330	1.328
0.20	1.885	1.620	1.522	1.472	1.442	1.422	1.407	1.396	1.389	1.380	1.374	1.369	1.365
0.30	2.156	1.763	1.627	1.558	1.517	1.489	1.469	1.453	1.443	1.432	1.423	1.416	1.411
0.40	2.521	1.942	1.755	1.652	1.607	1.569	1.543	1.523	1.510	1.494	1.483	1.473	1.467
0.50	2.990	2.160	1.907	1.785	1.712	1.664	1.630	1.604	1.587	1.567	1.552	1.540	1.532
0.60	3.542	2.417	2.084	1.926	1.834	1.773	1.729	1.696	1.675	1.650	1.632	1.617	1.606
0.70	4.136	2.708	2.284	2.085	1.970	1.896	1.840	1.800	1.774	1.743	1.721	1.703	1.690
0.80	4.742	3.023	2.503	2.260	2.119	2.027	1.962	1.914	1.882	1.845	1.818	1.796	1.781
0.90	5.349	3.353	2.736	2.447	2.280	2.171	2.094	2.036	1.998	1.955	1.923	1.898	1.880
1.00	5.955	3.691	2.980	2.644	2.450	2.324	2.234	2.167	2.123	2.073	2.036	2.006	1.985
1.25	7.466	4.558	3.617	3.167	2.904	2.732	2.610	2.518	2.459	2.391	2.340	2.300	2.271
1.50	8.973	5.436	4.276	3.713	3.383	3.166	3.012	2.896	2.820	2.733	2.669	2.617	2.581
1.75	10.48	6.319	4.944	4.273	3.877	3.615	3.429	3.289	3.198	3.092	3.014	2.951	2.907
2.00	11.98	7.206	5.619	4.842	4.380	4.075	3.857	3.693	3.586	3.461	3.370	3.296	3.244
2.50	14.99	8.986	6.979	5.990	5.401	5.010	4.730	4.518	4.380	4.220	4.102	4.006	3.938
3.0	18.00	10.77	8.346	7.147	6.434	5.958	5.617	5.359	5.190	4.994	4.850	4.733	4.650
3.5	21.00	12.56	9.717	8.312	7.473	5.913	6.511	6.208	6.009	5.778	5.607	5.469	5.370
4.0	24.00	14.34	11.09	9.480	8.516	7.873	7.411	7.062	6.832	6.566	6.370	6.210	6.097
4.5	27.01	16.13	12.47	10.65	9.562	8.836	8.314	7.919	7.660	7.360	7.138	6.957	6.829
5.0	30.01	17.92	13.84	11.82	10.61	9.800	9.219	8.779	8.490	8.155	7.907	7.706	7.563
6	36.02	21.49	16.06	14.17	12.71	11.74	11.03	10.50	10.153	9.75	9.453	9.210	9.037
7	42.02	25.07	19.35	16.51	14.81	13.67	12.82	12.23	11.826	11.35	11.005	10.723	10.520
8	48.03	28.65	22.11	18.86	16.91	15.61	14.67	13.96	13.496	12.96	12.560	12.234	12.000
9	54.03	32.23	24.87	21.21	19.02	17.55	16.50	15.70	15.173	14.56	14.109	13.741	13.480
10	60.04	35.81	27.63	23.56	21.12	19.49	18.32	17.43	16.846	16.17	15.669	15.261	14.970

after Land (1975) with lagrange 3-point interpolation fill in



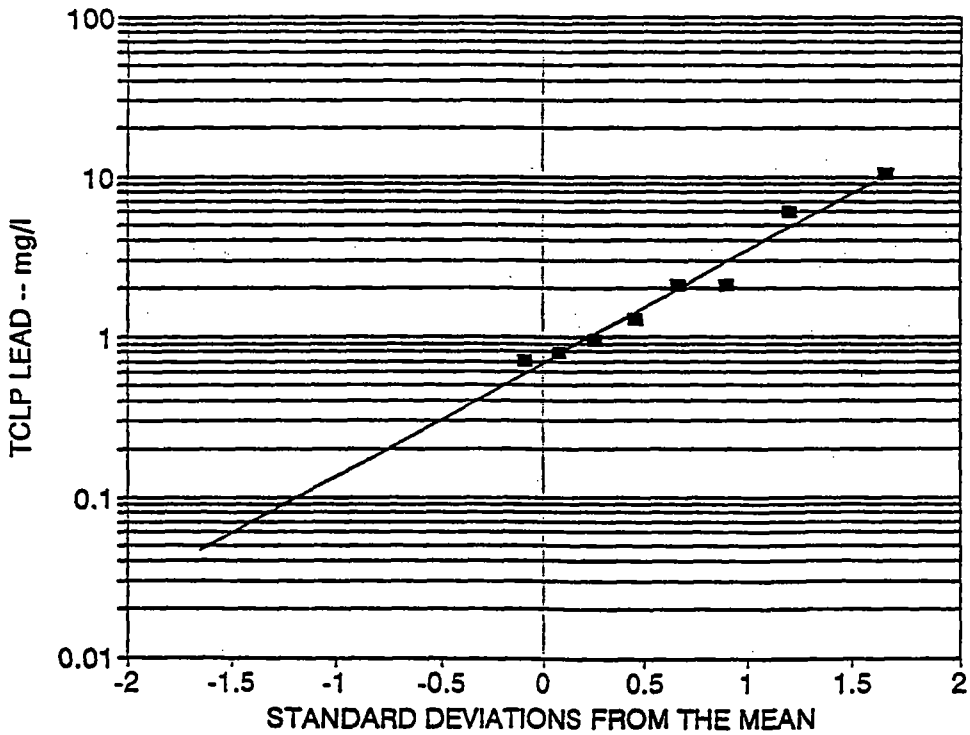
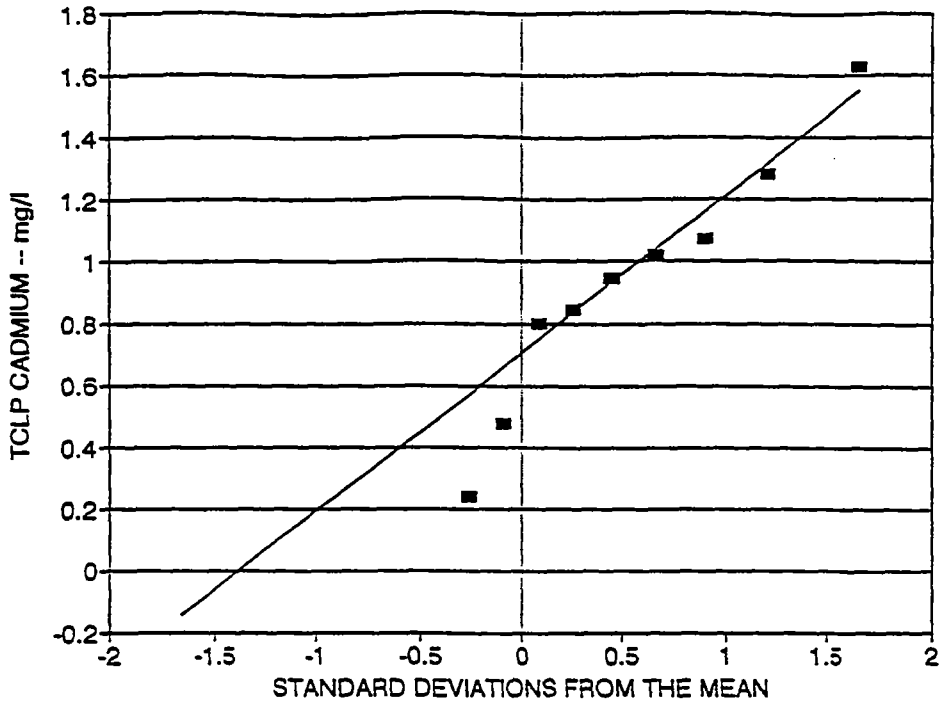


Figure 1. Quantile-Quantile plots of TCLP lead concentrations.



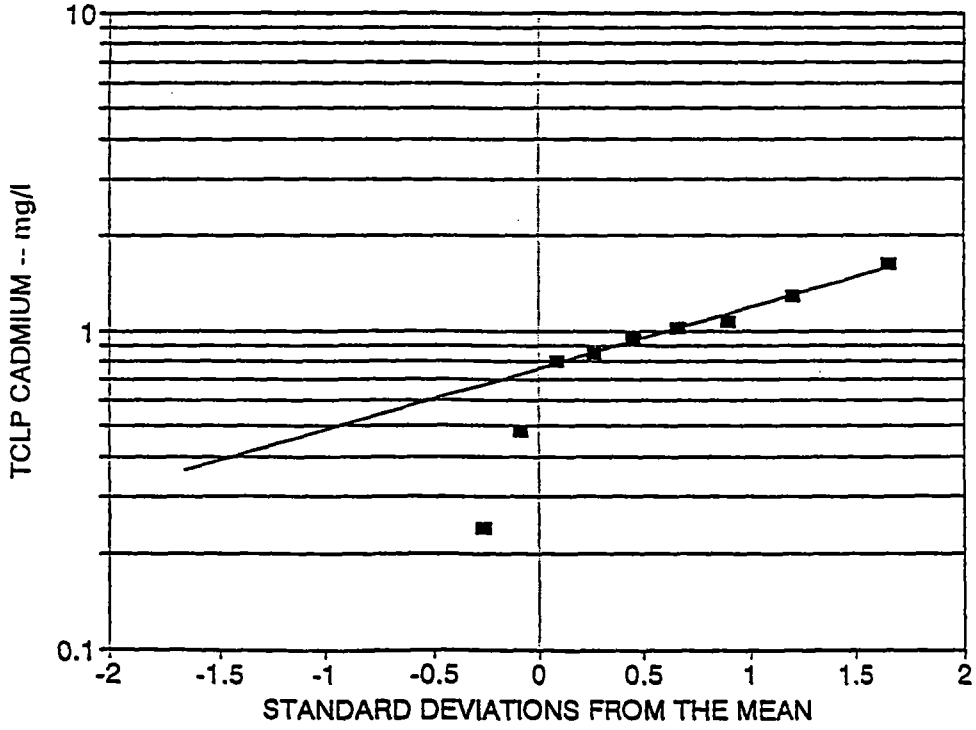


Figure 2. Quantile-quantile plots of TCLP cadmium concentrations.

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EPA POLICY INTERPRETATION ON POINT AT WHICH RCRA SECTION 3001(i) JURISDICTION BEGINS FOR MUNICIPAL WASTE COMBUSTION ASH AT WASTE-TO-ENERGY FACILITIES

HISTORY: 60 FR 6666,Feb. 3, 1995; Effective Feb. 3, 1995

Determination of Point at Which RCRA Subtitle C Jurisdiction Begins for Municipal Waste Combustion Ash at Waste-to-Energy Facilities

I. Authority

This action interpreting RCRA Section 3001(i) and the hazardous waste regulations in 40 CFR Parts 260-271 is being taken under the authority of sections 2002 and 3001 of the Solid Waste Disposal Act of 1970 as amended by the Resource Conservation and Recovery Act of 1976, as amended (42 U.S.C. 6912 and 6921).

II. Background

A. Nature of Ash From Waste-to- Energy Facilities

Combustion of municipal solid waste, particularly through WTE facilities, can be an important component of a local government's waste management practices. As of 1993, approximately 207 million tons of municipal solid waste were generated annually in the U.S., 16 percent of which (33 million tons) was combusted. There are approximately 150 municipal waste combustors in the U.S., 80 percent of which are WTE facilities. The remaining 20 percent incinerate waste without recovering energy.

Approximately 25 percent (dry weight) of the waste that is combusted remains as ash, amounting to around eight million tons of municipal waste combustor (MWC) ash generated annually. While the ash may be collected at a number of locations within a WTE facility, it typically is characterized as either "bottom ash" or "fly ash." Bottom ash collects at the bottom of the combustion unit and comprises approximately 75-80% of the total ash by weight. Fly ash collects in the air pollution control devices that "clean" the gases produced during the combustion of the waste and comprises around 20-25% of the total by weight. The fly ash from a WTE facility's different air pollution control devices typically is consolidated and then combined with the bottom ash via enclosed conveyors at the bottom of the MWC where it is cooled and conveyed to a storage area. EPA estimates that nearly 80% of WTE facilities routinely combine their ash.

The regulation of WTE ash has been the subject of controversy and debate ever since the inception of the hazardous waste management program under Subtitle C of RCRA. EPA's notice of June 7, 1994 (59 Fed. Reg. 29372) provides a discussion of the regulatory history of ash from WTE facilities. The following section summarizes that discussion.

B. Regulatory History of Waste-to- Energy Ash

In 1980, EPA promulgated a rule exempting household wastes from all RCRA requirements for hazardous wastes (40 CFR 261.4(b)(1)). EPA interpreted this exemption to extend to the residuals from the treatment of household wastes, including ash from the combustion of household wastes. The exemption, however, did not address ash from the combustion of household wastes combined with nonhazardous commercial and industrial wastes.

In 1984, Congress added to RCRA a new Section 3001(i). This provision addressed WTE facilities burning exempt household hazardous wastes and nonhazardous commercial and industrial wastes to produce energy. In July 1985, EPA promulgated a rule that codified this provision. In the preamble accompanying this rule, EPA announced that it interpreted the statute to exempt the combustion of waste, but not the management of ash, from Subtitle C (50 Fed. Reg.

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28702, 28725-26 (July 15, 1985)). Since 1985, the Agency's interpretation of §3001(i) of RCRA has been a subject of much debate.

In September 1992, EPA Administrator William Reilly signed a memorandum announcing that the Agency interpreted Section 3001(i) to exempt from all Subtitle C requirements ash from WTE facilities burning household wastes and nonhazardous wastes. On May 2, 1994, the Supreme Court issued an opinion interpreting Section 3001(i) of RCRA, 42 U.S.C. 6921(i). City of Chicago v. EDF, 114 S.Ct. 1588 (1994). The Court held that this provision does not exempt ash generated at WTE facilities burning household wastes and nonhazardous commercial wastes from the hazardous waste requirements of Subtitle C of RCRA.

As a result of this decision, persons generating ash from WTE facilities must determine whether the ash is hazardous. Studies show that ash sometimes is a hazardous waste under RCRA because it exhibits EPA's toxicity characteristic (TC). Generally, this determination is made by either testing using the Toxicity Characteristic Leaching Procedure (TCLP) (see 40 CFR §261.24) or by using knowledge of the combustion process to determine whether the ash would exhibit the TC. Typically, ash that "fails" the TC leaches lead or cadmium above levels of concern. Existing studies also show that fly ash contains the highest concentrations of inorganic chemical constituents. It is more likely to exhibit the TC than either bottom ash or combinations of bottom ash and fly ash. Ash that is determined to be a hazardous waste must be handled in compliance with EPA regulations for hazardous waste management. Ash that is determined not to be a hazardous waste may be disposed in a non-hazardous waste facility.

C. Initial Agency Reaction to the Supreme Court Decision

While the Supreme Court decision ended nearly a decade of controversy over the general regulatory status of ash, it also raised some new legal and policy issues. To provide some immediate interim guidance, the Agency issued several documents shortly after the Supreme Court decision.

First, on May 24, 1994, the Agency released for immediate use a draft guidance manual for "Sampling and Analysis of Municipal Refuse Incinerator Ash." The purpose of the manual was to assist owners and operators of MWCs in designing a plan for testing ash to determine whether it is hazardous. On June 23, 1994, EPA formally requested public comment on the draft guidance (59 Fed. Reg. 32427). The comment period ended on September 21, 1994. The Agency intends to issue a final guidance manual in the Spring of 1995.

Second, on May 27, 1994, EPA issued a memorandum outlining an implementation strategy to assist affected parties in achieving compliance with the Court's decision. The strategy identified the Agency's priorities for pursuing enforcement actions concerning the management of MWC ash. The Agency intends to issue a revised implementation strategy shortly.

Third, on June 7, 1994, the Agency published a notice addressing two issues of statutory and regulatory interpretation related to the management of WTE ash that is hazardous (59 Fed. Reg. 29372). First, the notice extended the deadline within which owners/operators of facilities that treat, store, or dispose of hazardous ash must file a hazardous waste permit application. This action gave owners and operators of facilities that manage hazardous ash six months to apply for "interim status" under the RCRA hazardous waste regulatory program. Without interim status, the facility would be out of compliance with RCRA's permit requirements and face potentially significant civil and criminal penalties.

The second issue discussed in this notice was the Agency's interpretation that ash from WTE facilities be classified as a "newly identified waste" for the purposes of the RCRA land disposal restrictions (LDRs), meaning that the current land disposal restrictions do not apply. When the restrictions apply, hazardous ash will have to meet specified treatment standards prior to land disposal. EPA currently takes the position that if a waste exhibits a hazardous waste characteristic at its point of generation, it must meet LDR standards even if it ceases to exhibit the characteristic prior to land disposal.

III. The Point of Subtitle C Jurisdiction

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A. EPA's Interpretation

1. Legal Analysis

Neither the Supreme Court's decision on ash nor any of EPA's previous policy statements on ash address the point at which the ash generated by a WTE facility becomes subject to Subtitle C of RCRA--in other words, at which point or points in the facility the owner/operator must determine whether the ash exhibits the toxicity characteristic of a hazardous waste (and, in the future, the point at which LDR restrictions will begin to apply).

Section 3001(i) provides that "[a] resource recovery facility recovering energy from the mass burning of municipal solid waste shall not be deemed to be treating, storing, disposing of, or otherwise managing hazardous waste * * *." if certain conditions regarding waste receipt are met. In the City of Chicago case, the Supreme Court issued a narrowly focused opinion addressing the issue of whether this language created an exemption for ash generated by resource recovery facilities. Noting that the provision fails to mention ash and fails to include "generation" in the list of exempted activities, the Court found that no exemption for ash was intended. 114 S. Ct. at 1591-92. In fact, the Court found the statute to be so free from ambiguity on this issue that there was no need to consult legislative history and no occasion to defer, under the principles of Chevron, U.S.A. v. NRDC, 467 U.S. 837 (1984), to the interpretation preferred by the Agency. Id. at 1594.

The Court, however, failed to reach the issue of the precise point at which regulation of ash must begin, and section 3001(i) does not expressly address the issue. For the reasons set out below, EPA believes it is reasonable to interpret Section 3001(i) to first impose hazardous waste regulation at the point that the ash leaves the "resource recovery facility," defined as the combustion building (including connected air pollution equipment). Consequently, the point at which an ash hazardous waste determination should be made (and, in the future, at which the LDRs will begin to apply) is the point at which ash exits the combustion building following the combustion and air pollution control processes.

Section 3001(i) does not define the term "resource recovery facility." EPA believes that it is reasonable to conclude that Congress intended to refer to the building that houses the combustion device. This is the common sense reading of the term, and it strikes a better balance between the objectives of section 3001(i) and the rest of Subtitle C than either of the alternative readings described below. Further, EPA believes that it is reasonable to conclude that Congress intended to exempt all handling of any hazardous waste within the building, including the handling of hazardous ash. Subjecting ash within the building to hazardous waste regulation could, for example, require operators to collect samples of ash for waste determination purposes. It also could affect the number of hazardous ash waste streams that would become subject to LDR treatment standards. "Collection" and "treatment" are among the activities included in the definition of "management" in section 1004(7) of RCRA. Section 3001(i) expressly exempts treatment, storage, disposal and management of hazardous waste at resource recovery facilities. See City of Chicago, 114 S. Ct. at 1592.

This interpretation is not only a reasonable reading of the statutory language, it also serves Congress' intent to "encourage commercially viable resource recovery facilities and to remove impediments to their operation." (Emphasis added.) S. Rep. 98-284, 98th Cong., 2d Sess. at 61. Regulating ash only at the point it exits the combustion building removes some potentially significant impediments. If the statute allowed regulation of ash inside the building, the facility owner/operator might need to sample and analyze ash at multiple points. This approach could require owners and operators to deal with major logistical problems associated with shutting down individual boilers and retrofitting/reconfiguring the combustor to accommodate installation of multiple handling and storage systems to separately convey the ash streams to different load out areas and ash conditioning systems. Some facilities may not currently have the space to accommodate the additional equipment required and could be forced to either close or temporarily shut down until additional space could be procured. Retrofitting a facility in this manner could be costly. Some state and industry representatives, in fact, have projected costs in excess of several million dollars per facility. Hence, this interpretation could conflict with Congressional intent by serving as an "impediment" to resource recovery facilities. S. Rep. 98-284 at 61. In addition, the cost of sampling and analysis alone probably would at least

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double considering collection and analysis of at least two different ash streams--bottom ash and fly ash--instead of a single combined ash stream. (Although owners and operators may legally use knowledge in lieu of testing, due to the variable nature of ash, virtually all owners and operators conduct TCLP testing.) These costs would contribute to the total burden imposed on the WTE facility.

Finally, in selecting an interpretation of section 3001(i), EPA also must consider Subtitle C's general goal of protecting human health and the environment from the threats posed by hazardous waste. As explained in greater detail in section C below, EPA does not believe that this interpretation would have any significant impact on the level of environmental protection for ash.

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EPA also believes that today's interpretation is consistent with the Supreme Court's 1994 decision construing RCRA §3001(i). In City of Chicago v. EDF, 114 S. Ct. 1588 (1994), the Court held that Congress intended to exempt "resource recovery facilities," but did not define the term. See, e.g., 114 S. Ct. at 1591-92. While the Court clearly stated that the statute did not exempt facility owners from regulation as hazardous waste generators, id. at 1592, determining that ash is not subject to regulation until it exits the combustion building does not exempt the facility owner from regulation as a generator. Rather, it defines the point at which the owner must begin to perform the generator's duties. Further, today's interpretation does not create the type of total exemption for ash that the Supreme Court rejected in City of Chicago. Operators of MWC facilities still must comply with the generator's duty to make a hazardous waste determination. Any ash that exhibits a characteristic when exiting the combustion building must be managed in compliance with all applicable Subtitle C requirements. EPA's interpretation merely clarifies the location at which the determination for waste characterization purposes must occur (and the point at which future LDRs requirements will begin to apply).

2. Illustrative Examples

Today's interpretation is perhaps best explained through the use of specific examples. For instance, many WTE facilities automatically convey, via enclosed conveyor, the fly ash collected at its various locations (including any air pollution control devices such as the acid gas scrubbers, baghouse filters, and electrostatic precipitators that may exist outside the combustion building) to a quench tank within the combustion building where it is combined with the bottom ash. The combined ash is then conveyed to a separate, detached storage building or to trucks for direct transport to an off-site disposal facility. The point at which RCRA hazardous waste jurisdiction would begin for these facilities would be the point where the ash exits the combustion building. Under this interpretation, the owner/operator could combine fly ash and bottom ash within the combustion building before making any hazardous waste determination. Any type of device could be used within the building for ash management activities such as collection, mixing, and conditioning.

EPA includes in its interpretation of "resource recovery facility" those air pollution control devices that are integral components of the combustion process. Ash from air pollution control devices that is reconveyed back to the combustion building in enclosed ducts has, in EPA's view, not left the "resource recovery facility" exempted under §3001(i). Moreover, the ducts and air pollution control devices contain the ash so it does not come into contact with the environment.

A few WTE facilities may exist where the combustion device is not housed within a building. In these instances, the combustion device (including air pollution control equipment and proximate areas for handling ash) may constructively constitute a combustion building, within the meaning discussed above. Thus, if fly ash and bottom ash were handled in enclosed systems that operate in the same manner as they would if a building existed and the fly ash and bottom ash were mixed in an enclosed unit proximate to the combustion device, that management activity would be considered to take place within a combustion building as described above. In this circumstance, the point at which hazardous waste jurisdiction would begin would be the point where the combined ash exits the last enclosed ash management unit that is located proximate to the combustion device.

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By contrast, where a WTE facility collects bottom ash within the combustion building and collects the fly ash outside the combustion building in, for example, roll-off containers, two distinct exit points from the combustion building exist: (1) the point where the bottom ash ultimately leaves the combustion building and (2) the point where the fly ash leaves the air pollution control devices (located outside the combustion building). The WTE facility operator would thus sample and make a hazardous waste determination at each location. Should the operator determine that either the bottom ash or fly ash as is hazardous, management of that ash would have to be conducted pursuant to RCRA Subtitle C.

B. Other Interpretations Considered

Since the Supreme Court decision, the Agency has received numerous letters from states, local governments, industry, environmental groups, and others suggesting various approaches to determining the point at which the ash initially becomes subject to RCRA Subtitle C jurisdiction. For example, a number of comments received in response to the Agency's draft sampling and analysis guidance notice of May 24, 1994, addressed this issue. Some members of the public urged EPA to adopt the interpretation described above. Other members, however, suggested two additional options for interpreting §3001(i) to establish the point at which ash becomes subject to Subtitle C regulation.

1. Facility Property Boundary

Some members of the public argued that the hazardous waste exclusion under RCRA §3001(i) applies to all ash management operations within the property boundary of the WTE facility. This interpretation potentially would allow all ash generated at a WTE facility to be managed on-site, without testing, as a non-hazardous waste. It could allow a WTE facility to dispose of ash that would have otherwise failed the TCLP within the facility property boundary in a landfill that does not meet the requirements of RCRA Subtitle C.

EPA is rejecting the option of designating the point of Subtitle C jurisdiction at the property boundary. The most natural reading of the term "resource recovery facility" is the combustion device itself. Nothing in the text of the statute or the legislative history refers to land holdings or suggests that Congress was familiar with them and the types of waste management conducted on them. Rather, the discussion focuses on the combustion process. EPA believes that an exemption for the entire property would conflict with the general goals of Subtitle C because it would provide too many opportunities for potential mismanagement of ash at the WTE facility without the proper environmental controls. Such a broad reading of RCRA could allow potential mismanagement of ash that tested hazardous within the land boundaries of the facility in units (e.g., waste piles, landfills) that were not appropriately regulated under Subtitle C of RCRA. EPA believes that this option would not strike the balance that Congress intended between section 3001(i)'s goal of promoting resource recovery facilities and the general environmental protection goals of the rest of RCRA Subtitle C.

2. Inside the Combustion Building

Other members of the public argued that the exemption in section 3001(i) ends at the instant that ash is generated. In particular, they objected to any temporary exemption for ash that would allow facility owners to combine fly ash and bottom ash before making hazardous waste determinations. Since combined ash tends to "pass" the TC, postponing regulation until combination has occurred could allow the ash to escape Subtitle C management. These commentors argued that such a "de facto" exemption for WTE ash would be inconsistent with the spirit of the Supreme Court's decision in City of Chicago.

EPA has decided not to read the statute to require regulation of ash within the combustion building. This interpretation would permit regulation of the management of hazardous ash within the "resource recovery facility," in apparent contradiction with the text of section 3001(i). Further, requiring sampling, testing, and management of ash from multiple locations could, as described below, be unnecessarily expensive and burdensome in relation to the environmental benefits received. Thus, this interpretation could conflict with Congress' goal of "promoting resource recovery facilities." S. Rep. 98-284, 98th Cong. at 61.

Many of the people advocating this interpretation maintained that this interpretation would require bottom ash and

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fly ash to be sampled separately, before a facility owner combines them. Ash, however, may collect in as many as 20 separate locations within an average WTE facility. This interpretation, if applied literally to the first locations where ash becomes identifiable, could lead to a policy requiring that a waste determination be made at each of these locations. Such a policy would only increase the impediments to viable resource recovery facilities.

C. Additional Policy Considerations

EPA believes that today's interpretation of §3001(i) designating the point of Subtitle C jurisdiction at the exit of the combustion building provides an approach that local governments will find practical and implementable, yet environmentally protective. In accordance with today's interpretation, ash that is combined (and conditioned, for example, with lime and/or phosphoric acid) at the end of the combustion process and within the combustion building, and exhibits no hazardous waste characteristics (i.e., it passes the TCLP) when it exits that building, may be sent to a nonhazardous waste facility for disposal.

In comparison, if the Agency had selected the option requiring hazardous waste determinations inside the combustion building, the fly ash and bottom ash that would have been tested separately at locations inside the combustion building and found to exhibit the toxicity characteristic would not be handled much differently. The WTE facility operator could treat (using similar conditioning techniques that are performed inside the combustion building under today's interpretation) the fly ash and bottom ash in on-site tanks, containers, or containment buildings under the provisions of §262.34. Such treatment does not require a federal hazardous waste (Subtitle C) permit so long as the ash is not retained for more than 90 days. Once the ash ceased to exhibit hazardous waste toxicity characteristics, it too would be combined and sent for disposal in a nonhazardous waste facility. Similarly, once the LDR treatment standards for WTE ash hazardous constituents are promulgated, the ash would be treated (perhaps using some of the same conditioning techniques used today) to meet those standards at which point the ash could then be sent for disposal in a nonhazardous waste facility.

EPA also believes that current regulations promulgated under RCRA Subtitle D provide protection for the disposal of ash as a nonhazardous waste. In 1991, the Agency promulgated new criteria for municipal solid waste landfills, including landfills and monofills that accept MWC ash (40 CFR Part 258). These criteria impose a comprehensive set of requirements on municipal solid waste landfills (MSWLFs) including requirements for location restrictions, facility design and operation, ground-water monitoring and corrective action, closure and post-closure care, and financial assurance. The Agency has conducted studies on the land disposal of MWC ash from WTE facilities and has found no evidence to suggest that disposal in a Subtitle D landfill will endanger human health and the environment. Copies of these studies are available in the docket for this notice.

For example, EPA has conducted a study on the effects of MWC ash leachate on natural and synthetic lining materials commonly employed in the construction of municipal solid waste landfill liners. That study indicates that carefully selected landfill liner materials can, when exposed to MWC ash leachate, be expected to function as an effective barrier to leachate migration. In addition, EPA is conducting ongoing, in situ studies of leachate from monofills receiving ash from a WTE facility. These studies reveal leachate concentrations of relevant metals are below their respective TC limits. The States have indicated that their data also corroborates EPA's findings.

It is important to note that while states may allow varying liner designs for ash monofills or co-disposal facilities, these designs must still meet a performance standard intended to protect ground water resources. In addition, all landfills regulated under RCRA Subtitle D are required to perform ground-water monitoring as a way of detecting a release should one occur. In the event of a release to ground water, the owner/operator of the landfill must perform corrective action to clean up the ground water.

The Agency also does not believe that the process of combining and treating asn within the combustion building will pose risks to human health. The Agency understands that many State environmental programs allow the ash to be combined and conditioned prior to exiting the combustion building for testing. These states have not indicated to the Agency that these current practices are presenting a risk to human health. In fact, the risk of exposure to fugitive ash emissions

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could be heightened if WTE facilities were required to sample or otherwise manage fly ash separately from bottom ash. This is because fly ash is generally a fine powdery substance that would become readily airborne were it not for such normal practices as combining the fly ash with the bottom ash in a quench tank to impede air emissions. Handling fly ash before it is combined could increase the risk of release to the environment.

Further, EPA recently published proposed regulations under the Clean Air Act for new and existing municipal waste combustors that address ash. These regulations would prohibit visible emissions of fugitive fly ash and/or bottom ash from all ash handling activities at the facility. They also address the ash loading areas and ash transport vehicles (59 FR 48222, September 20, 1994).

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Finally, the Agency understands that some groups are concerned about the potential environmental risk posed by the reuse of ash in projects such as road base, building blocks, and sidewalks. These groups have expressed a desire that the Agency either ban ash reuse or place stringent controls on reuse. While reuse of ash currently is not common in the U.S. (the Agency believes that significantly less than ten percent of the ash generated in the U.S. is reused), the Agency does not believe that today's interpretation will stimulate increased interest in ash reuse. It is important to note that, if the WTE facility were required to test bottom ash and fly ash separately and found that either ash failed the TC determination, that facility could treat the ash on-site to either below TC limits or in accordance with the land disposal restrictions (when they are set). After this treatment, ash would no longer be classified as a hazardous waste and could be used without further hazardous waste regulation (e.g., in construction projects). EPA does not currently anticipate that future LDR treatment will differ significantly from some of the ash conditioning techniques currently used at WTE facilities. It also is important to note that many states have programs addressing the management of ash from WTE facilities. Currently, over one-half of the states address the reuse of ash.

Should information come to EPA's attention suggesting that WTE ash is being managed or disposed of in a manner that is not protective of human health and the environment under Subtitle D, the Agency will consider additional actions, including issuing management guidelines and, if appropriate, promulgating additional regulations to address those situations. In addition, at individual sites, if the disposal of ash presents an imminent and substantial endangerment to human health and the environment, EPA may require responsible persons to undertake appropriate action under §7003(a) of RCRA.

IV. Conclusion

In conclusion, today's interpretation of RCRA §3001(i) designates the point of Subtitle C jurisdiction for WTE ash at the exit of the combustion building following the combustion and air pollution control processes. The Agency believes that this reading is a reasonable interpretation of the statute that serves the stated goals of §3001(i).

EPA emphasizes that today's decision on the appropriate location to make the hazardous waste determination for MWC ash is unique based on its interpretation of RCRA §3001(i). EPA's analysis and conclusions are not relevant to facilities that do not fall within the scope of RCRA §3001(i).

EPA considers this action to be an interpretative rule exempt from the requirement for prior notice and opportunity to comment under section 553(b)(3)(A) of the Administrative Procedure Act, 5 USC 553(b)(3)(A). The notice merely informs the public of EPA's view of the definition of "facility" in section 3001(i) as derived from the text of the statute, legislative history, and EPA's view of Congressional intent.

Dated: January 27, 1995

Carol M. Browner,

Administrator.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 22 1995

MEMORANDUM

SUBJECT: Revised Implementation Strategy for City of Chicago v. EDF Municipal Waste Combustion (MWC) Ash Supreme Court Decision

FROM: Elliott P. Laws
Assistant Administrator for Solid Waste and Emergency Response (OSWER)

Steven A. Herman
Assistant Administrator for Enforcement and Compliance Assurance (OECA)

TO: Regional Administrators (Regions I-X)

Background

Supreme Court Decision

On May 2, 1994, the U.S. Supreme Court issued the opinion in City of Chicago v. EDF, ___ U.S. ___, 114 S.Ct. 1588 (1994). The Court, interpreting Section 3001(i) of the Resource Conservation and Recovery Act (RCRA), held that ash generated at resource recovery facilities (i.e., waste-to-energy facilities burning household wastes and nonhazardous commercial wastes) that exhibits a hazardous waste characteristic is not exempt from the hazardous waste requirements of RCRA Subtitle C. The Court's decision took effect as a matter of federal law on June 1, 1994. It makes eligible for regulation a waste that, under EPA's prior interpretation of RCRA, was exempt from Subtitle C.

Recent EPA Actions

1. Implementation Strategy

On May 27, 1994, the Assistant Administrators for OECA and OSWER issued an implementation strategy for the City of Chicago v. EDF decision to the Regions. This initial strategy intended to bring waste-to-energy (WTE) facilities affected by the decision into compliance with RCRA Subtitle C as quickly as possible. In addition, the strategy stated that EPA would revisit it within 6 months of its issuance. The purpose of this

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memorandum is to revise the initial implementation strategy. These revisions define the Agency's approach towards management of hazardous ash generated by WTE facilities.

2. Determination of Point of RCRA Subtitle C Jurisdiction for MWC Ash

In the City of Chicago v. EDF case, the Supreme Court issued a narrowly focused opinion holding that § 3001(i) does not exempt ash generated by WTE facilities. The Court, however, failed to reach the issue of the precise point at which regulation of ash must begin, and § 3001(i) does not expressly address the issue. In an effort to address the issue, EPA recently published a Notice of Statutory Interpretation entitled "Determination of Point at Which Subtitle C Jurisdiction Begins for Municipal Waste Combustion Ash at Waste-to-Energy Facilities" (60 FR 6666, February 3, 1995).

As discussed in the Notice of Statutory Interpretation, EPA believes it is reasonable to interpret § 3001(i) of RCRA to first impose hazardous waste regulation at the point that the ash leaves the "resource recovery facility," defined as the combustion building (including connected air pollution control equipment). Consequently, the point at which an ash hazardous waste determination should be made (and, in the future, at which the Land Disposal Restrictions will begin to apply) is the point at which ash exits the combustion building following the combustion and air pollution control processes. We emphasize that EPA's decision on the appropriate location to make the hazardous waste determination for WTE ash is uniquely based on the Agency's interpretation of RCRA § 3001(i). EPA's analysis and conclusions are not relevant to facilities that do not fall within the scope of RCRA § 3001(i).

Nearly every resource recovery facility is configured differently. In several instances, these facilities are not confined within a single structure enclosed by four walls. A few facilities, in fact, exist where the combustion device is not enclosed at all within a building structure. However, in WTE facilities where the ash always moves between structures in enclosed conveyors, such configurations would fall within the common sense meaning of the "resource recovery facility" that congress exempted in § 3001(i). These configurations are illustrated in examples one through three, below. In contrast, in the fourth example, ash is exposed to the environment rather than in an enclosed system. The definition of "resource recovery facility" does not include ash handling operations allowing exposure to the environment.

Example 1. Many resource recovery facilities automatically convey, via enclosed conveyor, the fly ash collected at various locations (including any air pollution control equipment such as the acid gas scrubbers, baghouse filters, and electrostatic precipitators that may exist outside the building where the combustion device is located but are connected to the building via enclosed conveyors) to a quench tank within the combustion device building where it is combined with the bottom ash. The combined ash is then loaded into trucks for direct transport to an off-site disposal facility. In this example, the "resource recovery facility" is composed of the combustion device building, the air pollution control equipment, and the enclosed conveyors. The point at which RCRA hazardous waste jurisdiction would begin for these facilities would be the point where the ash exits the building housing the combustion device.

Example 2. Several resource recovery facilities collect the bottom ash and the fly ash separately and convey these two ash types separately via enclosed conveyors to an ash building where the two ash types are then mixed and loaded into a transport vehicle for off-site disposal. The ash building may abut the combustion device building, or it may be separate from the combustion device building but connected by enclosed conveyors. In this example, the "resource recovery facility" is composed of the interconnected combustion device building, the air pollution control equipment, the ash building, and the enclosed conveyors. The point at which RCRA hazardous waste jurisdiction would begin for these facilities would be the point where the ash exits the ash building.

Example 3. A few resource recovery facilities exist where the combustion device is not housed within a building. In these instances, the combustion device, the air pollution control equipment, the proximate enclosed ash handling areas, and the interconnecting enclosed conveyors constructively constitute the "resource recovery facility." Thus, if fly ash and bottom ash were handled in an enclosed system that operates in the same manner as if a building existed and the fly ash and bottom ash were mixed in an enclosed unit proximate to the combustion device, that management activity would be considered to take place within a "resource recovery facility." In this example, the point at which RCRA hazardous waste jurisdiction would begin would be the point where the combined ash exits the last enclosed ash management unit that is located proximate to the combustion device.

Example 4. Some resource recovery facilities may collect bottom ash within the building housing the combustion device and collect the fly ash outside the combustion device building in a manner that exposes that ash to the environment; for example, in roll-off containers. In these instances, the "resource recovery facility" is composed of the building housing the combustion device as well as the air pollution control equipment. In this example, RCRA hazardous waste jurisdiction begins at the two exit points from the "resource recovery facility," specifically, at: (1) the point where the bottom ash ultimately leaves the combustion device building and (2) the point where the fly ash becomes exposed to the environment as it is discharged from the air pollution control equipment into open roll-off containers. The WTE facility operator would thus make a hazardous waste determination at each location. Should the operator determine that either the bottom ash or fly ash is hazardous, management of that ash would have to be conducted pursuant to RCRA Subtitle C.

If you have any questions about EPA's § 3001(i) interpretation, please contact Andrew Teplitsky (703-308-7275) or Allen Geswein (703-308-7261) of OSWER, or Kate Andersen (202-564-4016) or Andrew Cherry (202-564-5011) of OECA.

Revised Implementation Strategy

1. Overview

In the May 27, 1994 implementation strategy, EPA acknowledged that, for economic and technical reasons, it would be difficult for affected facilities to immediately comply with the City of Chicago v. EDF decision and all applicable RCRA Subtitle C requirements. In recognition of this difficulty, EPA adjusted its enforcement priorities for three months for facilities to implement an ash testing program, and for 6 months during which all WTE ash could be disposed of in solid waste management units in compliance with 40 CFR Part 258. Through these actions, EPA has demonstrated a commitment to working with states and the regulated universe to phase affected facilities into compliance with Subtitle C with minimal disruption of waste handling practices at WTE facilities.

EPA now believes that all affected facilities should be on notice of the duties imposed by the Supreme Court in the City of Chicago v. EDF decision and its ramifications for the management of hazardous ash. Since all WTE facilities should now have programs in place to make hazardous waste determinations of their ash, the Agency expects these facilities to manage ash that is determined to be a hazardous waste in full compliance with RCRA Subtitle C.

2. Situations Presenting Potential Health and Environmental Threats and Releases of Hazardous Constituents

In all circumstances, when considering appropriate enforcement responses for potential violations of Subtitle C, Agency personnel should consider whether a facility may be managing its WTE ash in an environmentally irresponsible manner, posing a potential threat to human health and the environment. Regions should, of course, bring actions, pursuant to RCRA § 7003, upon information that improper handling of any ash (whether it is hazardous or not) may present an imminent and substantial endangerment. In addition, Regions should evaluate whether formal enforcement actions pursuant to RCRA § 3008(h) are appropriate in the event the Agency has information that there is or has been a release of a hazardous waste or hazardous constituents from a facility subject to interim status for management of hazardous ash.

3. Enforcement Actions Under RCRA Section 3008(a)

As discussed above, EPA now expects all generators to have in place an effective hazardous waste determination program, including sampling and analysis where appropriate.[1] Facilities which have failed to set up and implement a method to determine whether their ash exhibits a hazardous waste characteristic are appropriate targets for enforcement response.

EPA is aware, however, that because of configurations unique to individual facilities, some facilities may not combine fly ash and bottom ash before it exits the "resource recovery facility." Such facilities may now have to make separate hazardous waste determinations at separate locations for both bottom ash and fly ash. While the previous implementation strategy allowed any WTE facility to sample and test combined bottom ash and fly ash, the Agency's recent § 3001(i) interpretation of "resource recovery facility" may now require some WTE facilities to make separate

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[1]. On May 24, 1994, OSW issued draft "Sampling and Analysis of Municipal Refuse Incineration Ash Guidance" which assists generators that do not have guidance in place to make a hazardous waste determination in accordance with 40 CFR § 262.4. This manual was intended to provide guidance to waste-to-energy facilities on how to sample and analyze ash to determine whether it is a hazardous waste. Since the release of the initial implementation strategy, OSW published a Federal Register Notice of Availability requesting comment on the draft (59 FR 32427, June 23, 1994). The public comment period closed on September 21, 1994, and OSW is currently evaluating the comments. The final manual is projected to be released in the Spring of 1995.

EPA continues to encourage the use of the draft (and when finalized, the final) "Sampling and Analysis of Municipal Refuse Incineration Ash Guidance" or similar guidance issued by the states.

determinations on the fly ash and bottom ash. EPA will very likely regard as an indicator of environmentally irresponsible management of hazardous ash (which may warrant an enforcement action under RCRA § 3008(a)) any failure to implement, within 75 days of the date of the February 3, 1995, interpretive notice (60 FR 6666), all modifications to existing hazardous waste determination programs necessary to allow separate hazardous waste determinations for fly ash and bottom ash. During the first 75 days, however, environmentally sound management of ash in accordance with the results of combined testing is unlikely to merit an enforcement response.

If you have specific questions as to the appropriate enforcement response for a particular situation, please contact Mark Pollins (202-564-4001) or Kate Anderson (202-564-4016) of OECA-RCRA Enforcement Division.

Thank you for your continued support in ensuring the proper management of hazardous WTE ash. If you have any questions regarding this revised implementation strategy, please have your staff contact Mark Pollins (202-564-4001) or Kate Anderson (202-564-4016) of OECA-Office of Regulatory Enforcement, Andrew Cherry (202-564-5011) of OECA-Office of Compliance, or Andrew Teplitzky (703-308-7275) of OSWER-Office of Solid Waste.

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GUIDANCE FOR THE SAMPLING AND ANALYSIS OF MUNICIPAL WASTE COMBUSTION ASH FOR THE TOXICITY CHARACTERISTIC

June 1995

Office of Solid Waste
U.S. Environmental Protection Agency
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APPENDIX: DEFINITIONS OF TERMS USED IN THE GUIDANCE

I. INTRODUCTION: PURPOSE OF THIS GUIDANCE DOCUMENT

The purpose of this document is to assist generators of ash from municipal waste combustion facilities in determining whether their ash is hazardous because it exhibits the Toxicity Characteristic (TC). This document is guidance, and ash generators are not required by regulation or otherwise to follow its approach to sampling and analysis for the TC. It is also not intended that this guidance be used to replace the guidance or requirements for TC determinations developed by authorized States or for the sampling and analysis of ash for any other purpose under State or local programs.

The Toxicity Characteristic (40 CFR § 261.24) is one of four characteristics described in Subpart C of 40 CFR part 261 by which a hazardous waste is identified. A hazardous waste identified by any one of these characteristics, including the TC, is subject to the notification requirements of section 3010 of the Resource and Recovery Act (RCRA) and all applicable requirements under parts 262 through 265, 268 and 270 of the RCRA regulations. A TC determination is the responsibility of the generator, and is generally made by either testing using the Toxicity Characteristic Leaching Procedure (TCLP), or by using knowledge of the process (pursuant to 40 CFR 262.11). All solid waste, unless excluded by 40 CFR § 261.4, is subject to this determination.

Ash generated by municipal waste combustion (MWC) facilities with resource recovery is not exempt from RCRA, Subtitle C, regulation. Therefore, persons who generate such ash must determine whether their ash is hazardous because it exhibits the TC. Ash first becomes subject to this hazardous waste determination at the point that the ash leaves the "resource recovery facility", defined as the combustion building (including connected air pollution equipment). For further information regarding the Agency's interpretation of when RCRA, Subtitle C, jurisdiction begins for MWC ash at waste-to-energy facilities, see 60 FR 6666, February 3, 1995 and EPA's "Revised Implementation Strategy for City of Chicago vs. EDF Municipal Waste Combustion Ash (MWC) Supreme Court Decision" found in the public docket for this guidance (Docket No. F-95-MRIF-FFFFF). Any ash that exhibits the TC when exiting the combustion building must be managed in compliance with all applicable Subtitle C requirements.

This guidance assumes that the generator has elected to conduct testing to determine whether the ash exhibits the TC for any of the TC contaminants. In addition to general information regarding this determination, this document includes a sampling and analysis approach which is one example of a prescriptive sampling and analysis plan that can be used by MWC facilities, especially those that do not have the resources to develop their own plans. The Agency maintains that, where possible, generators should use

the guidance of Chapter Nine in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" (SW-846), the Agency's guidance for all RCRA sampling (including TC determinations), to develop a sampling and analysis plan tailored to site-specific conditions and to meet the data quality objectives (DQOs) of the study.

This document contains the following sections:

II. The Sampling Approach: Discusses typical concerns during development of a sampling plan, and presents one example of an approach to ash sampling.

III. Analysis for the Toxicity Characteristic: Describes analysis using the TCLP from "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods"(SW-846) for the contaminants listed in 40 CFR § 261.24.

IV. Quality Assurance and Quality Control: Discusses the importance of quality assurance/quality control (QA/QC) and references portions of SW-846 that contain information regarding QA/QC.

V. TCLP Data Evaluation: Describes criteria for evaluating data to determine whether ash is hazardous for the TC.

VI. References: Provides a listing of resources for designing a sampling and analysis plan.

Appendix: Definitions of Terms Used in the Guidance

II. THE SAMPLING APPROACH

As explained in "Introduction: Purpose of this Guidance Document", the generator (e.g., facility owner/operator) is responsible for determining whether his ash exhibits the TC. Ash first becomes subject to this determination at the point that it leaves the "resource recovery facility", defined as the combustion building (including connected air pollution control equipment). All handling of the ash within the building is exempt from RCRA Subtitle C regulations (see 60 FR 6666, February 3, 1995). Thus, a facility can treat the ash or combine fly ash and bottom ash within the combustion building before collecting samples outside the building for the hazardous waste determination.

Nearly every resource recovery facility is configured differently. In several instances, these facilities are not confined within a single structure enclosed by four walls. A few facilities, in fact, exist where the combustion device is not enclosed at all within a building structure. However, in WTE facilities where the ash always moves between structures in enclosed conveyors, such configurations fall within the common sense meaning of "resource recovery facility". In contrast, some facilities may collect bottom ash within the combustion building housing the combustion device and collect the fly ash outside the combustion device building in a manner that exposes that ash to the environment. In that case, RCRA Subtitle C jurisdiction begins at the two exit points from the resource recovery facility; specifically at: (1) the point where the bottom ash leaves the combustion device building, and (2) the point where the fly ash becomes exposed to the environment as it is discharged from the air pollution equipment into the containers. Thus, the generator should collect samples for a TC determination at each exit point.

In any case, should a generator determine that either bottom ash, fly ash, or combined ash is hazardous based on the TC, management of that ash must be conducted pursuant to RCRA Subtitle C. [For further information regarding the Agency's interpretation of when RCRA Subtitle C jurisdiction begins for MWC ash at waste-to-energy facilities, see 60 FR 6666, February 3, 1995 and EPA's "Revised Implementation Strategy for City of Chicago vs. EDF Municipal Waste Combustion (MWC) Supreme Court Decision" found in the public docket for this guidance (Docket No. F-95-MRIF-FFFFF.)]

The generator also is responsible for ascertaining ash variability over time and has a continuing responsibility for knowing whether the ash is hazardous at any point in time. Thus, given this responsibility for making an accurate TC determination and insuring appropriate ash management (e.g., management as a nonhazardous or hazardous waste), it is up to the generator to decide how frequently retesting or reevaluation of ash for a TC determination should be made. Generators should also consult with

their authorized States regarding any State requirements or recommendations regarding both the initial characterization and any recharacterization of their ash for the TC.

The Agency recommends retesting or reevaluation of MWC ash for the TC whenever the generator suspects that the leachability of ash for the TC contaminants may have significantly changed, e.g., such that a previous determination that the ash is nonhazardous for the TC may no longer be accurate. In determining whether to recharacterize ash, the generator should consider all facility-specific and external factors that could cause ash leachability to vary. For example, a facility may retrofit pollution control equipment by adding a scrubber acid gas removal system and a fabric filter to replace an existing electrostatic precipitator. This equipment change may significantly change the leachability of certain TC metals of concern in the combustion residue. The leachability of ash may be affected by changes in ash treatment (e.g., lime addition) or conditioning practices which occur before it is subject to a TC determination. These factors also can be used to identify which contaminants of the TC should be the analytes of concern during the retesting or reevaluation.

The sampling plan in this section is just one example of a prescriptive sample collection approach that can be used by MWC facilities, especially those that do not have the resources to develop their own plans. The Agency maintains that, where possible, generators should use Chapter Nine of SW-846, the Agency's guidance for all RCRA sampling (including TC determinations), to develop a sampling and analysis plan tailored to site-specific conditions and to meet the DQOs of the study.

Regardless of whether SW-846, this guidance, or State guidance is used, common objectives include the need to obtain representative samples which exhibit the average properties of the ash as a whole, and to make a correct determination regarding the status of the ash under RCRA. Determining whether ash passes or fails the TC requires reliable information on the leachability of the TC contaminants of concern in the ash. Several factors contribute to this reliability, including accuracy, precision, and the prevention of bias. (See Chapter Nine of SW-846 for an in-depth discussion regarding the consideration of these factors in any sampling effort.)

The approach in this guidance is designed to determine the concentration of TC contaminants in the ash leachate through the collection and analysis of fourteen (14) composite ash samples over a minimum of one-week of operation. This approach is one example of a sampling approach that might be taken by some facilities. However, it may not be appropriate for all facilities. It is largely based on the assumption that one week is an adequate sampling period for the collection of samples that are fully representative of any temporal variability in the ash. If the

above assumption is not valid or if the generator finds for any reason that the approach may compromise the collection of representative samples, then a facility-specific sampling and analysis program designed by knowledgeable personnel should instead be employed. Examples of "knowledgeable personnel" that might be involved in designing a sampling plan include the end user of the data, an experienced member of the sample collection team, an analytical chemist familiar with the analytical requirements, an engineer or other person familiar with the process, a statistician, and a quality assurance representative.

The sampling procedure is as follows:

1. Determine the most convenient location for sampling at the point the ash exits the combustion building and is subject to RCRA Subtitle C jurisdiction. For example, sampling can be conducted either from the ash conveyance device, an ash pile, or transport vehicles.

2. Obtain or construct a sampling device (trough, bucket, shovel, thief, etc.) to be used to gather a grab sample of the entire depth of the hopper, pile, or truck load, or the entire depth and width of the belt conveyor, drag chain flight, or vibrating conveyor.

3. If a conveyor is to be the sample location point, collect the entire width and depth of the conveyor at a fixed point each hour for eight (8) hours. If trucks are to be sampled, randomly select 8 trucks to sample during the eight (8) hour period. (In certain situations, where less than 8 truckloads are generated, a different schedule may be necessary, e.g., less than 1 truck per hour.) Composite all samples for the period into an eight (8) hour composite. Containerize, label, and set aside for reduction.

4. Collect a second eight (8) hour composite during the course of the work day. The second composite should be collected during a different shift from the first composite.

5. For an initial ash characterization, samples should be collected each day for a minimum of one week's operation. Two daily composite samples over the course of one week will yield a total of 14 composite samples.

6. Each composite should be mixed (a cement or other mechanical mixer is acceptable for this purpose), and then a representative subsample should be obtained from the composite. The subsample should be obtained by taking a full core or "slice" of equal proportions through the mixed composite. To reduce the size of this subsample and obtain a 1000-gram aliquot suitable for shipment to the laboratory, the sample may need to be riffled or coned and quartered. Another

acceptable procedure (for example, if riffling is difficult due to ash moisture content) is alternate shoveling, whereby the sample is divided (subsampled) using a system of alternate shoveling wherein the large composite sample is apportioned into two or more smaller piles. One of the small piles (subsamples) is then randomly chosen for analysis.

7. In accordance with the TCLP, each composite sample (e.g., the 1000-gram aliquot obtained during step 6) should be passed over a 3/8-inch (9.5 mm) screen. Materials which do not pass through the screen should be subjected to a particle size reduction step. Materials can be reduced by crushing, cutting, or grinding. A mechanical crusher can be used. Sometimes, ash contains large pieces of structurally intact material that cannot be crushed or otherwise reduced by means available to generators for sample reduction. The hammer blow test can be used to determine whether a particle is a candidate for size reduction. (Note: the hammer test is not itself a method of particle size reduction, but rather is a method of determining whether the material can be reduced.) In that test, the material is subjected to blows with a 5-pound sledge hammer dropped from one foot above the pieces. The hammer blow test should be performed on a hard surface (e.g., iron or steel plate) which will not break upon impact by the hammer and will not cause sample contamination or loss.

Particles that do not pass through the 3/8-inch screen after the particle size reduction step are discarded. It is not necessary to weigh the discarded material and, in the case of MWC ash analysis for the TC, TCLP results should not be adjusted based on the weight of discarded material.

8. Samples should be properly labelled and stored. Submit samples for analysis by the TCLP (Method 1311 of SW-846).

Once a sample has been collected, it must be stored and preserved to maintain the chemical and physical properties that it possessed at the time of collection. The sample type, type of containers and their preparation, possible forms of contamination, and preservation methods are all items which must be thoroughly examined in order to maintain the integrity of samples. SW-846 contains guidance in its chapters and methods regarding these important considerations.

For the purposes of a TC determination, the ash and ash samples should not be dried before sample reduction and analysis unless that represents the actual state of the ash at the point of Subtitle C jurisdiction. (Sample drying may be appropriate for other types of ash characterizations; in those instances, the generator should check with his State or other appropriate regulatory authority for guidance.) Also, volatile organics are not expected to be detected in ash because municipal waste

combustion facilities typically operate at temperatures higher than the boiling points of the compounds. However, should the generator have reason to believe that TC volatile organic contaminants are present in the ash, practical measures should be taken to avoid the loss of those volatile organics. Guidance regarding such measures can be found in SW-846.

III. ANALYSIS FOR THE TOXICITY CHARACTERISTIC

In order to determine whether the ash exhibits the TC by conducting analysis for the TC contaminants, the Toxicity Characteristic Leaching Procedure (TCLP, Method 1311 of SW-846) must be used pursuant to 40 CFR § 261.24(a). Use of the TCLP generates an extract (also called a leachate), which is then analyzed for the TC contaminants listed in Table 1 of 40 CFR § 261.24 (see Exhibit 1) using the appropriate determinative methods. Determinative methods for all of the TC contaminants can be found in SW-846 (see Exhibit 2). Depending on the analytes of concern and other factors, more than one aliquot of at least 100 grams from each composite sample may be needed for use in the TCLP. Process or waste knowledge can be used in lieu of testing for a TC determination regarding any of the TC constituents. This guidance assumes that the generator has elected to at least initially test for most (inorganic and organic) of the TC contaminants.

After sample preparation and selection of an extraction fluid, the TCLP consists of mixing 100 grams of sample with an acetic acid extraction fluid in a liquid-to-solid ratio of 20:1. The sample extract is then agitated end-over-end for 18 hours, after which it is filtered through a 0.7 μm filter and the filtrate is analyzed for the contaminants found in Table 1 of 40 CFR § 261.24. The analyst must follow section 8.5 of the TCLP regarding the maximum sample holding times for all stages of a TC determination.

Given the low probability of their occurrence in municipal waste combustion ash, it is recommended that, should the generator believe TC organic contaminants are present, analysis for the TC organic compounds only occur in the first one or two extracts of each sampling and analysis event (during the initial TC determination testing event and subsequently if the generator believes that the leachability of the organic contaminants of concern in the ash may have changed). It is further recommended that only if one or more TC organic compounds (semivolatile or volatile) are detected in the first extracts should the remaining extracts be analyzed for the TC organics.

Prior to analysis of the extracts using atomic absorption spectrometry (AA), inductively coupled plasma spectroscopy (ICP), gas chromatography (GC) or other appropriate determinative procedure, the extracts should be prepared using the appropriate methods (e.g., Methods 3010 and 3510, see Exhibit 2). The SW-846 manual contains several analytical techniques for trace metal determinations: ICP atomic emission spectroscopy (ICP-AES) and ICP mass spectrometry (ICP-MS), direct aspiration flame atomic absorption (FAA), graphite furnace atomic absorption (GFAA), hydride-generation atomic absorption (HGAA) and cold-vapor atomic absorption (CVAA). Each of these is briefly discussed below in terms of their advantages and disadvantages.

1. ICP's primary advantage is that it allows simultaneous or rapid sequential determinations of many elements in a short time. The primary disadvantage is interference by background radiation from other elements and the plasma gases. Although all ICP instruments use high-resolution optics and background correction to minimize these interferences, analysis for traces of metals in the presence of a large excess of a single metal is difficult. For example, analysis for trace metals in a limed (high calcium) waste might be difficult. ICP and FAA have comparable detection limits (within a factor of 4), except that ICP exhibits greater sensitivity for refractory elements (e.g., aluminum, barium). GFAA, in general, exhibits lower detection limits than does either ICP or FAA. However, all these techniques have adequate sensitivity. Detection limits are improved when ICP-MS is used. In general, ICP-MS exhibits greater sensitivity than either GFAA or FAA for most elements. The greatest disadvantage of ICP-MS is isobaric elemental interferences. Mathematical correction for interfering ions can minimize these interferences.

2. FAA determinations, as opposed to ICP determinations, are normally completed as single-element analyses and are relatively free of inter-element spectral interferences. Either a nitrous-oxide/acetylene or an air/acetylene flame is used as an energy source for dissociating the aspirated samples into the free atomic state, making analyte atoms available for absorption of light. In the analysis of some elements, the temperature or type of flame used is critical. If the proper flame and analytical conditions are not used, chemical and ionization interferences can occur.

3. GFAA replaces the flame with an electrically heated graphite furnace. This allows gradual heating of the sample in several stages. Thus, the processes of dissolution, drying, decomposition of organic and inorganic molecules and salts, and formation of atoms, which must occur in FAA or ICP in a few milliseconds, may be allowed to occur over a much longer time and at a controlled temperature in the furnace. This allows an experienced analyst to remove unwanted matrix components by using temperature programming and/or matrix modifiers. The major advantage of this technique is that it affords extremely low detection limits. It is the easiest to perform on relatively clean samples. Because this technique is so sensitive, interferences can be a real problem with complex matrices. Finding the optimum combination of digestion, heating times and temperatures requires an analyst experienced in the use of a GFAA.

4. HGAA uses chemical reduction to reduce and separate arsenic or selenium selectively from a sample digestate. The technique therefore has the advantage of being able to isolate these two elements from complex samples that may cause

interferences for other analytical procedures. However, significant interferences have been reported when any of the following is present: an easily reduced metal (copper, silver, mercury); a high concentration (>200 mg/L) of transition metals; or an oxidizing agent (oxides of nitrogen) remaining after sample digestion.

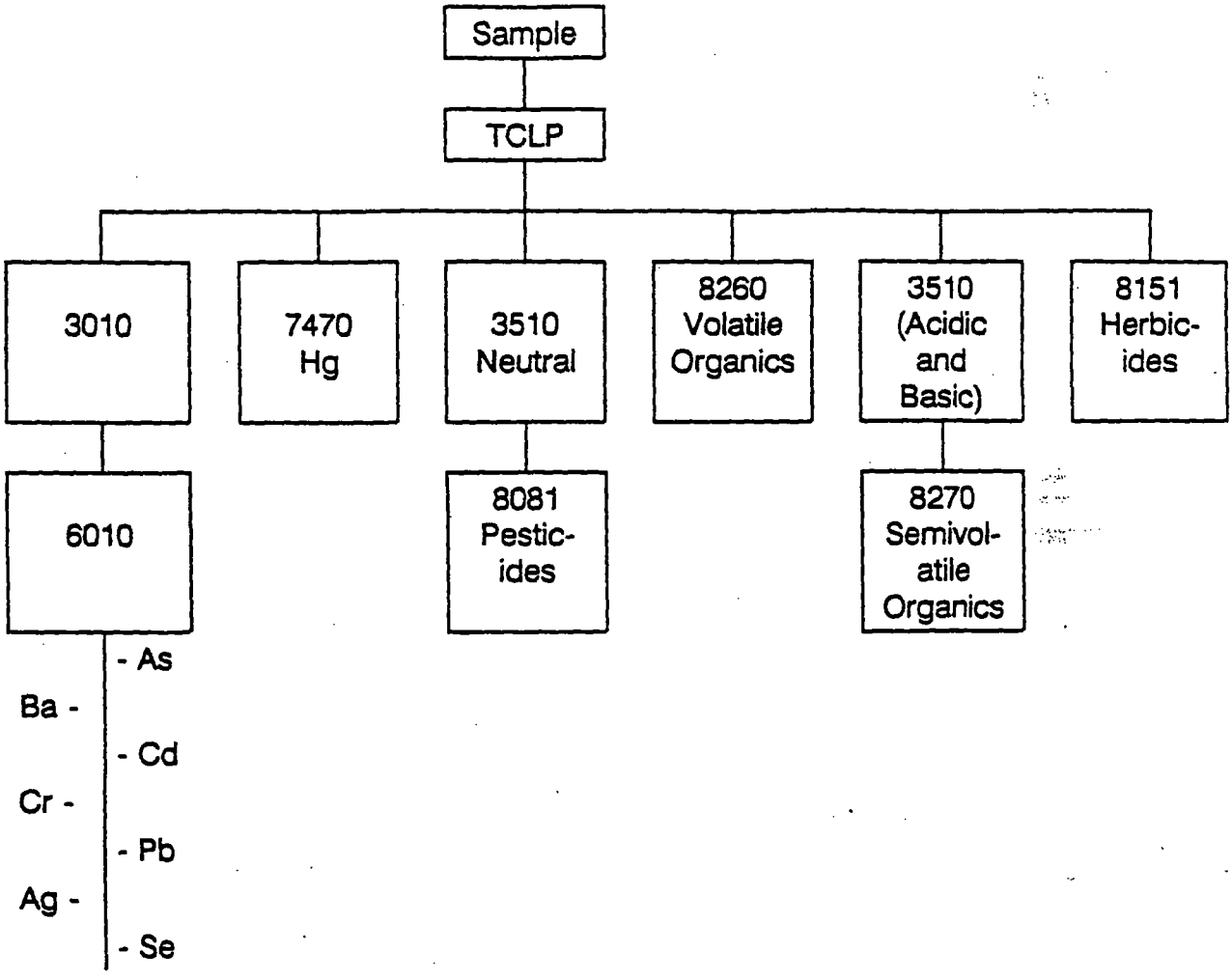
5. CVAA uses a chemical reduction to reduce mercury selectively. The procedure is extremely sensitive but is subject to interferences from some volatile organics, chlorine, and sulfur compounds.

EXHIBIT 1. LIST OF TC CONTAMINANTS AND REGULATORY LEVELS FOUND IN 40 CFR §261.24

EPA HW No.[1]	Contaminant	CAS No.[2]	Regulatory Level (mg/L)
D004	Arsenic	7440-38-2	5.0
D005	Barium	7440-39-3	100.0
D018	Benzene	71-43-2	0.5
D006	Cadmium	7440-43-9	1.0
D019	Carbon tetrachloride	56-23-5	0.5
D020	Chlordane	57-74-9	0.03
D021	Chlorobenzene	108-90-7	100.0
D022	Chloroform	67-66-3	6.0
D007	Chromium	7440-47-3	5.0
D023	o-Cresol	95-48-7	[4]200.0
D024	m-Cresol	108-39-4	[4]200.0
D025	p-Cresol	106-44-5	[4]200.0
D026	Cresol	--	[4]200.0
D016	2,4-D	94-75-7	10.0
D027	1,4-Dichlorobenzene	106-46-7	7.5
D028	1,2-Dichloroethane	107-06-2	0.5
D029	1,1-Dichloroethylene	75-35-4	0.7
D030	2,4-Dinitrotoluene	121-14-2	[3]0.13
D012	Endrin	72-20-8	0.02
D031	Heptachlor (and its epoxide)	76-44-8	0.008
D032	Hexachlorobenzene	118-74-1	[3]0.13
D033	Hexachlorobutadiene	87-68-3	0.5
D034	Hexachloroethane	67-72-1	3.0
D008	Lead	7439-92-1	5.0
D013	Lindane	58-89-9	0.4
D009	Mercury	7439-97-6	0.2
D014	Methoxychlor	72-43-5	10.0
D035	Methyl ethyl ketone	78-93-3	200.0
D036	Nitrobenzene	98-95-3	2.0
D037	Pentachlorophenol	87-86-5	100.0
D038	Pyridine	110-86-1	[3]5.0
D010	Selenium	7782-49-2	1.0
D011	Silver	7440-22-4	5.0
D039	Tetrachloroethylene	127-18-4	0.7
D015	Toxaphene	8001-35-2	0.5
D040	Trichloroethylene	79-01-6	0.5
D041	2,4,5-Trichlorophenol	95-95-4	400.0
D042	2,4,6-Trichlorophenol	88-06-2	2.0
D017	2,4,5-TP (Silvex)	93-72-1	1.0
D043	Vinyl chloride	75-01-4	0.2

[1] Hazardous waste number.
[2] Chemical abstracts service number.
[3] Quantitation limit is greater than the calculated regulatory level. The quantitation limit therefore becomes the regulatory level.
[4] If o-, m-, and p-Cresol concentrations cannot be differentiated, the total cresol (D026) concentration is used. The regulatory level of total cresol is 200 mg/l.

EXHIBIT 2. SW-846 METHODS OF ANALYSIS FOR TCLP EXTRACTS



IV. QUALITY ASSURANCE AND QUALITY CONTROL

To ensure that the analytical data used for the TC determination are of known and desired quality, all activities associated with sampling and analysis should be conducted under strict quality assurance and quality control (QA/QC) procedures.

Prior to initiating a sampling and analysis program, generators should prepare a detailed quality assurance project plan (QAPjP) describing the QA/QC steps and controls to be followed. In addition, a person knowledgeable regarding the QA/QC procedures should oversee the sampling and analysis effort to insure that all QAPjP procedures are followed. For more information on preparing and implementing quality assurance programs, see Chapter One of SW-846.

In addition, the appropriate use of data generated under the great range of analytical conditions encountered in waste characterization requires reliance on the quality control practices incorporated into the various testing methods. The Agency has, in many cases, issued approved methods for sampling and analysis operations that are intended to fulfill regulatory requirements. However, the mere use of approved methods does not guarantee accurate results. Inaccuracies can result from many causes, including unanticipated matrix effects, equipment malfunctions, and operator error. Therefore, the quality control component of each method is indispensable. The TCLP and the determinative methods of SW-846 contain method-specific quality assurance procedures that should be followed during a TC determination. All of the QA procedures found in section 8.0 of the TCLP must be followed during the determination.

V. TCLP DATA EVALUATION

To evaluate the analytical data and determine whether the ash exhibits the TC, the data evaluation approach below can be followed. For the statistical formulas and equations (e.g., "equation 2a", "equations 3a and 4", etc.), refer to Exhibit 3. Exhibit 4 contains tabulated values of Student's t distribution.

1. Determine the mean TC concentration ($\bar{X}$) of the fourteen eight-hour composite samples for each regulated analyte (equation 2a).

2. Determine the standard deviation (s) of the data employed to calculate the mean (i.e., the individual composite extract results) (equations 3a and 4).

3. Determine the upper limit of a two-sided 80 percent confidence interval, which is equivalent to a 90 percent (one-sided) confidence interval, for the mean for each analyte (equation 6). (Note: Exhibit 3 does not include equations for arcsine or square root transformations. The Agency is currently revising Chapter Nine of SW-846 whereby arcsine and square root transformation discussions are being considered for removal from the chapter. Transformations should only be used if the data distribution and valid statistical practices indicate such transformations are warranted. If transformations are used, methods for obtaining unbiased estimates of the mean and confidence limits should be employed.)

4. If the 80 percent upper confidence limit is less than the applicable regulatory threshold for all analytes listed in 40 CFR § 261.24, then the waste (ash) passes the TC. If the 80 percent upper confidence limit is greater than or equal to the applicable regulatory threshold for any contaminant listed in Table 1 of 40 CFR § 261.24, then the waste (ash) fails the TC and is a hazardous waste.

Results from multiple events may be combined for evaluation under certain limited conditions. Data sets representing two or more sampling events can be combined (pooled) into one data set, and a new confidence interval calculated, only if all of the following conditions apply:

- Sampling data are for the same waste (e.g., for the bottom ash and not for any other waste or ash type generated by the facility).

- Field sampling and laboratory analysis procedures were the same for all sampling and analysis events (e.g., the data are from use of the TCLP and the same procedures

were followed by the laboratory during testing, including the same preparative and determinative methods).

- There are no other reasons to believe that the waste and sampling events were different (e.g., the ash has not changed over time or space due to changes in pollution control equipment).

If there is some doubt whether the two data sets can be combined, statistical tests are available for testing the assumption that the samples were drawn from identical populations. For example, the "t" test methods to compare population means can be used if the underlying populations have normal distributions, and the Wilcoxon Rank Sum Test (also known as the Mann-Whitney U Test) can be used to test whether the two populations are identical but not normal. Generators should seek assistance from a statistician prior to combining results from multiple sampling events.

Regarding the treatment of "non-detects", a number of approaches are available and the appropriate treatment will depend on characteristics of the data (e.g., what percentage of the data is reported as less than the detection limit). Some of these approaches are described in references 2, 3, and 4 listed in section VI of this manual. Generators should consult their appropriate authorized State or, if in an unauthorized State, their EPA Regional Offices regarding the evaluation of data sets which include values reported as less than the analyte detection limit.

Regarding identification and handling of "outliers", testing for outliers should be done only if an observation seems particularly high or low compared to the rest of the data set. If an outlier is identified, the result should not be treated as such until a specific reason for the abnormal measurement can be determined. Valid reasons may, for example, include:

- Contaminated sampling equipment.
- Laboratory contamination of the sample.
- Errors in transcription of the data values.

Once a specific reason is documented, the result should be excluded from any further statistical analysis. If a plausible reason cannot be found, the observation should be treated as a true, but extreme value, and <u>not</u> be excluded from the data evaluation.

EXHIBIT 3. BASIC STATISTICAL TERMINOLOGY APPLICABLE TO SAMPLING PLANS FOR SOLID WASTES

Terminology	Symbol	Mathematical Equation	(Equation)
• Variable (e.g., barium or endrin)	x	--	
• Individual measurement of variable	x_i	--	
• Mean of possible measurements of variable (population mean)	μ	$\mu = \frac{\sum_{i=1}^{N} x_i}{N}$, with N = number of possible measurements	(1)
• Mean of measurements generated by sample (sample mean)	$\bar{x}$	<u>Simple random sampling and systematic random sampling</u>	
		$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$, with N = number of sample measurements	(2a)
		<u>Stratified random sampling</u>	
		$\bar{x} = \sum_{k=1}^{r} W_k \bar{x}_k$, with $\bar{x}_k$ = stratum mean and W_k = fraction of population represented by Stratum k (number of strata [k] range from 1 to r)	(2b)
• Variance of sample	s^2	<u>Simple random sampling and systematic random sampling</u>	
		$s^2 = \frac{\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2/n}{n-1}$	(3a)
		<u>Stratified random sampling</u>	
		$s^2 = \sum_{k=1}^{r} W_k s_k^2$, with s_k^2 = stratum variance and W_k = fraction of population represented by Stratum k (number of strata [k] ranges from 1 to r)	(3b)

(Source: Adoption of Table 9-1 of Chapter Nine, SW-846, Third Edition as Amended by Updates I, II, IIA, and IIB)

EXHIBIT 3. BASIC STATISTICAL TERMINOLOGY APPLICABLE TO SAMPLING PLANS FOR SOLID WASTES (Continued)

Terminology	Symbol	Mathematical Equation	(Equation)
• Standard deviation of sample	s	$s = \sqrt{s^2}$	(4)
• Standard error (also standard error of mean and standard deviation of mean) of sample	$s_{\bar{x}}$	$s_{\bar{x}} = \frac{s}{\sqrt{n}}$	(5)
• Confidence interval for μ*	CI	$CI = \bar{x} \pm t_{.20}\, s_{\bar{x}}$, with $t_{.20}$ obtained from Exhibit 4 for appropriate degrees of freedom	(6)
• Regulatory threshold*	RT	Defined by EPA	(7)
• Appropriate number of samples to collect from a solid waste (financial constraints not considered)	n	$n = \frac{t^2_{.20}\, s^2}{\Delta^2}$ with $\Delta = RT - \bar{x}$	(8)
• Degrees of freedom	df	df = n - 1	(9)

* The upper limit of the CI for μ is compared with the applicable regulatory threshold (RT) to determine if a solid waste contains the variable (chemical contaminant) of concern at a hazardous level. The contaminant of concern is not considered to be present in the waste at a hazardous level if the upper limit of the CI is less than the applicable RT. Otherwise, the opposite conclusion is reached.

(Source: Adoption of Table 9-1 of Chapter Nine, SW-846, Third Edition as Amended by Updates I, II, IIA, and IIB)

EXHIBIT 4. TABULATED VALUES OF STUDENT'S "t" FOR EVALUATING SOLID WASTES

Degrees of freedom (n-1)[a]	Tabulated "t" value[b]
1	3.078
2	1.886
3	1.638
4	1.533
5	1.476
6	1.440
7	1.415
8	1.397
9	1.393
10	1.372
11	1.363
12	1.356
13	1.350
14	1.345
15	1.341
16	1.337
17	1.333
18	1.330
19	1.328
20	1.325
21	1.323
22	1.321
23	1.319
24	1.318
25	1.316
26	1.315
27	1.314
28	1.313
29	1.311
30	1.310
40	1.303
60	1.296
120	1.289
	1.282

[a]Degrees of freedom (df) are equal to the number of samples (n) collected from a solid waste less one.

[b]Tabulated "t" values are for a two-tailed confidence interval and a probability of 0.20 (the same values are applicable to a one-tailed confidence interval and a probability of 0.10).

(Source: Adoption of Table 9-2 of Chapter Nine, SW-846, Third Edition, as Amended by Updates I, II, IIA, and IIB)

VI. REFERENCES

The references listed below represent resources that may be helpful during the development of a QAPjP and a sampling and analysis plan. The TCLP, preparative and determinative methods for analysis of the TCLP extract, and Agency guidance regarding quality assurance/quality control, the development of sampling and analysis plans, and data evaluation can all be found in reference number 1 (SW-846). The other listed references provide information regarding statistical evaluations of data that may prove useful during a TC determination.

1. USEPA, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), Third Edition as amended by Updates I, II, IIA, and IIB, Washington, DC.

2. USEPA, 1989, Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities, Interim Final Guidance and Draft Addendum to Interim Final Guidance (July, 1992). EPA Office of Solid Waste, Washington, DC.

3. Gilbert, R.O., 1987, Statistical Methods for Environmental Pollution Monitoring, New York: Van Nostrand Reinhold, 320 pp.

4. Helsel, D.R., 1990, "Less Than Obvious, Statistical Treatment of Data Below the Detection Limit", in Environ. Sci. Technol, 24(12): 1766-1774.

APPENDIX:
DEFINITIONS OF TERMS USED IN THE GUIDANCE

Accuracy: The closeness of agreement between an observed value and a true or accepted reference value.

Bottom Ash: Coarse, relatively dense (40-70 lbs/ft^3 dry) solid material that remains on a hearth or falls off the furnace grate after thermal processing is complete.

Composite sampling: Sample collection whereby a number of random samples are initially collected from a waste and then combined into a single sample, which is then analyzed for the contaminants of concern. Composite samples are composed of several distinct subsamples (or grab samples), and are often collected when it is not economically feasible to analyze a large number of individual samples.

Confidence interval: The numerical interval constructed around a point estimate of a population parameter, combined with a probability statement (the confidence coefficient) linking the interval to the population's true parameter value.

Data Quality Objectives: Qualitative and quantitative statements about the data and of the overall level of uncertainty that a decision-maker is willing to accept in results derived from data. DQOs should take into account both sampling considerations and analytical protocols.

Detection limit: The lowest concentration or amount of a target analyte that can be determined by a single measurement to be different from zero or background level at a defined level of probability. The detection limit is generally recognized to be sample matrix and measurement method dependent.

Disposal: The discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid or hazardous waste into or on any land or water.

EPA Hazardous Waste No.: The number assigned by EPA to each hazardous waste listed in part 261, subpart D of 40 CFR and to each characteristic identified in part 261, subpart C of 40 CFR.

EPA Region: The states and territories found in any one of ten regions identified by EPA.

Fly Ash: Light (usually less than 20 lbs/ft^3 dry weight basis) flue gas-entrainable particle material carried off the furnace grate during combustion by the updrafting of underfire air. Depending on the facility design, these flue gas entrained particles, volatilized elements/compounds, and gaseous fractions will be partially collected in post combustion fly ash hoppers

mostly in solid particle form, with some smaller gaseous fractions entrapped in gaseous form.

Generator: Any person, by site, whose act or process produces waste.

Hazardous Waste: A solid waste, as defined in 40 CFR § 261.2 that (1) is not excluded from regulation as a hazardous waste under 40 CFR § 261.4(b), and (2) meets any of the criteria under 40 CFR § 261.3(2) (e.g., exhibits one of the characteristics of a hazardous wastes or is listed as a hazardous waste). A hazardous waste is a material that poses a substantial present or potential hazard to human health or living organisms due to its lethal, non-degradable or persistent nature or because it may cause or tend to cause detrimental cumulative effects.

Heterogeneous: Consisting of dissimilar or diverse ingredients or constituents.

Homogeneous: Of uniform structure or composition throughout.

Management or Waste Management: The systematic control of the collection, source separation, storage, transportation, processing, treatment, recovery, and disposal of waste.

Operator: The person responsible for the overall operation of a facility.

Owner: The person who owns a facility or part of a facility.

Pile: Any non-containerized accumulation of solid, nonflowing waste that is used for treatment or storage.

Precision: The agreement among a set of replicate measurements without assumption or knowledge of the true value. Precision is estimated by means of duplicate or replicate analyses.

Project: Single or multiple data collection activities that are related through the same planning sequence.

Quality Assurance: The process for ensuring that all data and the decisions based on these data are technically sound, statistically valid, and properly documented.

Quality Assurance Project Plan: An orderly assemblage of detailed procedures designed to produce data of sufficient quality to meet the data quality objectives for a specific data collection activity.

Quality Control: Procedures employed to measure the degree to which the quality assurance objectives are met.

Representative Sample: A sample of a universe or whole which (1) has the properties and chemical composition of the population from

which it was collected, and (2) has them in the same average proportions found in the universe or whole.

Solid Waste: Any discarded material that is not excluded by 40 CFR § 261.4(a) or that is not excluded by a variance granted under 40 CFR §§ 260.30 and 260.31, and as defined by 40 CFR § 261.2.

Storage: The holding of waste for a temporary period, at the end of which the waste is treated, disposed of, or stored elsewhere.

Transport Vehicle: A motor vehicle or rail car used for the transportation of cargo (including waste) by any mode. Each cargo-carrying body (trailer, freight car, etc.) is a separate transport vehicle.

Treatment: Any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any waste, or so as to recover energy or material resources from the waste, or so as to render such waste non-hazardous or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.

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United States
Environmental Protection
Agency

Office of Solid Waste
and Emergency Response
Washington, DC 20460

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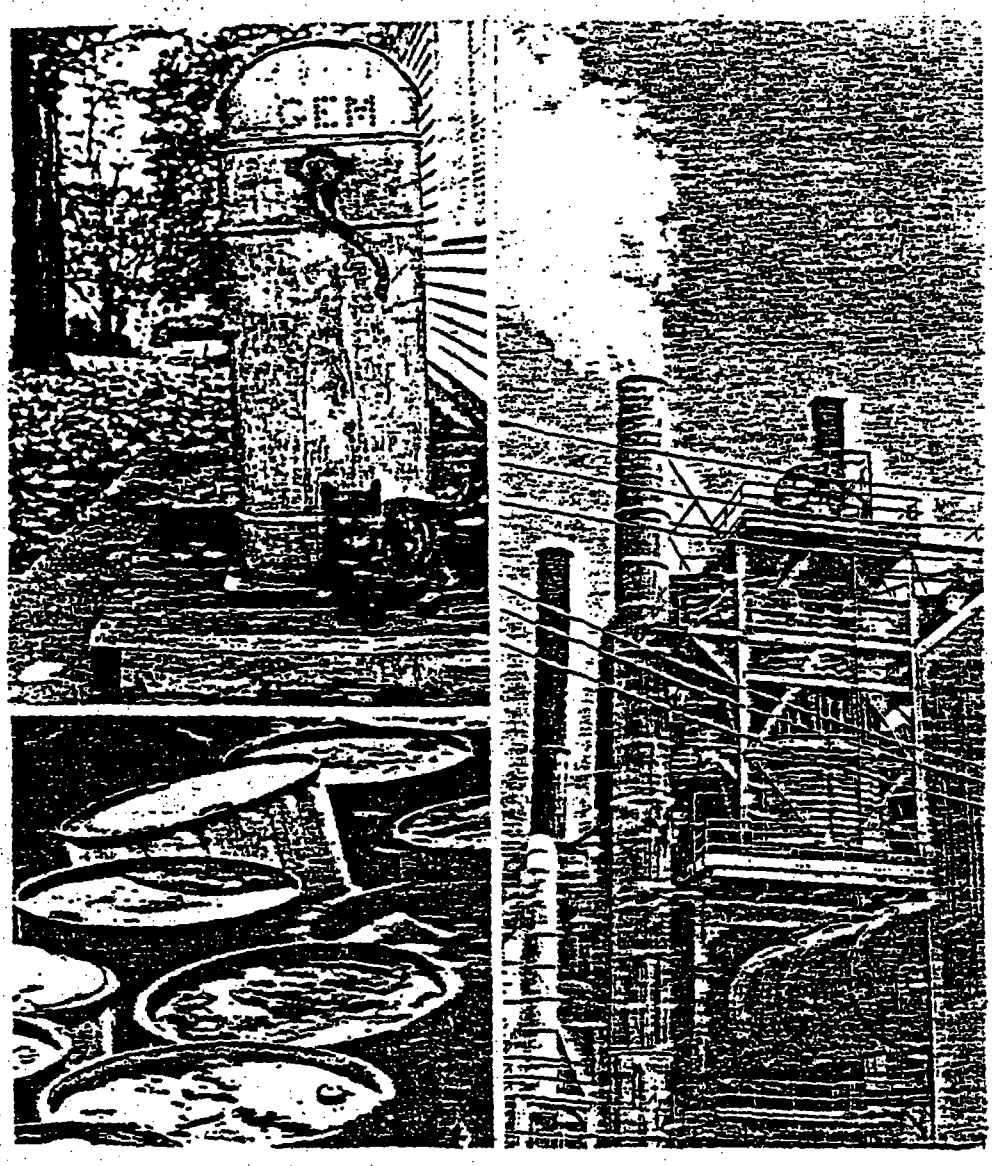
Solid Waste

Test Methods for Evaluating Solid Waste

Volume II: Field Manual
Physical / Chemical Methods



ABSTRACT

Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846) provides test procedures and guidance which are recommended for use in conducting the evaluations and measurements needed to comply with the Resource Conservation and Recovery Act (RCRA), Public Law 94-580, as amended. These methods are approved by the U.S. Environmental Protection Agency for obtaining data to satisfy the requirements of 40 CFR Parts 122 through 270 promulgated under RCRA, as amended. This manual presents the state-of-the-art in routine analytical tested adapted for the RCRA program. It contains procedures for field and laboratory quality control, sampling, determining hazardous constituents in wastes, determining the hazardous characteristics of wastes (toxicity, ignitability, reactivity, and corrosivity), and for determining physical properties of wastes. It also contains guidance on how to select appropriate methods.

Several of the hazardous waste regulations under Subtitle C of RCRA require that specific testing methods described in SW-846 be employed for certain applications. Refer to 40 *Code of Federal Regulations* (CFR), Parts 260 through 270, for those specific requirements. Any reliable analytical method may be used to meet other requirements under Subtitle C of RCRA.

CHAPTER NINE

SAMPLING PLAN

9.1 DESIGN AND DEVELOPMENT

The initial -- and perhaps most critical -- element in a program designed to evaluate the physical and chemical properties of a solid waste is the plan for sampling the waste. It is understandable that analytical studies, with their sophisticated instrumentation and high cost, are often perceived as the dominant element in a waste characterization program. Yet, despite that sophistication and high cost, analytical data generated by a scientifically defective sampling plan have limited utility, particularly in the case of regulatory proceedings.

This section of the manual addresses the development and implementation of a scientifically credible sampling plan for a solid waste and the documentation of the chain of custody for such a plan. The information presented in this section is relevant to the sampling of any solid waste, which has been defined by the EPA in its regulations for the identification and listing of hazardous wastes to include solid, semisolid, liquid, and contained gaseous materials. However, the physical and chemical diversity of those materials, as well as the dissimilarity of storage facilities (lagoons, open piles, tanks, drums, etc.) and sampling equipment associated with them, preclude a detailed consideration of any specific sampling plan. Consequently, because the burden of responsibility for developing a technically sound sampling plan rests with the waste producer, it is advisable that he/she seek competent advice before designing a plan. This is particularly true in the early developmental stages of a sampling plan, at which time at least a basic understanding of applied statistics is required. Applied statistics is the science of employing techniques that allow the uncertainty of inductive inferences (general conclusions based on partial knowledge) to be evaluated.

9.1.1 Development of Appropriate Sampling Plans

An appropriate sampling plan for a solid waste must be responsive to both regulatory and scientific objectives. Once those objectives have been clearly identified, a suitable sampling strategy, predicated upon fundamental statistical concepts, can be developed. The statistical terminology associated with those concepts is reviewed in Table 9-1; Student's "t" values for use in the statistics of Table 9-1 appear in Table 9-2.

9.1.1.1 Regulatory and Scientific Objectives

The EPA, in its hazardous waste management system, has required that certain solid wastes be analyzed for physical and chemical properties. It is mostly chemical properties that are of concern, and, in the case of a number of chemical contaminants, the EPA has promulgated levels (regulatory thresholds) that cannot be equaled or exceeded. The regulations pertaining to the management of hazardous wastes contain three references regarding the

TABLE 9-1. BASIC STATISTICAL TERMINOLOGY APPLICABLE TO SAMPLING PLANS FOR SOLID WASTES

Terminology	Symbol	Mathematical equation	(Equation)
• Variable (e.g., barium or endrin)	x	—	
• Individual measurement of variable	x_i	—	
• Mean of all possible measurements of variable (population mean)	μ	$\mu = \frac{\sum_{i=1}^{N} x_i}{N}$, with N = number of possible measurements	(1)
• Mean of measurements generated by sample (sample mean)	$\bar{x}$	<u>Simple random sampling and systematic random sampling</u>	
		$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$, with n = number of sample measurements	(2a)
		<u>Stratified random sampling</u>	
		$\bar{x} = \sum_{k=1}^{r} W_k \bar{x}_k$, with $\bar{x}_k$ = stratum mean and W_k = fraction of population represented by Stratum k (number of strata [k] range from 1 to r)	(2b)
• Variance of sample	s^2	<u>Simple random sampling and systematic random sampling</u>	
		$s^2 = \frac{\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2/n}{n - 1}$	(3a)
		<u>Stratified random sampling</u>	
		$s^2 = \sum_{k=1}^{r} W_k s_k^2$, with s_k^2 = stratum variance and W_k = fraction of population represent by Stratum k (number of strata [k] ranges from 1 to r)	(3b)

TABLE 9-1. (Continued)

Terminology	Symbol	Mathematical equation	(Equation)
• Standard deviation of sample	s	$s = \sqrt{s^2}$	(4)
• Standard error (also standard error of mean and standard deviation of mean) of sample	$s_{\bar{x}}$	$s_{\bar{x}} = \frac{s}{\sqrt{n}}$	(5)
• Confidence interval for μ[a]	CI	$CI = \bar{x} \pm t_{.20}\, s_{\bar{x}}$, with $t_{.20}$ obtained from Table 2 for appropriate degrees of freedom	(6)
• Regulatory threshold[a]	RT	Defined by EPA (e.g., 100 ppm for barium in elutriate of EP toxicity)	(7)
• Appropriate number of samples to collect from a solid waste (financial constraints not considered)	n	$n = \frac{t^2_{.20} s^2}{\Delta^2}$, with $\Delta = RT - \bar{x}$	(8)
• Degrees of freedom	df	$df = n - 1$	(9)
• Square root transformation	---	$X_i + 1/2$	(10)
• Arcsin transformation	---	Arcsin p; if necessary, refer to any text on basic statistics; measurements must be converted to percentages (p)	(11)

[a]The upper limit of the CI for μ is compared with the applicable regulatory threshold (RT) to determine if a solid waste contains the variable (chemical contaminant) of concern at a hazardous level. The contaminant of concern is not considered to be present in the waste at a hazardous level if the upper limit of the CI is less than the applicable RT. Otherwise, the opposite conclusion is reached.

TABLE 9-2. TABULATED VALUES OF STUDENT'S "t" FOR EVALUATING SOLID WASTES

Degrees of freedom (n-1)[a]	Tabulated "t" value[b]
1	3.078
2	1.886
3	1.638
4	1.533
5	1.476
6	1.440
7	1.415
8	1.397
9	1.393
10	1.372
11	1.363
12	1.356
13	1.350
14	1.345
15	1.341
16	1.337
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18	1.330
19	1.328
20	1.325
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23	1.319
24	1.318
25	1.316
26	1.315
27	1.314
28	1.313
29	1.311
30	1.310
40	1.303
60	1.296
120	1.289
	1.282

[a]Degrees of freedom (df) are equal to the number of samples (n) collected from a solid waste less one.

[b]Tabulated "t" values are for a two-tailed confidence interval and a probability of 0.20 (the same values are applicable to a one-tailed confidence interval and a probability of 0.10).

sampling of solid wastes for analytical properties. The first reference, which occurs throughout the regulations, requires that representative samples of waste be collected and defines representative samples as exhibiting average properties of the whole waste. The second reference, which pertains just to petitions to exclude wastes from being listed as hazardous wastes, specifies that enough samples (but in no case less than four samples) be collected over a period of time sufficient to represent the variability of the wastes. The third reference, which applies only to ground water monitoring systems, mandates that four replicates (subsamples) be taken from each ground water sample intended for chemical analysis and that the mean concentration and variance for each chemical constituent be calculated from those four subsamples and compared with background levels for ground water. Even the statistical test to be employed in that comparison is specified (Student's t-test).

The first of the above-described references addresses the issue of sampling accuracy, and the second and third references focus on sampling variability or, conversely, sampling precision (actually the third reference relates to analytical variability, which, in many statistical tests, is indistinguishable from true sampling variability). Sampling accuracy (the closeness of a sample value to its true value) and sampling precision (the closeness of repeated sample values) are also the issues of overriding importance in any scientific assessment of sampling practices. Thus, from both regulatory and scientific perspectives, the primary objectives of a sampling plan for a solid waste are twofold: namely, to collect samples that will allow measurements of the chemical properties of the waste that are both accurate and precise. If the chemical measurements are sufficiently accurate and precise, they will be considered reliable estimates of the chemical properties of the waste.

It is now apparent that a judgment must be made as to the degree of sampling accuracy and precision that is required to estimate reliably the chemical characteristics of a solid waste for the purpose of comparing those characteristics with applicable regulatory thresholds. Generally, high accuracy and high precision are required if one or more chemical contaminants of a solid waste are present at a concentration that is close to the applicable regulatory threshold. Alternatively, relatively low accuracy and low precision can be tolerated if the contaminants of concern occur at levels far below or far above their applicable thresholds. However, a word of caution is in order. Low sampling precision is often associated with considerable savings in analytical, as well as sampling, costs and is clearly recognizable even in the simplest of statistical tests. On the other hand, low sampling accuracy may not entail cost savings and is always obscured in statistical tests (i.e., it cannot be evaluated). Therefore, although it is desirable to design sampling plans for solid wastes to achieve only the minimally required precision (at least two samples of a material are required for any estimate of precision), it is prudent to design the plans to attain the greatest possible accuracy.

The roles that inaccurate and imprecise sampling can play in causing a solid waste to be inappropriately judged hazardous are illustrated in Figure 9-1. When evaluating Figure 9-1, several points are worthy of consideration. Although a sampling plan for a solid waste generates a mean concentration ($\bar{X}$) and standard deviation (s, a measure of the extent to which individual sample concentrations are dispersed around $\bar{X}$) for each chemical contaminant of concern, it is not the variation of individual sample concentrations that is of ultimate concern, but rather the variation that characterizes $\bar{X}$ itself. That measure of dispersion is termed the standard deviation of the mean (also, the standard error of the mean or standard error) and is designated as $s_{\bar{X}}$. Those two sample values, $\bar{X}$ and $s_{\bar{X}}$, are used to estimate the interval (range) within which the true mean (μ) of the chemical concentration probably occurs, under the assumption that the individual concentrations exhibit a normal (bell-shaped) distribution. For the purposes of evaluating solid wastes, the probability level (confidence interval) of 80% has been selected. That is, for each chemical contaminant of concern, a confidence interval (CI) is described within which μ occurs if the sample is representative, which is expected of about 80 out of 100 samples. The upper limit of the 80% CI is then compared with the appropriate regulatory threshold. If the upper limit is less than the threshold, the chemical contaminant is not considered to be present in the waste at a hazardous level; otherwise, the opposite conclusion is drawn. One last point merits explanation. Even if the upper limit of an estimated 80% CI is only slightly less than the regulatory threshold (the worst case of chemical contamination that would be judged acceptable), there is only a 10% (not 20%) chance that the threshold is equaled or exceeded. That is because values of a normally distributed contaminant that are outside the limits of an 80% CI are equally distributed between the left (lower) and right (upper) tails of the normal curve. Consequently, the CI employed to evaluate solid wastes is, for all practical purposes, a 90% interval.

9.1.1.2 Fundamental Statistical Concepts

The concepts of sampling accuracy and precision have already been introduced, along with some measurements of central tendency ($\bar{X}$) and dispersion (standard deviation [s] and $s_{\bar{X}}$) for concentrations of a chemical contaminant of a solid waste. The utility of $\bar{X}$ and $s_{\bar{X}}$ in estimating a confidence interval that probably contains the true mean (μ) concentration of a contaminant has also been described. However, it was noted that the validity of that estimate is predicated upon the assumption that individual concentrations of the contaminant exhibit a normal distribution.

Statistical techniques for obtaining accurate and precise samples are relatively simple and easy to implement. Sampling accuracy is usually achieved by some form of random sampling. In random sampling, every unit in the population (e.g., every location in a lagoon used to store a solid waste) has a theoretically equal chance of being sampled and measured. Consequently, statistics generated by the sample (e.g., $\bar{X}$ and, to a lesser degree, $s_{\bar{X}}$) are unbiased (accurate) estimators of true population parameters (e.g., the CI for μ). In other words, the sample is representative of the population. One of the commonest methods of selecting a random sample is to divide the

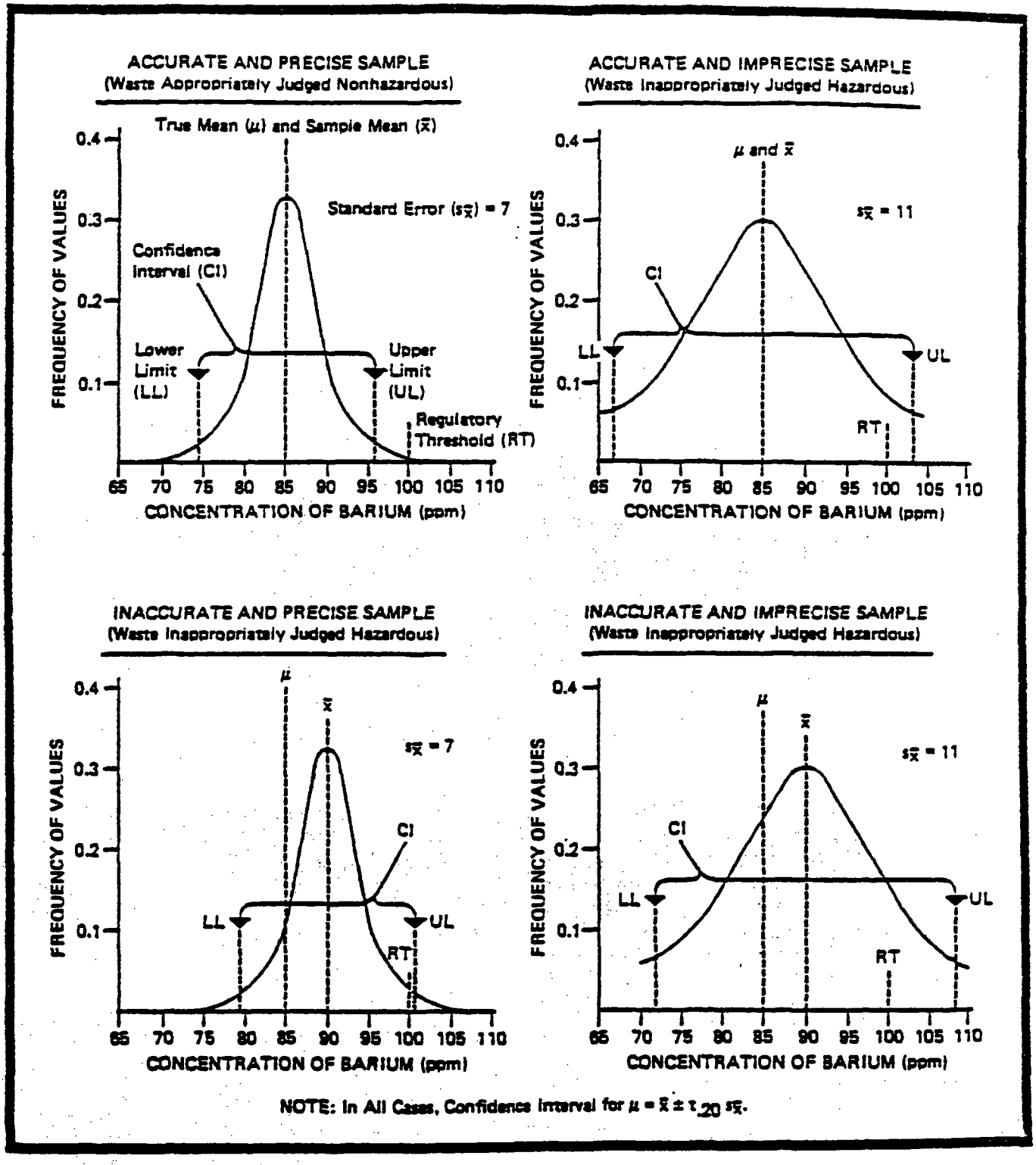


Figure 9-1.—Important theoretical relationships between sampling accuracy and precision and regulatory objectives for a chemical contaminant of a solid waste that occurs at a concentration marginally less than its regulatory threshold. In this example, barium is the chemical contaminant. The true mean concentration of barium in the elutriate of the EP toxicity test is 85 ppm, as compared to a regulatory threshold of 100 ppm. The upper limit of the confidence interval for the true mean concentration, which is estimated from the sample mean and standard error, must be less than the regulatory threshold if barium is judged to be present in the waste at a nonhazardous level.

population by an imaginary grid, assign a series of consecutive numbers to the units of the grid, and select the numbers (units) to be sampled through the use of a random-numbers table (such a table can be found in any text on basic statistics). It is important to emphasize that a haphazardly selected sample is not a suitable substitute for a randomly selected sample. That is because there is no assurance that a person performing undisciplined sampling will not consciously or subconsciously favor the selection of certain units of the population, thus causing the sample to be unrepresentative of the population.

Sampling precision is most commonly achieved by taking an appropriate number of samples from the population. As can be observed from the equation for calculating $s_{\bar{x}}$, precision increases ($s_{\bar{x}}$ and the CI for μ decrease) as the number of samples (n) increases, although not in a 1:1 ratio. For example, a 100% increase in the number of samples from two to four causes the CI to decrease by approximately 62% (about 31% of that decrease is associated with the critical upper tail of the normal curve). However, another 100% increase in sampling effort from four to eight samples results in only an additional 39% decrease in the CI. Another technique for increasing sampling precision is to maximize the physical size (weight or volume) of the samples that are collected. That has the effect of minimizing between-sample variation and, consequently, decreasing $s_{\bar{x}}$. Increasing the number or size of samples taken from a population, in addition to increasing sampling precision, has the secondary effect of increasing sampling accuracy.

In summary, reliable information concerning the chemical properties of a solid waste is needed for the purpose of comparing those properties with applicable regulatory thresholds. If chemical information is to be considered reliable, it must be accurate and sufficiently precise. Accuracy is usually achieved by incorporating some form of randomness into the selection process for the samples that generate the chemical information. Sufficient precision is most often obtained by selecting an appropriate number of samples.

There are a few ramifications of the above-described concepts that merit elaboration. If, for example, as in the case of semiconductor etching solutions, each batch of a waste is completely homogeneous with regard to the chemical properties of concern and that chemical homogeneity is constant (uniform) over time (from batch to batch), a single sample collected from the waste at an arbitrary location and time would theoretically generate an accurate and precise estimate of the chemical properties. However, most wastes are heterogeneous in terms of their chemical properties. If a batch of waste is randomly heterogeneous with regard to its chemical characteristics and that random chemical heterogeneity remains constant from batch to batch, accuracy and appropriate precision can usually be achieved by simple random sampling. In that type of sampling, all units in the population (essentially all locations or points in all batches of waste from which a sample could be collected) are identified, and a suitable number of samples is randomly selected from the population. More complex stratified random sampling is appropriate if a batch of waste is known to be nonrandomly heterogeneous in terms of its chemical properties and/or nonrandom chemical heterogeneity is known to exist from batch to batch. In such cases, the population is stratified to isolate the known sources of nonrandom chemical heterogeneity.

After stratification, which may occur over space (locations or points in a batch of waste) and/or time (each batch of waste), the units in each stratum are numerically identified, and a simple random sample is taken from each stratum. As previously intimated, both simple and stratified random sampling generate accurate estimates of the chemical properties of a solid waste. The advantage of stratified random sampling over simple random sampling is that, for a given number of samples and a given sample size, the former technique often results in a more precise estimate of chemical properties of a waste (a lower value of $s_{\bar{x}}$) than the latter technique. However, greater precision is likely to be realized only if a waste exhibits substantial nonrandom chemical heterogeneity and stratification efficiently "divides" the waste into strata that exhibit maximum between-strata variability and minimum within-strata variability. If that does not occur, stratified random sampling can produce results that are less precise than in the case of simple random sampling. Therefore, it is reasonable to select stratified random sampling over simple random sampling only if the distribution of chemical contaminants in a waste is sufficiently known to allow an intelligent identification of strata and at least two or three samples can be collected in each stratum. If a strategy employing stratified random sampling is selected, a decision must be made regarding the allocation of sampling effort among strata. When chemical variation within each stratum can be estimated with a great degree of detail, samples should be optimally allocated among strata, i.e., the number of samples collected from each stratum should be directly proportional to the chemical variation encountered in the stratum. When detailed information concerning chemical variability within strata is not available, samples should be proportionally allocated among strata, i.e., sampling effort in each stratum should be directly proportional to the size of the stratum.

Simple random sampling and stratified random sampling are types of probability sampling, which, because of a reliance upon mathematical and statistical theories, allows an evaluation of the effectiveness of sampling procedures. Another type of probability sampling is systematic random sampling, in which the first unit to be collected from a population is randomly selected, but all subsequent units are taken at fixed space or time intervals. An example of systematic random sampling is the sampling of a waste lagoon along a transect in which the first sampling point on the transect is 1 m from a randomly selected location on the shore and subsequent sampling points are located at 2-m intervals along the transect. The advantages of systematic random sampling over simple random sampling and stratified random sampling are the ease with which samples are identified and collected (the selection of the first sampling unit determines the remainder of the units) and, sometimes, an increase in precision. In certain cases, for example, systematic random sampling might be expected to be a little more precise than stratified random sampling with one unit per stratum because samples are distributed more evenly over the population. As will be demonstrated shortly, disadvantages of systematic random sampling are the poor accuracy and precision that can occur when unrecognized trends or cycles occur in the population. For those reasons, systematic random sampling is recommended only when a population is essentially random or contains at most a modest stratification. In such cases, systematic random sampling would be employed for the sake of convenience, with little expectation of an increase in precision over other random sampling techniques.

Probability sampling is contrasted with authoritative sampling, in which an individual who is well acquainted with the solid waste to be sampled selects a sample without regard to randomization. The validity of data gathered in that manner is totally dependent on the knowledge of the sampler and, although valid data can sometimes be obtained, authoritative sampling is not recommended for the chemical characterization of most wastes.

It may now be useful to offer a generalization regarding the four sampling strategies that have been identified for solid wastes. If little or no information is available concerning the distribution of chemical contaminants of a waste, simple random sampling is the most appropriate sampling strategy. As more information is accumulated for the contaminants of concern, greater consideration can be given (in order of the additional information required) to stratified random sampling, systematic random sampling, and, perhaps, authoritative sampling.

The validity of a CI for the true mean (μ) concentration of a chemical contaminant of a solid waste is, as previously noted, based on the assumption that individual concentrations of the contaminant exhibit a normal distribution. This is true regardless of the strategy that is employed to sample the waste. Although there are computational procedures for evaluating the correctness of the assumption of normality, those procedures are meaningful only if a large number of samples are collected from a waste. Because sampling plans for most solid wastes entail just a few samples, one can do little more than superficially examine resulting data for obvious departures from normality (this can be done by simple graphical methods), keeping in mind that even if individual measurements of a chemical contaminant of a waste exhibit a considerably abnormal distribution, such abnormality is not likely to be the case for sample means, which are our primary concern. One can also compare the mean of the sample ($\bar{X}$) with the variance of the sample (s^2). In a normally distributed population, $\bar{X}$ would be expected to be greater than s^2 (assuming that the number of samples [n] is reasonably large). If that is not the case, the chemical contaminant of concern may be characterized by a Poisson distribution ($\bar{X}$ is approximately equal to s^2) or a negative binomial distribution ($\bar{X}$ is less than s^2). In the former circumstance, normality can often be achieved by transforming data according to the square root transformation. In the latter circumstance, normality may be realized through use of the arcsine transformation. If either transformation is required, all subsequent statistical evaluations must be performed on the transformed scale.

Finally, it is necessary to address the appropriate number of samples to be employed in the chemical characterization of a solid waste. As has already been emphasized, the appropriate number of samples is the least number of samples required to generate a sufficiently precise estimate of the true mean (μ) concentration of a chemical contaminant of a waste. From the perspective of most waste producers, that means the minimal number of samples needed to demonstrate that the upper limit of the CI for μ is less than the applicable regulatory threshold (RT). The formula for estimating appropriate sampling effort (Table 9-1, Equation 8) indicates that increased sampling effort is generally justified as s^2 or the "$t_{.20}$" value (probable error rate) increases

and as $\Delta(RT - \bar{X})$ decreases. In a well-designed sampling plan for a solid waste, an effort is made to estimate the values of $\bar{X}$ and s^2 before sampling is initiated. Such preliminary estimates, which may be derived from information pertaining to similar wastes, process engineering data, or limited analytical studies, are used to identify the approximate number of samples that must be collected from the waste. It is always prudent to collect a somewhat greater number of samples than indicated by preliminary estimates of $\bar{X}$ and s^2 since poor preliminary estimates of those statistics can result in an underestimate of the appropriate number of samples to collect. It is usually possible to process and store the extra samples appropriately until analysis of the initially identified samples is completed and it can be determined if analysis of the additional samples is warranted.

9.1.1.3 Basic Sampling Strategies

It is now appropriate to present general procedures for implementing the three previously introduced sampling strategies (simple random sampling, stratified random sampling, and systematic random sampling) and a hypothetical example of each sampling strategy. The hypothetical examples illustrate the statistical calculations that must be performed in most situations likely to be encountered by a waste producer and, also, provide some insight into the efficiency of the three sampling strategies in meeting regulatory objectives.

The following hypothetical conditions are assumed to exist for all three sampling strategies. First, barium, which has an RT of 100 ppm as measured in the EP elutriate test, is the only chemical contaminant of concern. Second, barium is discharged in particulate form to a waste lagoon and accumulates in the lagoon in the form of a sludge, which has built up to approximately the same thickness throughout the lagoon. Third, concentrations of barium are relatively homogeneous along the vertical gradient (from the water-sludge interface to the sludge-lagoon interface), suggesting a highly controlled manufacturing process (little between-batch variation in barium concentrations). Fourth, the physical size of sludge samples collected from the lagoon is as large as practical, and barium concentrations derived from those samples are normally distributed (note that we do not refer to barium levels in the samples of sludge because barium measurements are actually made on the elutriate from EP toxicity tests performed with the samples). Last, a preliminary study of barium levels in the elutriate of four EP toxicity tests conducted with sludge collected from the lagoon several years ago identified values of 86 and 90 ppm for material collected near the outfall (in the upper third) of the lagoon and values of 98 and 104 ppm for material obtained from the far end (the lower two-thirds) of the lagoon.

For all sampling strategies, it is important to remember that barium will be determined to be present in the sludge at a hazardous level if the upper limit of the CI for μ is equal to or greater than the RT of 100 ppm (Table 9-1, Equations 6 and 7).

9.1.1.3.1 Simple Random Sampling

Simple random sampling (Box 1) is performed by general procedures in which preliminary estimates of $\bar{x}$ and s^2, as well as a knowledge of the RT, for each chemical contaminant of a solid waste that is of concern are employed to estimate the appropriate number of samples (n) to be collected from the waste. That number of samples is subsequently analyzed for each chemical contaminant of concern. The resulting analytical data are then used to conclude definitively that each contaminant is or is not present in the waste at a hazardous concentration or, alternatively, to suggest a reiterative process, involving increased sampling effort, through which the presence or absence of hazard can be definitively determined.

In the hypothetical example for simple random sampling (Box 1), preliminary estimates of $\bar{x}$ and s^2 indicated a sampling effort consisting of six samples. That number of samples was collected and initially analyzed, generating analytical data somewhat different from the preliminary data (s^2 was substantially greater than was preliminarily estimated). Consequently, the upper limit of the CI was unexpectedly greater than the applicable RT, resulting in a tentative conclusion of hazard. However, a reestimation of appropriate sampling effort, based on statistics derived from the six samples, suggested that such a conclusion might be reversed through the collection and analysis of just one more sample. Fortunately, a resampling effort was not required because of the foresight of the waste producer in obtaining three extra samples during the initial sampling effort, which, because of their influence in decreasing the final values of $\bar{x}$, $s_{\bar{x}}$, $t_{.20}$, and, consequently, the upper limit of the CI -- values obtained from all nine samples -- resulted in a definitive conclusion of nonhazard.

9.1.1.3.2 Stratified Random Sampling

Stratified random sampling (Box 2) is conducted by general procedures that are similar to the procedures described for simple random sampling. The only difference is that, in stratified random sampling, values of $\bar{x}$ and s^2 are calculated for each stratum in the population and then integrated into overall estimates of those statistics, the standard deviation (s), $s_{\bar{x}}$, and the appropriate number of samples (n) for all strata.

The hypothetical example for stratified random sampling (Box 2) is based on the same nine sludge samples previously identified in the example of simple random sampling (Box 1) so that the relative efficiencies of the two sampling strategies can be fully compared. The efficiency generated through the process of stratification is first evident in the preliminary estimate of n (Step 2 in Boxes 1 and 2), which is six for simple random sampling and four for stratified random sampling. (The lesser value for stratified sampling is the consequence of a dramatic decrease in s^2, which more than compensated for a modest increase in Δ.) The most relevant indication of sampling efficiency is the value of $s_{\bar{x}}$, which is directly employed to calculate the CI. In the case of simple random sampling, $s_{\bar{x}}$ is calculated as 2.58 (Step 9 in Box 1), and, for stratified random sampling, $s_{\bar{x}}$ is determined to be 2.35 (Steps 5 and 7 in Box 2). Consequently, the gain in efficiency attributable to stratification is approximately 9% (0.23/2.58).

BOX 1. STRATEGY FOR DETERMINING IF CHEMICAL CONTAMINANTS OF SOLID WASTES ARE PRESENT AT HAZARDOUS LEVELS - SIMPLE RANDOM SAMPLING

Step	General Procedures
1.	Obtain preliminary estimates of $\bar{x}$ and s^2 for each chemical contaminant of a solid waste that is of concern. The two above-identified statistics are calculated by, respectively, Equations 2a and 3a (Table 9-1).
2.	Estimate the appropriate number of samples (n_1) to be collected from the waste through use of Equation 8 (Table 9-1) and Table 9-2. Derive individual values of n_1 for each chemical contaminant of concern. The appropriate number of samples to be taken from the waste is the greatest of the individual n_1 values.
3.	Randomly collect at least n_1 (or $n_2 - n_1$, $n_3 - n_2$, etc., as will be indicated later in this box) samples from the waste (collection of a few extra samples will provide protection against poor preliminary estimates of $\bar{x}$ and s^2). Maximize the physical size (weight or volume) of all samples that are collected.
4.	Analyze the n_1 (or $n_2 - n_1$, $n_3 - n_2$ etc.) samples for each chemical contaminant of concern. Superficially (graphically) examine each set of analytical data for obvious departures from normality.
5.	Calculate $\bar{x}$, s^2, the standard deviation (s), and $s_{\bar{x}}$ for each set of analytical data by, respectively, Equations 2a, 3a, 4, and 5 (Table 9-1).
6.	If $\bar{x}$ for a chemical contaminant is equal to or greater than the applicable RT (Equation 7, Table 9-1) and is believed to be an accurate estimator of μ, the contaminant is considered to be present in the waste at a hazardous concentration, and the study is completed. Otherwise, continue the study. In the case of a set of analytical data that does not exhibit obvious abnormality and for which $\bar{x}$ is greater than s^2, perform the following calculations with nontransformed data. Otherwise, consider transforming the data by the square root transformation (if $\bar{x}$ is about equal to s^2) or the arcsine transformation (if $\bar{x}$ is less than s^2) and performing all subsequent calculations with transformed data. Square root and arcsine transformations are defined by, respectively, Equations 10 and 11 (Table 9-1).
7.	Determine the CI for each chemical contaminant of concern by Equation 6 (Table 9-1) and Table 9-2. If the upper limit of the CI is less than the applicable RT (Equations 6 and 7, Table 9-1), the chemical contaminant is not considered to be present in the waste at a hazardous concentration and the study is completed. Otherwise, the opposite conclusion is tentatively reached.

8. If a tentative conclusion of hazard is reached, reestimate the total number of samples (n_2) to be collected from the waste by use of Equation 8 (Table 9-1) and Table 9-2. When deriving n_2, employ the newly calculated (not preliminary) values of x and s^2. If additional $n_2 - n_1$ samples of waste cannot reasonably be collected, the study is completed, and a definitive conclusion of hazard is reached. Otherwise, collect extra $n_2 - n_1$ samples of waste.

9. Repeat the basic operations described in Steps 3 through 8 until the waste is judged to be nonhazardous or, if the opposite conclusion continues to be reached, until increased sampling effort is impractical.

Hypothetical Example

Step

1. The preliminary study of barium levels in the elutriate of four EP toxicity tests, conducted with sludge collected from the lagoon several years ago, generated values of 86 and 90 ppm for sludge obtained from the upper third of the lagoon and values of 98 and 104 ppm for sludge from the lower two-thirds of the lagoon. Those two sets of values are not judged to be indicative of nonrandom chemical heterogeneity (stratification) within the lagoon. Therefore, preliminary estimates of $\bar{x}$ and s^2 are calculated as:

$$\bar{x} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{86 + 90 + 98 + 104}{4} = 94.50, \text{ and} \qquad \text{(Equation 2a)}$$

$$s^2 = \frac{\sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2/n}{n - 1} \qquad \text{(Equation 3a)}$$

$$= \frac{35{,}916.00 - 35{,}721.00}{3} = 65.00.$$

2. Based on the preliminary estimates of $\bar{x}$ and s^2, as well as the knowledge that the RT for barium is 100 ppm,

$$n_1 = \frac{t^2_{.20} s^2}{\Delta^2} = \frac{(1.638^2)(65.00)}{5.50^2} = 5.77. \qquad \text{(Equation 8)}$$

3. As indicated above, the appropriate number of sludge samples (n_1) to be collected from the lagoon is six. That number of samples (plus three extra samples for protection against poor preliminary estimates of $\bar{x}$ and s^2) is collected from the lagoon by a single randomization process (Figure 9-2). All samples consist of the greatest volume of sludge that

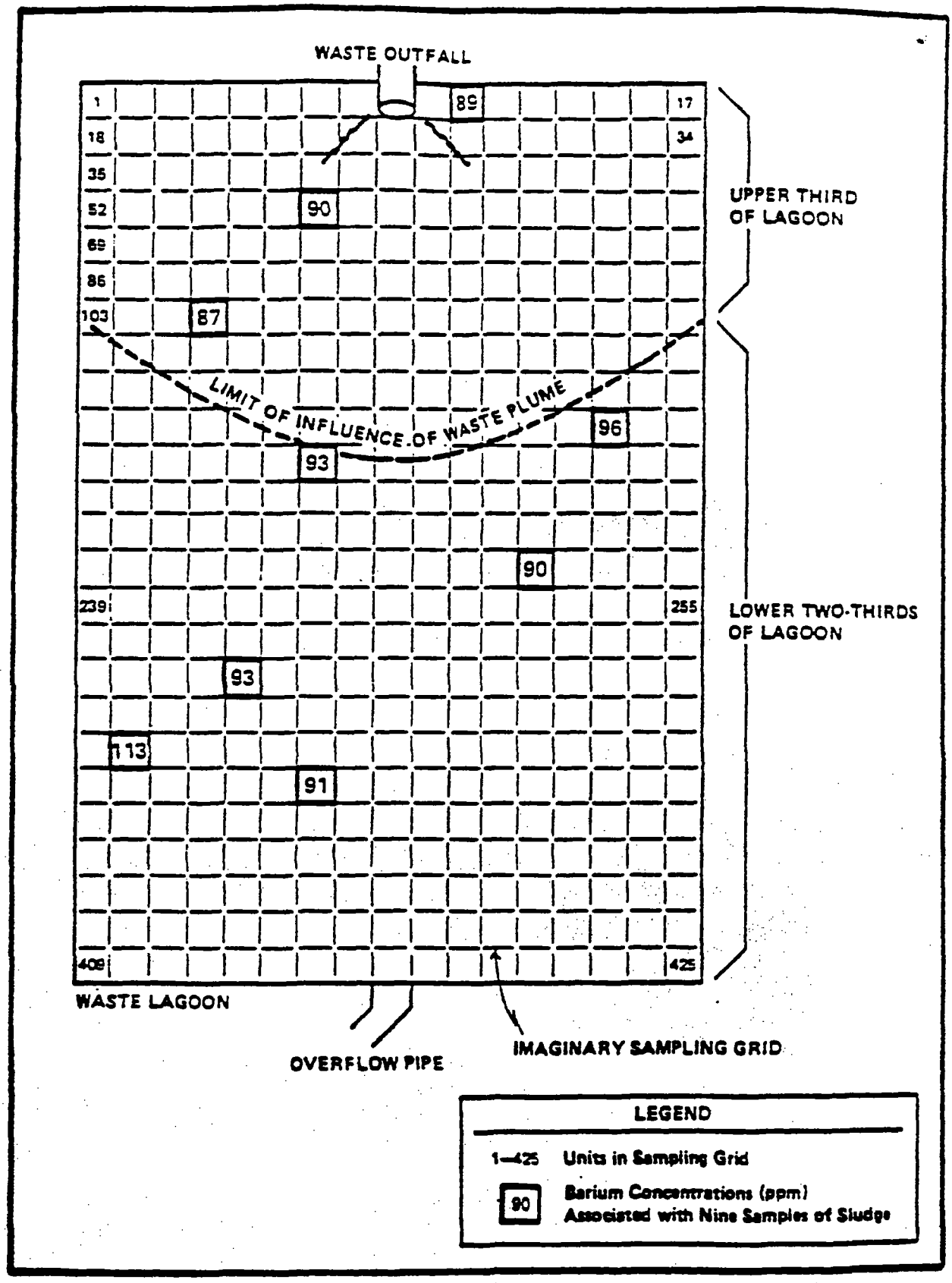


Figure 9-2.—Hypothetical sampling conditions in waste lagoon containing sludge contaminated with barium. Barium concentrations associated with samples of sludge refer to levels measured in the elutriate of EP toxicity tests conducted with the samples.

can be practically collected. The three extra samples are suitably processed and stored for possible later analysis.

4. The six samples of sludge (n_1) designated for immediate analysis generate the following concentrations of barium in the EP toxicity test: 89, 90, 87, 96, 93, and 113 ppm. Although the value of 113 ppm appears unusual as compared with the other data, there is no obvious indication that the data are not normally distributed.

5. New values for $\bar{x}$ and s^2 and associated values for the standard deviation (s) and $s_{\bar{x}}$ are calculated as:

$$\bar{x} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{89 + 90 + 87 + 96 + 93 + 113}{6} = 94.67, \qquad \text{(Equation 2a)}$$

$$s^2 = \frac{\sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2/n}{n - 1} \qquad \text{(Equation 3a)}$$

$$= \frac{54,224.00 - 53,770.67}{5} = 90.67,$$

$$s = \sqrt{s^2} = 9.52, \text{ and} \qquad \text{(Equation 4)}$$

$$s_{\bar{x}} = s/\sqrt{n} = 9.52/\sqrt{6} = 3.89. \qquad \text{(Equation 5)}$$

6. The new value for $\bar{x}$ (94.67) is less than the RT (100). In addition, $\bar{x}$ is greater (only slightly) than s^2 (90.67), and, as previously indicated, the raw data are not characterized by obvious abnormality. Consequently, the study is continued, with the following calculations performed with nontransformed data.

7. $$CI = \bar{x} \pm t_{.20} s_{\bar{x}} = 94.67 \pm (1.476)(3.89) \qquad \text{(Equation 6)}$$

$$= 94.67 \pm 5.74.$$

Because the upper limit of the CI (100.41) is greater than the applicable RT (100), it is tentatively concluded that barium is present in the sludge at a hazardous concentration.

8. n is now reestimated as:

$$n_2 = \frac{t^2_{.20} s^2}{\Delta^2} \frac{(1.476^2)(90.67)}{5.33^2} = 6.95. \qquad \text{(Equation 8)}$$

The value for n_2 (approximately 7) indicates that an additional ($n_2 - n_1 = 1$) sludge sample should be collected from the lagoon.

9. The additional sampling effort is not necessary because of the three extra samples that were initially collected from the lagoon. All extra samples are analyzed, generating the following levels of barium for the EP toxicity test: 93, 90, and 91 ppm. Consequently, $\bar{x}$, s^2, the standard deviation (s), and $s_{\bar{x}}$ are recalculated as:

$$\bar{x} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{86 + 90 + \ldots + 91}{9} = 93.56\ , \qquad \text{(Equation 2a)}$$

$$s^2 = \frac{\sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2/n}{n - 1} \qquad \text{(Equation 3a)}$$

$$= \frac{79{,}254.00 - 78{,}773.78}{8} = 60.03,$$

$$s = \sqrt{s^2} = 7.75, \text{ and} \qquad \text{(Equation 4)}$$

$$s_{\bar{x}} = s/\sqrt{n} = 7.75/\sqrt{9} = 2.58. \qquad \text{(Equation 5)}$$

The value for $\bar{x}$ (93.56) is again less than the RT (100), and there is no indication that the nine data points, considered collectively, are abnormally distributed (in particular, $\bar{x}$ is now substantially greater than s^2). Consequently, CI, calculated with nontransformed data, is determined to be:

$$CI = \bar{x} \pm t_{.20} s_{\bar{x}} = 93.56 \pm (1.397)(2.58) \qquad \text{(Equation 6)}$$

$$= 93.56 \pm 3.60.$$

The upper limit of the CI (97.16) is now less than the RT of 100. Consequently, it is definitively concluded that barium is not present in the sludge at a hazardous level.

BOX 2. STRATEGY FOR DETERMINING IF CHEMICAL CONTAMINANTS OF SOLID WASTES ARE PRESENT AT HAZARDOUS LEVELS - STRATIFIED RANDOM SAMPLING

Step	General Procedures
1.	Obtain preliminary estimates of $\bar{x}$ and s^2 for each chemical contaminant of a solid waste that is of concern. The two above-identified statistics are calculated by, respectively, Equations 2b and 3b (Table 9-1).
2.	Estimate the appropriate number of samples (n_1) to be collected from the waste through use of Equation 8 (Table 9-1) and Table 9-2. Derive individual values of n_1 for each chemical contaminant of concern. The appropriate number of samples to be taken from the waste is the greatest of the individual n_1 values.
3.	Randomly collect at least n_1 (or $n_2 - n_1$, $n_3 - n_2$, etc., as will be indicated later in this box) samples from the waste (collection of a few extra samples will provide protection against poor preliminary estimates of $\bar{x}$ and s^2). If s_k for each stratum (see Equation 3b) is believed to be an accurate estimate, optimally allocate samples among strata (i.e., allocate samples among strata so that the number of samples collected from each stratum is directly proportional to s_k for that stratum). Otherwise, proportionally allocate samples among strata according to size of the strata. Maximize the physical size (weight or volume) of all samples that are collected from the strata.
4.	Analyze the n_1 (or $n_2 - n_1$, $n_3 - n_2$ etc.) samples for each chemical contaminant of concern. Superficially (graphically) examine each set of analytical data from each stratum for obvious departures from normality.
5.	Calculate $\bar{x}$, s_2, the standard deviation (s), and $s_{\bar{x}}$ for each set of analytical data by, respectively, Equations 2b, 3b, 4, and 5 (Table 9-1).
6.	If $\bar{x}$ for a chemical contaminant is equal to or greater than the applicable RT (Equation 7, Table 9-1) and is believed to be an accurate estimator of u, the contaminant is considered to be present in the waste at a hazardous concentration, and the study is completed. Otherwise, continue the study. In the case of a set of analytical data that does not exhibit obvious abnormality and for which $\bar{x}$ is greater than s^2, perform the following calculations with nontransformed data. Otherwise, consider transforming the data by the square root transformation (if $\bar{x}$ is about equal to s^2) or the arcsine transformation (if $\bar{x}$ is less than s^2) and performing all subsequent calculations with transformed data. Square root and arcsine transformations are defined by, respectively, Equations 10 and 11 (Table 9-1).
7.	Determine the CI for each chemical contaminant of concern by Equation 6 (Table 9-1) and Table 9-2. If the upper limit of the CI is less than the applicable RT (Equations 6 and 7, Table 9-1), the chemical contaminant is not considered to be present in the waste at a hazardous concentration, and the study is completed. Otherwise, the opposite conclusion is tentatively reached.

8. If a tentative conclusion of hazard is reached, reestimate the total number of samples (n_2) to be collected from the waste by use of Equation 8 (Table 9-1) and Table 9-2. When deriving n_2, employ the newly calculated (not preliminary) values of $\bar{x}$ and s^2. If additional $n_2 - n_1$ samples of waste cannot reasonably be collected, the study is completed, and a definitive conclusion of hazard is reached. Otherwise, collect extra $n_2 - n_1$ samples of waste.

9. Repeat the basic operations described in steps 3 through 8 until the waste is judged to be nonhazardous or, if the opposite conclusion continues to be reached, until increased sampling effort is impractical.

Hypothetical Example

Step

1. The preliminary study of barium levels in the elutriate of four EP toxicity tests, conducted with sludge collected from the lagoon several years ago, generated values of 86 and 90 ppm for sludge obtained from the upper third of the lagoon and values of 98 and 104 ppm for sludge from the lower two-thirds of the lagoon. Those two sets of values are not judged to be indicative of nonrandom chemical heterogeneity (stratification) within the lagoon. Therefore, preliminary estimates of $\bar{x}$ and s^2 are calculated as:

$$\bar{x} = \sum_{k=1}^{r} W_k \bar{x}_k = \frac{(1)(88.00)}{3} + \frac{(2)(101.00)}{3} = 96.67, \text{ and} \qquad \text{(Equation 2b)}$$

$$s^2 = \sum_{k=1}^{r} W_k s_k^2 = \frac{(1)(8.00)}{3} + \frac{(2)(18.00)}{3} = 14.67. \qquad \text{(Equation 3b)}$$

2. Based on the preliminary estimates of $\bar{x}$ and s^2, as well as the knowledge that the RT for barium is 100 ppm,

$$n_1 = \frac{t_{.20}^2 s^2}{\Delta^2} = \frac{(1.368^2)(14.67)}{3.33^2} = 3.55. \qquad \text{(Equation 8)}$$

3. As indicated above, the appropriate number of sludge samples (n_1) to be collected from the lagoon is four. However, for purposes of comparison with simple random sampling (Box 1), six samples (plus three extra samples for protection against poor preliminary estimates of $\bar{x}$ and s^2) are collected from the lagoon by a two-stage randomization process (Figure 2). Because s_k for the upper (2.12 ppm) and lower (5.66 ppm) strata are not believed to be very accurate estimates, the nine samples to be collected from the lagoon are not optimally allocated between the two strata (optimum allocation would require two and seven samples to be

collected from the upper and lower strata, respectively). Alternatively, proportional allocation is employed: three samples are collected from the upper stratum (which represents one-third of the lagoon), and six samples are taken from the lower stratum (two-thirds of the lagoon). All samples consist of the greatest volume of sludge that can be practically collected.

4. The nine samples of sludge generate the following concentrations of barium in the EP toxicity test: upper stratum -- 89, 90, and 87 ppm; lower stratum -- 96, 93, 113, 93, 90, and 91 ppm. Although the value of 113 ppm appears unusual as compared with the other data for the lower stratum, there is no obvious indication that the data are not normally distributed.

5. New values for $\bar{x}$ and s^2 and associated values for the standard deviation (s) and $s_{\bar{x}}$ are calculated as:

$$\bar{x} = \sum_{k=1}^{r} W_k \bar{x}_k = \frac{(1)(88.67)}{3} + \frac{(2)(96.00)}{3} = 93.56, \qquad \text{(Equation 2b)}$$

$$s^2 = \sum_{k=1}^{r} W_k s_k^2 = \frac{(1)(2.33)}{3} + \frac{(2)(73.60)}{3} = 49.84, \qquad \text{(Equation 3b)}$$

$$s = \sqrt{s^2} = 7.06, \text{ and} \qquad \text{(Equation 4)}$$

$$s_{\bar{x}} = s/\sqrt{n} = 7.06/\sqrt{9} = 2.35. \qquad \text{(Equation 5)}$$

6. The new value for $\bar{x}$ (93.56) is less than the RT (100). In addition, $\bar{x}$ is greater than s^2 (49.84), and, as previously indicated, the raw data are not characterized by obvious abnormality. Consequently, the study is continued, with the following calculations performed with nontransformed data.

7. $$CI = \bar{x} \pm t_{.20} s_{\bar{x}} = 93.56 \pm (1.397)(2.35) \qquad \text{(Equation 6)}$$

$$= 93.56 \pm 3.28$$

The upper limit of the CI (96.84) is less than the applicable RT (100). Therefore, it is concluded that barium is not present in the sludge at a hazardous concentration.

9.1.1.3.3 Systematic Random Sampling

Systematic random sampling (Box 3) is implemented by general procedures that are identical to the procedures identified for simple random sampling. The hypothetical example for systematic random sampling (Box 3) demonstrates the bias and imprecision that are associated with that type of sampling when unrecognized trends or cycles exist in the population.

9.1.1.4 Special Considerations

The preceding discussion has addressed the major issues that are critical to the development of a reliable sampling strategy for a solid waste. The remaining discussion focuses on several "secondary" issues that should be considered when designing an appropriate sampling strategy. These secondary issues are applicable to all three of the basic sampling strategies that have been identified.

9.1.1.4.1 Composite Sampling

In composite sampling, a number of random samples are initially collected from a waste and combined into a single sample, which is then analyzed for the chemical contaminants of concern. The major disadvantage of composite sampling, as compared with noncomposite sampling, is that information concerning the chemical contaminants is lost, i.e., each initial set of samples generates only a single estimate of the concentration of each contaminant. Consequently, because the number of analytical measurements (n) is small, $s_{\bar{x}}$ and $t_{.20}$ are large, thus decreasing the likelihood that a contaminant will be judged to occur in the waste at a nonhazardous level (refer to appropriate equations in Table 9-1 and to Table 9-2). A remedy to that situation is to collect and analyze a relatively large number of composite samples, thereby offsetting the savings in analytical costs that are often associated with composite sampling, but achieving better representation of the waste than would occur with noncomposite sampling.

The appropriate number of composite samples to be collected from a solid waste is estimated by use of Equation 8 (Table 9-1), as previously described for the three basic sampling strategies. In comparison with noncomposite sampling, composite sampling may have the effect of minimizing between-sample variation (the same phenomenon that occurs when the physical size of a sample is maximized), thereby reducing somewhat the number of samples that must be collected from the waste.

9.1.1.4.2 Subsampling

The variance (s^2) associated with a chemical contaminant of a waste consists of two components in that:

$$s^2 = s_s^2 + \frac{s_a^2}{m}, \qquad \text{(Equation 12)}$$

BOX 3. STRATEGY FOR DETERMINING IF CHEMICAL CONTAMINANTS OF SOLID WASTES ARE PRESENT AT HAZARDOUS LEVELS - SYSTEMATIC RANDOM SAMPLING

Step	General Procedures
1.	Follow general procedures presented for simple random sampling of solid wastes (Box 1).

Step	Hypothetical Example
1.	The example presented in Box 1 is applicable to systematic random sampling, with the understanding that the nine sludge samples obtained from the lagoon would be collected at equal intervals along a transect running from a randomly selected location on one bank of the lagoon to the opposite bank. If that randomly selected transect were established between Units 1 and 409 of the sampling grid (Figure 9-2) and sampling were performed at Unit 1 and thereafter at three-unit intervals along the transect (i.e., Unit 1, Unit 52, Unit 103, ... , and Unit 409), it is apparent that only two samples would be collected in the upper third of the lagoon, whereas seven samples would be obtained from the lower two-thirds of the lagoon. If, as suggested by the barium concentrations illustrated in Figure 9-2, the lower part of the lagoon is characterized by greater and more variable barium contamination than the upper part of the lagoon, systematic random sampling along the above-identified transect, by placing undue (disproportionate) emphasis on the lower part of the lagoon, might be expected to result in an inaccurate (overestimated) and imprecise characterization of barium levels in the whole lagoon, as compared with either simple random sampling or stratified random sampling. Such inaccuracy and imprecision, which are typical of systematic random sampling when unrecognized trends or cycles occur in the population, would be magnified if, for example, the randomly selected transect were established solely in the lower part of the lagoon, e.g., between Units 239 and 255 of the sampling grid.

where s_s^2 = a component attributable to sampling (sample) variation, s_a^2 = a component attributable to analytical (subsample) variation, and m = number of subsamples. In general, s_a^2 should not be allowed to exceed one-ninth of s_s^2. If a preliminary study indicates that s_a^2 exceeds that threshold, a sampling strategy involving subsampling should be considered. In such a strategy, a number of replicate measurements are randomly made on a relatively limited number of randomly collected samples. Consequently, analytical effort is allocated as a function of analytical variability. The efficiency of that general strategy in meeting regulatory objectives has already been demonstrated in the previous discussions of sampling effort.

The appropriate number of samples (n) to be collected from a solid waste for which subsampling will be employed is again estimated by Equation 8 (Table 9-1). In the case of simple random sampling or systematic random sampling with an equal number of subsamples analyzed per sample:

$$\bar{x} = \sum_{i=1}^{n} x_i/n, \qquad \text{(Equation 13)}$$

where $\bar{x}_i$ = sample mean (calculated from values for subsamples) and n = number of samples. Also,

$$s^2 = \frac{\sum_{i=1}^{n} \bar{x}_i^2 - (\sum_{i=1}^{n} \bar{x}_i)^2/n}{n - 1} \qquad \text{(Equation 14)}$$

The optimum number of subsamples to be taken from each sample ($m_{opt.}$) is estimated as:

$$m_{(opt.)} = \frac{s_a}{s_s} \qquad \text{(Equation 15)}$$

when cost factors are not considered. The value for s_a is calculated from available data as:

$$s_a = \sqrt{\frac{\sum_{i=1}^{n} \sum_{j=1}^{m} x_{ij}^2 - (\sum x_{ij})^2/m}{n\,(m - 1)}}, \qquad \text{(Equation 16)}$$

and s_s, which can have a negative characteristic, is defined as:

$$s_s = \sqrt{s^2 - \frac{s_a^2}{m}}, \qquad \text{(Equation 17)}$$

with s_2 calculated as indicated in Equation 14.

In the case of stratified random sampling with subsampling, critical formulas for estimating sample size (n) by Equation 8 (Table 9-1) include:

$$\bar{x} = \sum_{k=1}^{r} W_k \bar{x}_k, \qquad \text{(Equation 2b)}$$

where $\bar{x}_k$ = stratum mean and W_k = fraction of population represented by Stratum K (number of strata, k, ranges from 1 to r). In Equation 2b, $\bar{x}_k$ for each stratum is calculated as the average of all sample means in the stratum (sample means are calculated from values for subsamples). In addition, s^2 is calculated by:

$$s^2 = \sum_{k=1}^{r} W_k s_k^2, \qquad \text{(Equation 3b)}$$

with s^2_k for each stratum calculated from all sample means in the stratum. The optimum subsampling effort when cost factors are not considered and all replication is symmetrical is again estimated as:

$$m_{(opt.)} = \frac{s_a}{s_s}, \text{ with} \qquad \text{(Equation 15)}$$

$$s_a = \sqrt{\frac{\sum_{k=1}^{r} \sum_{i=1}^{n} \sum_{j=1}^{m} x_{kij}^2 - (\Sigma x_{kij})^2/m}{rn\,(m-1)}}, \text{ and} \qquad \text{(Equation 18)}$$

$$s_s = \sqrt{s^2 - \frac{s_a^2}{m}}, \qquad \text{(Equation 17)}$$

with s^2 derived as shown in Equation 3b.

9.1.1.5 Cost and Loss Functions

The cost of chemically characterizing a waste is dependent on the specific strategy that is employed to sample the waste. For example, in the case of simple random sampling without subsampling, a reasonable cost function might be:

$$C_{(n)} = C_0 + C_1 n, \qquad \text{(Equation 19)}$$

where $C_{(n)}$ = cost of employing a sample size of n, C_0 = an overhead cost (which is independent of the number of samples that are collected and analyzed), and C_1 = a sample-dependent cost. A consideration of $C_{(n)}$ mandates an evaluation of $L_{(n)}$, which is the sample-size-dependent expected financial loss related to the erroneous conclusion that a waste is hazardous. A simple loss function is:

$$L_{(n)} = \frac{\alpha s^2}{n} , \qquad \text{(Equation 20)}$$

with α = a constant related to the cost of a waste management program if the waste is judged to be hazardous, s^2 = sample variance, and n = number of samples. A primary objective of any sampling strategy is to minimize $C_{(n)} + L_{(n)}$. Differentiation of Equations 19 and 20 indicates that the number of samples (n) that minimize $C_{(n)} + L_{(n)}$ is:

$$n = \sqrt{\frac{\alpha s^2}{C_1}} . \qquad \text{(Equation 21)}$$

As is evident from Equation 21, a comparatively large number of samples (n) is justified if the value of α or s^2 is large, whereas a relatively small number of samples is appropriate if the value of C_1 is large. These general conclusions are valid for any sampling strategy for a solid waste.

9.2 IMPLEMENTATION

This section discusses the implementation of a sampling plan for the collection of a "solid waste," as defined by Section 261.2 of the Resource Conservation and Recovery Act (RCRA) regulations. Due to the uniqueness of each sampling effort, the following discussion is in the general form of guidance which, when applied to each sampling effort, should improve and document the quality of the sampling and the representativeness of samples.

The following subsections address elements of a sampling effort in a logical order, from defining objectives through compositing samples prior to analysis.

9.2.1 Definition Of Objectives

After verifying the need for sampling, those personnel directing the sampling effort should define the program's objectives. The need for a sampling effort should not be confused with the objective. When management, a regulation, or a regulatory agency requires sampling, the need for sampling is established but the objectives must be defined.

The primary objective of any waste sampling effort is to obtain information that can be used to evaluate a waste. It is essential that the specific information needed and its uses are defined in detail at this stage. The information needed is usually more complex than just a concentration of a specified parameter; it may be further qualified (e.g., by sampling location or sampling time.) The manner in which the information is to be used can also have a substantial impact on the design of a sampling plan. (Are the data to be used in a qualitative or quantitative manner? If quantitative, what are the accuracy and precision requirements?)

All pertinent information should be gathered. For example, if the primary objective has been roughly defined as "collecting samples of waste which will be analyzed to comply with environmental regulations," then ask the following questions:

1. The sampling is being done to comply with which evironmental regulation? Certain regulations detail specific or minimum protocols (e.g., exclusion petitions as defined in §260.22 of the RCRA regulations); the sampling effort must comply with these regulatory requirements.

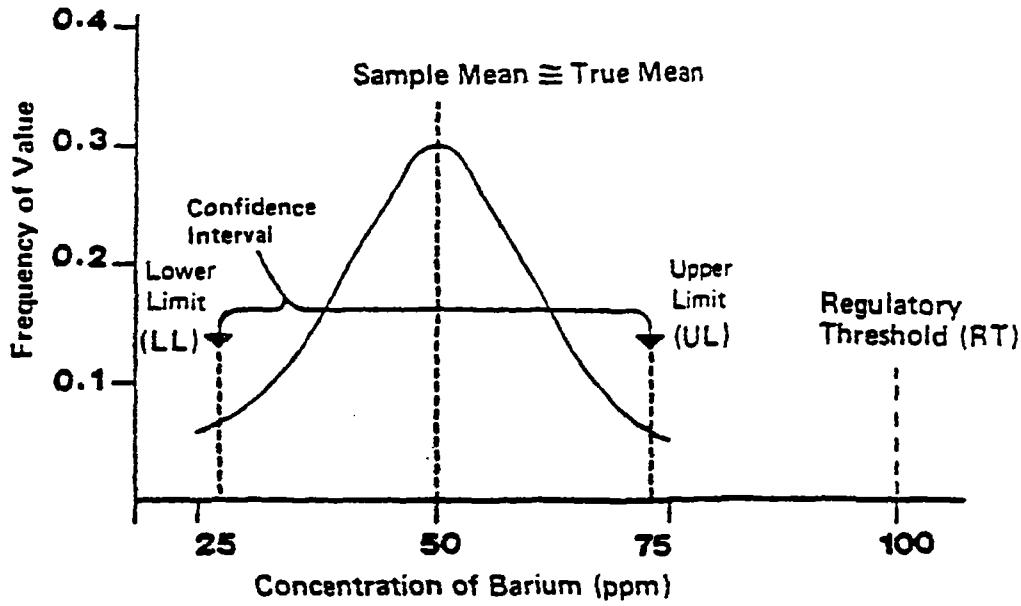
2. The collected samples are to be analyzed for which parameters? Why those and not others? Should the samples be analyzed for more or fewer parameters?

3. What waste is to be sampled: the waste as generated? the waste prior to or after mixing with other wastes or stabilizing agents? the waste after aging or drying or just prior to disposal? Should waste disposed of 10 years ago be sampled to acquire historical data?

4. What is the end-use of the generated data base? What are the required degrees of accuracy and precision?

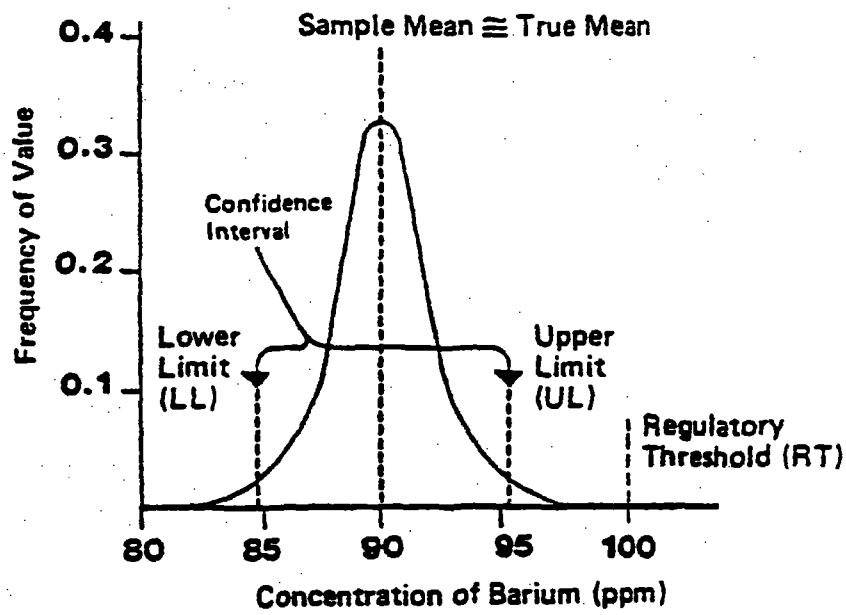
By asking such questions, both the <u>primary</u> objective and <u>specific</u> sampling, analytical, and data objectives can be established.

Two sampling efforts could have identical primary objectives but different specific objectives. For example, consider two situations in which the primary objective is to determine if the concentration of barium is less than the regulatory threshold of 100 ppm. The specific objectives will vary and have a substantial effect on sampling. (This situation is presented graphically in Figures 9-3 and 9-4.) In Figure 9-3, under the assumption that the true distribution of barium concentrations throughout the waste of interest is as shown, limited information has indicated that the average concentration is approximately 50 ppm. In Figure 9-4, assume that historical data indicated an average concentration of 90 ppm and the true distribution of barium concentrations is as shown. Therefore, the specific data objective for the latter case is to generate a data base that can discriminate between 90 and 100 ppm, whereas in the former case the data objective is to discriminate between 50 and 100 ppm. Greater accuracy and precision are required to discriminate between 90 and 100 ppm; this fact will affect the number, size, and degree of compositing of samples collected and analyzed.



Distance of true value from regulatory threshold requires less accuracy and precision.

Figure 9-3. Distribution of barium concentration removed from a regulatory threshold.



Proximity of true value from regulatory threshold requires more accuracy and precision.

Figure 9-4. Distribution of barium concentration near a regulatory threshold.

The form in Figure 9-5 can be used to document primary and specific objectives prior to development of a sampling plan. Once the objectives of a sampling effort are developed, it is important to adhere to them to ensure that the program maintains its direction.

9.2.2 Sampling Plan Considerations

The sampling plan is usually a written document that describes the objectives and details the individual tasks of a sampling effort and how they will be performed. (Under unusual circumstances, time may not allow for the sampling plan to be documented in writing, e.g., sampling during an emergency spill. When operating under these conditions, it is essential that the person directing the sampling effort be aware of the various elements of a sampling plan.) The more detailed the sampling plan, the less the opportunity for oversight or misunderstanding during sampling, analysis, and data treatment.

To ensure that the sampling plan is designed properly, it is wise to have all aspects of the effort represented. Those designing the sampling plan should include the following personnel:

1. An end-user of the data, who will be using the data to attain program objectives and thus would be best prepared to ensure that the data objectives are understood and incorporated into the sampling plan.

2. An experienced member of the field team who will actually collect samples, who can offer hands-on insight into potential problems and solutions, and who, having acquired a comprehensive understanding of the entire sampling effort during the design phase, will be better prepared to implement the sampling plan.

3. An analytical chemist, because the analytical requirements for sampling, preservation, and holding times will be factors around which the sampling plan will be written. A sampling effort cannot succeed if an improperly collected or preserved sample or an inadequate volume of sample is submitted to the laboratory for chemical, physical, or biological testing. The appropriate analytical chemist should be consulted on these matters.

4. An engineer should be involved if a complex manufacturing process is being sampled. Representation of the appropriate engineering discipline will allow for the optimization of sampling locations and safety during sampling and should ensure that all waste-stream variations are accounted for.

5. A statistician, who will review the sampling approach and verify that the resulting data will be suitable for any required statistical calculations or decisions.

6. A quality assurance representative, who will review the applicability of standard operating procedures and determine the number of blanks, duplicates, spike samples, and other steps required to document the accuracy and precision of the resulting data base.

Sampling Site: _____

_____

_____

Address: _____

_____

_____

Description of Waste to be Sampled: _____

_____

_____

Primary Objective: _____

_____

_____

Specific Sampling Objectives: _____

_____

_____

Specific Analysis Objectives: _____

_____

_____

Specific Data Objectives: _____

_____

_____

Figure 9-5. Form for Documenting Primary and Specific Objectives

At least one person should be familiar with the site to be sampled. If not, then a presampling site visit should be arranged to acquire site-specific information. If no one is familiar with the site and a presampling site visit cannot be arranged, then the sampling plan must be written so that it can address contingencies that may occur.

Even in those cases in which a detailed sampling plan is authored and a comprehensive knowledge of the site exists, it is unusual for a sampling plan to be implemented exactly as written. Waste-stream changes, inappropriate weather, sampling equipment failure, and problems in gaining access to the waste are some reasons why a sampling plan must be altered. Thus it is always necessary to have at least one experienced sampler as a member of a sampling team.

The sampling plan should address the considerations discussed below.

9.2.2.1 Statistics

A discussion of waste sampling often leads to a discussion of statistics. The goals of waste sampling and statistics are identical, i.e., to make inferences about a parent population based upon the information contained in a sample.

Thus it is not surprising that waste sampling relies heavily upon the highly developed science of statistics and that a sampling/analytical effort usually contains the same elements as does a statistical experiment. Analogously, the Harris pollster collects opinions from randomly chosen people, whereas environmental scientists collect waste at randomly chosen locations or times. The pollster analyzes the information into a useable data base; laboratories analyze waste samples and generate data. Then the unbiased data base is used to draw inferences about the entire population, which for the Harris pollster may be the voting population of a large city, whereas for the environmental scientist the population may mean the entire contents of a landfill.

During the implementation of a waste sampling plan or a statistical experiment, an effort is made to minimize the possibility of drawing incorrect inferences by obtaining samples that are representative of a population. In fact, the term "representative sample" is commonly used to denote a sample that (1) has the properties and chemical composition of the population from which it was collected, and (2) has them in the same average proportions as are found in the population.

In regard to waste sampling, the term "representative sample" can be misleading unless one is dealing with a homogeneous waste from which one sample can represent the whole population. In most cases, it would be best to consider a "representative data base" generated by the collection and analysis of more than one sample that defines the average properties or composition of the waste. A "representative data base" is a more realistic term because the evaluation of most wastes requires numerous samples to determine the average properties or concentrations of parameters in a waste. (The additional samples needed to generate a representative data base can also be used to determine the variability of these properties or concentrations throughout the waste population.)

Statisticians have developed a number of strategies to obtain samples that are unbiased and collectively representative of a population. A detailed discussion of these strategies is presented in Section 9.1 of this chapter. The following discussion of statistical considerations is a less technical summary of these strategies. It was written to complement Section 9.1 and will be most useful after Section 9.1 is read and studied.

Section 9.1 describes three basic sampling strategies: simple random, stratified random, and systematic random sampling. It should be noted that the word random has more than one meaning. When used in statistical discussions, it does not mean haphazard; it means that every part of a waste has a theoretically equal chance of being sampled. Random sampling, which entails detailed planning and painstaking implementation, is distinctly different from haphazard sampling, which may introduce bias into the collection of samples and the resulting data.

Systematic random sampling and authoritative sampling strategies require a substantial knowledge of the waste to ensure that: (1) a cycle or trend in waste composition does not coincide with the sampling locations; or (2) in the case of authoritative sampling, all or most of the assumptions regarding waste composition or generation are true. Because the variabilities of waste composition and the waste generation process are often unknown, systematic random and authoritative sampling strategies are usually not applicable to waste evaluation.

Therefore, for waste sampling, the usual options are simple or stratified random sampling. Of these two strategies, simple random sampling is the option of choice unless: (1) there are known distinct strata (divisions) in the waste over time or in space; (2) one wants to prove or disprove that there are distinct time and/or space strata in the waste of interest; or (3) one is collecting a minimum number of samples and desires to minimize the size of a hot spot (area of high concentration) that could go unsampled. If any of these three conditions exists, it may be determined that stratified random sampling would be the optimum strategy. To explain how these strategies can be employed, a few examples follow:

Example 1: Simple Random Sampling of Tanks

A batch manufacturing process had been generating a liquid waste over a period of years and storing it in a large open-top tank. As this tank approached capacity, some of the waste was allowed to overflow to a smaller enclosed tank. This smaller tank allowed for limited access through an inspection port on its top.

Because the on-site tank storage was approaching capacity, it was determined that the waste would have to be disposed of off-site.

The operators of the facility had determined that the waste was a nonhazardous solid waste when the RCRA regulations were first promulgated. However, upon recent passage of more stringent state regulations and concerns of potential liability, the operators determined that they should perform a more comprehensive analysis of the waste.

Because the waste was generated in a batch mode over a period of years, the operators were concerned that the waste composition might have varied between batches and that stratification might have occurred in the tank at unknown and random depths. Based on their knowledge, the operators knew that a grab sample would not suffice and that a sampling program would have to be designed to address the heterogeneity of the waste.

Because the operators intended to dispose of the entire contents of the tank and lacked any specific information regarding stratification and variability of the waste, it was decided that a simple random strategy would be employed. (If the operators had treated portions of the waste differently or had been aware of distinct strata, then stratified random sampling might have been more appropriate.)

The large, unenclosed tank had a diameter of 50 ft, a height of 20 ft, and an approximate volume of 295,000 gal allowed. It was encircled and traversed by catwalks (refer to Figure 9-6), which allowed access to the entire waste surface. The smaller tank had a diameter of 10 ft, a height of 10 ft, and an approximate volume of 6,000 gal; an inspection port located on the top allowed limited access. It was determined that the different construction of the two tanks would require different simple random sampling approaches.

In the case of the large tank, it was decided that vertical composite samples would be collected because the operators were interested in the average composition and variability of the waste and not in determining if different vertical strata existed. It was decided to select points randomly along the circumference (157 ft) and along the radius (25 ft). These numbers, which would constitute the coordinates of the sampling locations, were chosen from a random-number table by indiscriminately choosing a page and then a column on that page. The circumference coordinates were then chosen by proceeding down the column and listing the first 15 numbers that are greater than or equal to 0, but less than or equal to 157. The radius coordinates were chosen by continuing down the column and listing the first 15 numbers that are greater than or equal to 0, but less than or equal to 25. These numbers were paired to form the coordinates that determined the location of the 15 randomly chosen sampling points. These coordinates were recorded in the field notebook (refer to Table 9-3). Because no precision data on waste composition existed prior to sampling, the number of samples (15) was chosen as a conservative figure to more than allow for a sound statistical decision.

The actual samples were collected by employing a sampling device, which was constructed on site from available materials, and a weighted bottle. This device, which was used to access more remote areas of the tank, consisted of a weighted bottle, a rope marked off at 1-ft increments, and a discarded spool that originally contained electrical wire (refer to Figure 9-7).

Samples were collected by a three-person team. The person controlling the weighted bottle walked to the first circumference coordinate (149 ft), while the two persons holding the ropes attached to the spool walked along opposing catwalks toward the center of the tank. The person controlling the

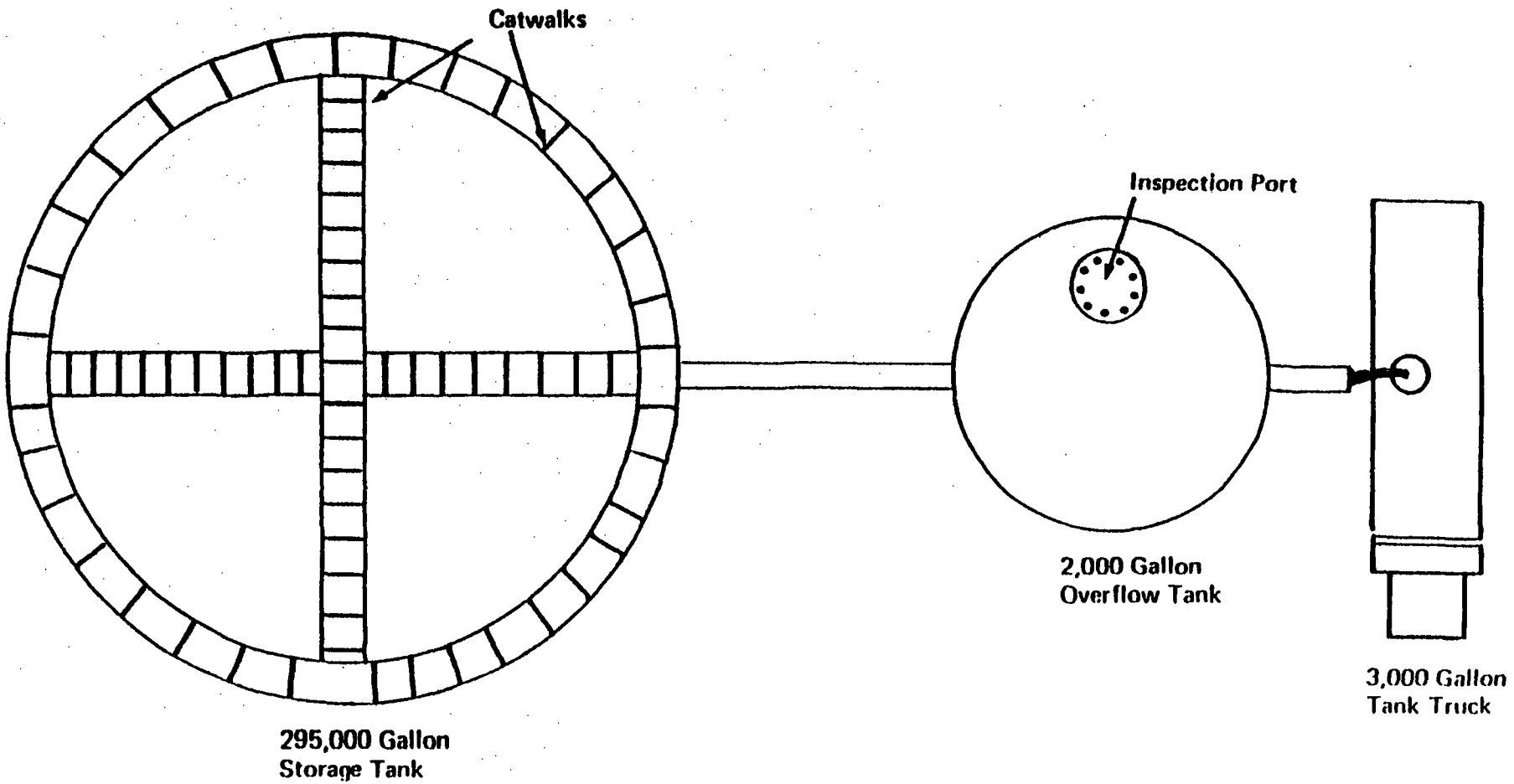


Figure 9-6. Bird's eye view of waste tank, overflow tank, tank truck and connecting plumbing.

TABLE 9-3. RANDOM COORDINATES FOR 295,000-GAL TANK

Sampling point	Circumference	Radius
1	149	4
2	86	22
3	94	13
4	99	0
5	23	10
6	58	2
7	52	22
8	104	16
9	23	25
10	51	4
11	77	14
12	12	5
13	151	15
14	83	23
15	99	18

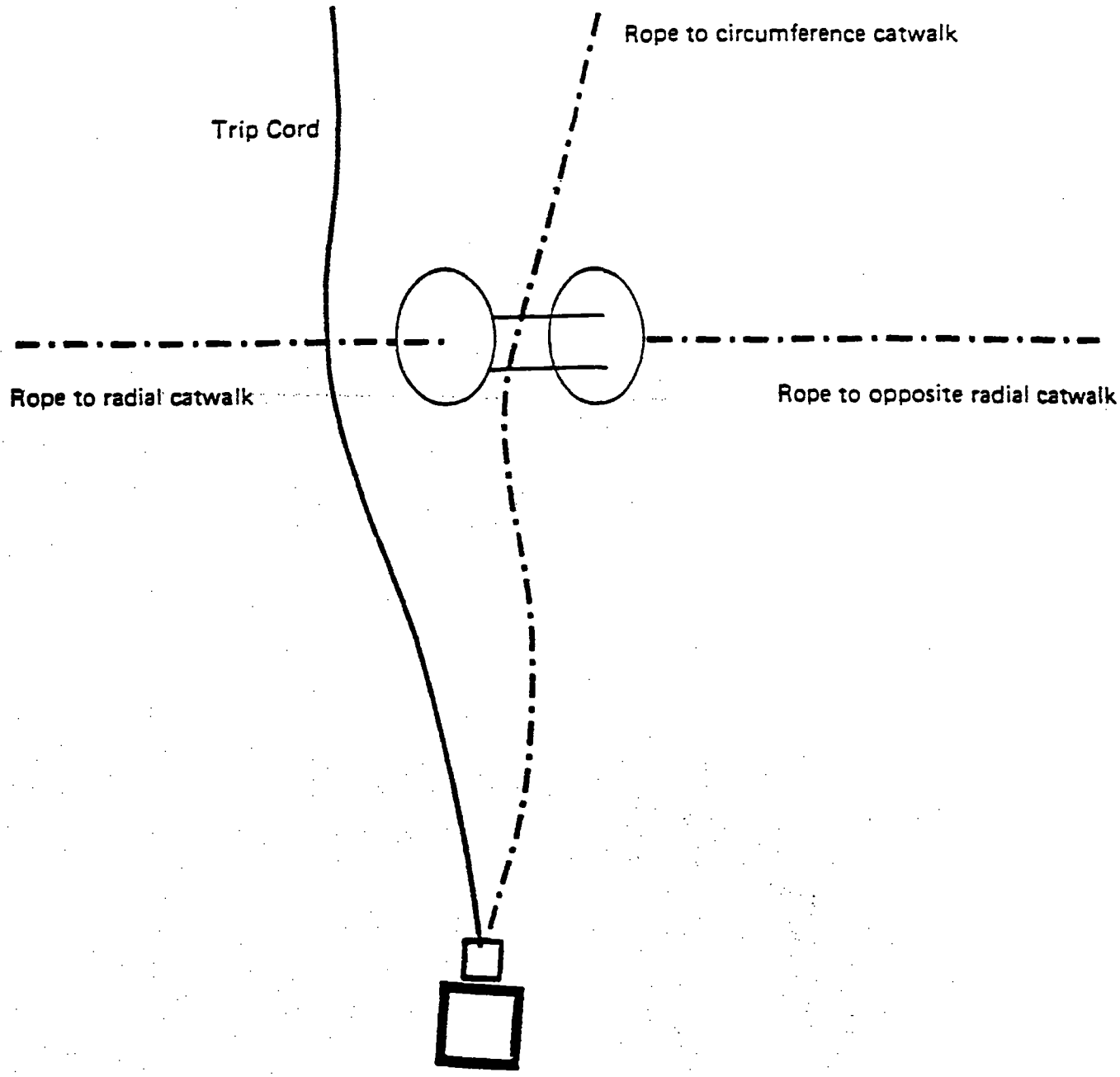


Figure 9-7. Device used to collect sample from the open tank.

weighted bottle measured off the radius coordinate (4 ft). The spool was then centered in the quadrant, the weighted bottle was lowered to the surface, and a sample was collected from the first 2 ft of waste. This sample was then transferred into a large, labeled sample container, which was used for compositing. This same process was repeated nine more times at the same location at different 2-ft depth intervals, resulting in the collection of a total of 10 component depth samples that were compiled in the field into one sample for that sampling point. This process was repeated at the remaining 14 sampling points, resulting in the collection of 15 vertical composite samples. These vertical composite samples were taken to address any vertical stratification that may have occurred.

The samples were properly preserved and stored, chain-of-custody procedures were completed, and the samples were submitted to the laboratory. A cost/benefit decision was made to composite aliquots of the samples into five composite samples that were submitted for analysis. (Following analysis, Equation 8 of Section 9.1 of this chapter was employed to determine if enough samples were analyzed to make a statistically sound decision. If the number of samples analyzed was not sufficient, then the samples would be recomposited to a lesser degree or analyzed individually.)

Because there was no information to prove that the waste in the smaller tank was the same as that in the larger tank, the operators decided that the smaller tank must also be sampled. The different construction of the smaller, enclosed tank mandated that a different sampling plan be designed. The only access to the tank was through a small inspection port on the top of the tank. This port would allow sampling only of a small portion of the tank contents; thus, to make a decision on the entire contents of the tank, one would have to assume that the waste in the vicinity of the inspection port was representative of the remainder of the tank contents. The operators were not willing to make this assumption because they determined that the liability of an incorrect decision overrode the convenience of facilitating the sampling effort.

To randomly sample the entire contents of the tank, a different plan was designed. This plan exploited the relatively small volume (approximately 6,000 gal) of the tank. A decision was made to rent two tank trucks and to sample the waste randomly over time as it drained from the tank into the tank trucks.

It was calculated that at a rate of 20 gal/min, it would take 300 min to drain the tank. From the random-number tables, 15 numbers that were greater than or equal to 0, but less than or equal to 300, were chosen in a manner similar to that employed for the larger tank. These numbers were recorded in the field notebook (refer to Table 9-4) at the time that they were encountered in the random-number table and were then assigned sampling point numbers according to their chronological order.

The 15 samples were collected at the previously chosen random times as the waste exited from a drainage hose into the tank trucks. These samples were collected in separate labeled containers, properly preserved and stored; chain-of-custody procedures were employed for transferral of the samples to the laboratory.

TABLE 9-4. RANDOM TIMES FOR 6,000-GAL TANK

Sampling point	Time (min)
11	153
10	122
8	85
6	55
5	46
15	294
12	195
1	5
13	213
9	99
2	29
4	41
7	74
3	31
14	219

The above example employed simple random sampling to determine the average composition and variance of the waste contained in the two tanks. The contents of the large tank were sampled randomly in space, whereas the contents of the smaller tank were sampled randomly over time.

The following example will involve the use of stratified random sampling, which is used when: (1) distinct strata are known to exist or (2) it is not known whether different strata exist, but an objective of the sampling effort is to discover the existence or nonexistence of strata.

A variation of this second reason for employing stratified random sampling is when cost considerations limit the number of samples that can be collected (e.g., when the budget allows for the collection of only six samples in a 40-acre lagoon). In this situation, where little is known about the composition of the waste, a concern exists that an area of the lagoon may be highly contaminated and yet may not be sampled. The smaller the number of samples, the greater the probability that an area of high contamination (a distinct stratum) could be missed, and the greater the probability that the sampling accuracy will suffer. Under such circumstances, a sampling plan may employ stratified random sampling to minimize the size of a highly contaminated area that could go unsampled.

For example, consider the situation where the budget allows only for the collection of six samples in a 40-acre lagoon. If simple random sampling is employed with such a small number of samples, there is a certain probability that large areas of the lagoon may go unsampled. One approach to minimizing the size of areas that may go unsampled is to divide the lagoon into three strata of equal size and randomly sample each stratum separately. This approach decreases the size of an area that can go unsampled to something less than one-third of the total lagoon area.

The following example details more traditional applications of stratified random sampling.

Example 2: Stratified Random Sampling of Effluents and Lagoons

A pigment manufacturing process has been generating wastes over a number of years. The pigment is generated in large batches that involve a 24-hr cycle. During the first 16 hr of the cycle, an aqueous sludge stream is discharged. This waste contains a high percentage of large-sized black particulate matter. The waste generated during the remaining 8 hr of the manufacturing cycle is an aqueous-based white sludge that consists of much smaller-sized particles than those found in the sludge generated in the first 16 hr of the batch process. This waste has been disposed of over the years into a 40-acre settling lagoon, allowing the particulate matter to settle out of solution while the water phase drains to an NPDES outfall at the opposite end of the lagoon. The smaller white pigment particles released in the last 8 hr of the batch process settle more slowly than the much larger black particles generated in the previous 16 hr. This settling pattern is quite apparent from the distinct colors of the wastes. The sludge in the quadrant closest to the waste influent pipe is black; the next quadrant is a light gray color, resulting from settling of both waste streams. The last two quadrants contain a pure white sludge, resulting from the settling of the small pigment particles.

Eventually, the facility operators decided that the settled particulate matter had to be removed to keep the settling lagoon functioning. In the past, this residual lagoon waste was found to be a hazardous waste due to its leachable barium content. Further studies determined that the source of the barium was a certain raw material that was released during the first 16 hr of batch process.

To minimize present disposal costs, the operators wanted to determine if the white sludge in the last two quadrants and the light gray waste were nonhazardous. Also, the operators had recently changed raw materials, with the intention of removing the source of barium in an attempt to minimize future disposal costs. Thus, the operators were interested in determining whether the currently generated waste was hazardous. If the altered waste stream was not hazardous, future lagoon sludge could be disposed of more economically as a solid waste. If the waste generated during the first 16 hr of the process remained hazardous but the waste generated during the following 8 hr was nonhazardous, the operators were willing to shift this latter waste to a second lagoon reserved for nonhazardous wastes. By sequestering the waste streams in this manner, the operators intended to decrease the amount of hazardous waste by precluding generation of additional amounts of hazardous waste under the "mixture rule."

To decide how the lagoon sludge should be handled, the operators arranged to have the lagoon sludge sampled. The objectives of sampling the lagoon sludge were to determine the average concentration and variance of leachable barium for the sludge in the entire lagoon and for each of the different sludges.

The dimensions of the 40-acre square lagoon were calculated to be 1,320 ft on a side, with the black and the gray sludge each covering a quadrant measuring 1,320 ft by 330 ft, and the white sludge covering the remaining area of the lagoon, which measured 1,320 ft by 660 ft (refer to Figure 9-8). The sludge had settled to a uniform thickness throughout the lagoon and was covered with 2 ft of water.

Because the leachable barium was assumed to be associated with the black sludge, which was concentrated in the first quadrant, a stratified random sampling approach was chosen. (Because of the obvious strata in the lagoon sludge, the stratified sampling strategy was expected to give a more precise estimate of the leachable barium, in addition to giving information specific to each stratum.)

When the actual sampling was being planned, it was decided that the hazards presented by the lagoon waste were minimal, and, that if proper precautions were employed, a stable and unsinkable boat could be used to collect samples. The samples were collected with a core sampler at random locations throughout each stratum. Because the cost of collecting samples was reasonable and no historical data were available to help determine the optimum number of samples, the operators decided to collect a total of 10 samples from each of the smaller strata and a total of 20 samples from the larger strata. They had confidence that this number of samples would allow them to detect a small significant difference between the mean concentration of leachable barium and the applicable regulatory threshold.

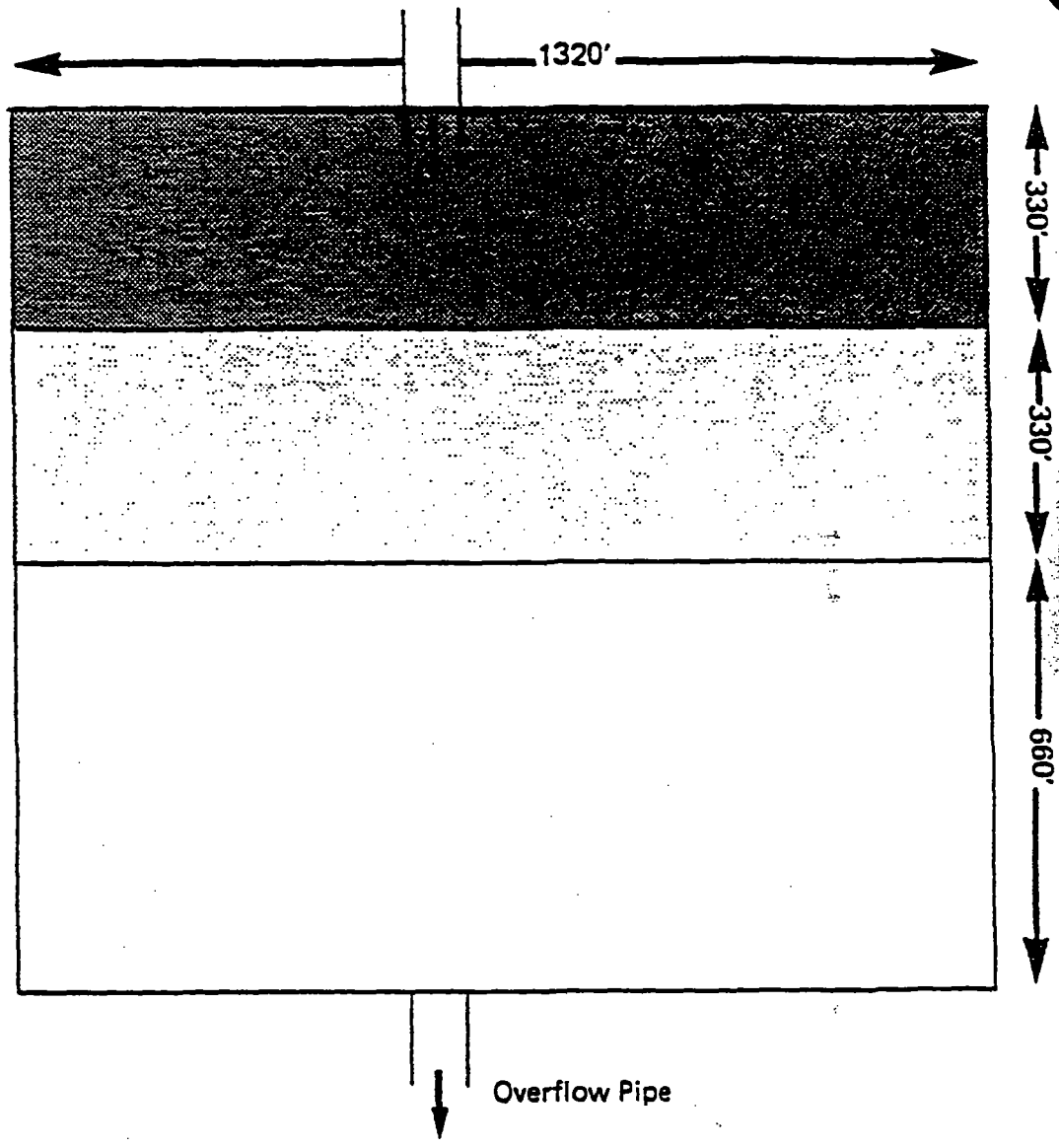


Figure 9-8. Schematic of the 40-acre settling lagoon displaying strata generated by a waste stream.

The locations of the random sampling points were determined by selecting length and width coordinates from a random-number table. This was done by indiscriminately choosing a page from the random-number tables and then a column on that page. The width coordinates of the two smaller quadrants were then chosen by proceeding down the column and listing the first 20 numbers that were greater than or equal to 0, but less than or equal to 330. The width coordinate for the third and largest stratum was chosen by proceeding down the column and selecting the first 20 numbers that were greater than or equal to 0, but less than or equal to 660. Because the lengths of the three quadrants were all 1,320 ft, the length coordinates were chosen by listing the first 40 numbers that were greater than or equal to 0 but less than or equal to 1,320. These coordinates were recorded in the field notebook (refer to nable 9-5).

The samples were collected by a four-person team. Two people remained onshore while two maneuvered the boat and collected the samples. The first sample in the first quadrant was collected by launching the boat at a distance of 41 ft from the corner, which was designated the origin, 0 ft. The boat proceeded out into the lagoon perpendicular to the long side of the quadrant. The person onshore released 134 ft of a measured rope, which allowed the boat to stop at the first sampling point (41, 134). The sample was then collected with a core sampler and transferred to a sample container. This process was repeated for all sampling points in the three strata. The samples were properly preserved and stored, and the chain-of-custody records documented the transfer of samples to the laboratory.

Aliquots of the samples were composited into five composite samples for each stratum. The mean and variance of each stratum were calculated by Equations 2(a) and 3(a), respectively. The mean and variance for the total lagoon were calculated by using Equations 2(b) and 3(b), respectively. Equation 6 was used to calculate a confidence interval for the leachable barium concentration, and the upper limit of this interval was compared with the regulatory threshold. (See Table 9-1, Section 9.1 of this chapter, for equations.)

As previously mentioned, the operators had recently changed their raw materials and were also interested in discovering if the currently generated waste was nonhazardous or if portions of this waste stream were nonhazardous. As described above, the waste effluent for the first 16 hr of the day was different from that discharged during the last 8 hr. However, because the same large plumbing system was used for both waste streams, there were two 2-hr periods during which the discharged waste was a mixture of the two different wastes.

With the above objectives in mind, the operators decided to employ stratified random sampling with four strata occurring over time, as opposed to the strata in space that were employed for sampling the lagoon. The four time strata were from 6:00 to 8:00 hr, from 8:00 to 20:00 hr, from 20:00 to 22:00 hr, and from 22:00 to 6:00 hr the following day. The two 2-hr strata were those time periods during which the waste was a mixture of the two different waste streams. The 12-hr stratum was the time period during which the large-sized particulate black waste was being discharged. The smaller particulate white waste was being discharged during the 8-hr stratum.

TABLE 9-5. RANDOM COORDINATES FOR EACH STRATUM IN THE 40-ACRE SETTLING LAGOON

	Sampling Point	Length (ft)	Width (ft)
Stratum #1 (Black)	1	41	134
	2	271	51
	3	968	32
	4	129	228
	5	472	137
	6	1,198	56
	7	700	261
	8	286	8
	9	940	26
	10	151	121
Stratum #2 (Gray)	1	1,173	109
	2	277	2
	3	438	302
	4	780	5
	5	525	135
	6	50	37
	7	26	127
	8	1,207	149
	9	1,231	325
	10	840	32
Stratum #3 (White)	1	54	374
	2	909	434
	3	1,163	390
	4	1,251	449
	5	1	609
	6	1,126	140
	7	717	235
	8	1,155	148
	9	668	433
	10	66	642
	11	462	455
	12	213	305
	13	1,220	541
	14	1,038	644
	15	508	376
	16	1,293	270
	17	30	38
	18	114	52
	19	1,229	570
	20	392	613

The flow rate was constant throughout the 24-hr period, and there were no precision data available for the waste. Therefore, it was decided that the number of samples collected in the 8- and 12-hr strata would be proportional to time. Because the 2-hr periods were times during which the composition of the waste was changing, it was decided to collect more samples to get a more precise estimate of the average composition of the waste during these time strata. Thus a total of 28 samples was collected.

The samples were collected at randomly chosen times within each time stratum. The random sampling times were chosen by employing a random-number table. After indiscriminately selecting a starting point, the first four numbers greater than or equal to 0, but less than or equal to 120 were selected for the 120-min strata from 6:00 to 8:00 hr. These minutes were then added to the starting time to determine when the four samples would be collected. In similar fashion, the remaining 24 sampling times were chosen. The random-number data were recorded in a laboratory notebook (refer to Table 9-6).

The samples were collected from the waste influent pipe with a wide-mouth bottle at the randomly chosen sampling times. The samples were properly preserved and stored and shipped to the laboratory, along with chain-of-custody records. The samples were subjected to analysis, and the data were evaluated in a manner similar to that employed for the samples of sludge collected in the different strata of the lagoon.

9.2.2.2 Waste

The sampling plan must address a number of factors in addition to statistical considerations. Obviously, one of the most important factors is the waste itself and its properties. The following waste properties are examples of what must be considered when designing a sampling plan:

1. Physical state: The physical state of the waste will affect most aspects of a sampling effort. The sampling device will vary according to whether the sample is liquid, gas, solid, or multiphasic. It will also vary according to whether the liquid is viscous or free-flowing, or whether the solid is hard or soft, powdery, monolithic, or clay-like.

   Wide-mouth sample containers will be needed for most solid samples and for sludges or liquids with substantial amounts of suspended matter. Narrow-mouth containers can be used for other wastes, and bottles with air-tight closures will be needed for gas samples or gases adsorbed on solids or dissolved in liquids.

   The physical state will also affect how sampling devices are deployed. A different plan will be developed for sampling a soil-like waste that can easily support the weight of a sampling team and its equipment than for a lagoon filled with a viscous sludge or a liquid waste.

TABLE 9-6. RANDOM TIMES FOR THE WASTE EFFLUENT

	Sampling Point	Random Minute	Time
Stratum #1 (6:00 to 8:00 hours)	1	28	6:28
	2	62	7:02
	3	99	7:39
	4	112	7:52
Stratum #2 (8:00 to 20:00 hours)	1	11	8:11
	2	107	9:47
	3	156	10:36
	4	173	10:53
	5	296	12:56
	6	313	13:13
	7	398	14:38
	8	497	16:17
	9	555	17:15
	10	600	18:00
	11	637	18:37
	12	706	19:46
Stratum #3 (20:00 to 22:00 hours)	1	13	20:13
	2	52	20:52
	3	88	21:28
	4	108	21:48
Stratum #4 (22:00 to 6:00 hours	1	48	22:48
	2	113	23:53
	3	153	24:33
	4	189	1:09
	5	227	1:47
	6	290	2:49
	7	314	3:14
	8	474	5:44

The sampling strategy will have to vary if the physical state of the waste allows for stratification (e.g., liquid wastes that vary in density or viscosity or have a suspended solid phase), homogenization or random heterogeneity.

2. Volume: The volume of the waste, which has to be represented by the samples collected, will have an effect upon the choice of sampling equipment and strategies. Sampling a 40-acre lagoon requires a different approach from sampling a 4-sq-ft container. Although a 3-ft depth can be sampled with a Coliwasa or a drum thief, a weighted bottle may be required to sample a 50-ft depth.

3. Hazardous properties: Safety and health precautions and methods of sampling and shipping will vary dramatically with the toxicity, ignitability, corrosivity, and reactivity of the waste.

4. Composition: The chosen sampling strategy will reflect the homogeneity, random heterogeneity, or stratification of the waste in time or over space.

9.2.2.3 Site

Site-specific factors must be considered when designing a sampling plan. A thorough examination of these factors will minimize oversights that can affect the success of sampling and prevent attainment of the program objectives. At least one person involved in the design and implementation of the sampling plan should be familiar with the site, or a presampling site visit should be arranged. If nobody is familiar with the site and a visit cannot be arranged, the sampling plan must be written to account for the possible contingencies. Examples of site-specific factors that should be considered follow:

1. Accessibility: The accessibility of waste can vary substantially. Some wastes are accessed by the simple turning of a valve; others may require that an entire tank be emptied or that heavy equipment be employed. The accessibility of a waste at the chosen sampling location must be determined prior to design of a sampling plan.

2. Waste generation and handling: The waste generation and handling process must be understood to ensure that collected samples are representative of the waste. Factors which must be known and accounted for in the sampling plan include: if the waste is generated in batches; if there is a change in the raw materials used in a manufacturing process; if waste composition can vary substantially as a function of process temperatures or pressures; and if storage time after generation may vary.

3. Transitory events: Start-up, shut-down, slow-down, and maintenance transients can result in the generation of a waste that is not representative of the normal waste stream. If a sample was unknowingly collected at one of these intervals, incorrect conclusions could be drawn.

4. Climate: The sampling plan should specify any clothing needed for personnel to accommodate any extreme heat or cold that may be encountered. Dehydration and extensive exposure to sun, insects, or poisonous snakes must be considered.

5. Hazards: Each site can have hazards -- both expected and unexpected. For example, a general understanding of a process may lead a sampling team to be prepared for dealing with toxic or reactive material, but not for dealing with an electrical hazard or the potential for suffocation in a confined space. A thorough sampling plan will include a health and safety plan that will counsel team members to be alert to potential hazards.

9.2.2.4 Equipment

The choice of sampling equipment and sample containers will depend upon the previously described waste and site considerations. For the following reasons, the analytical chemist will play an important role in the selection of sampling equipment:

1. The analytical chemist is aware of the potential interactions between sampling equipment or container material with analytes of interest. As a result, he/she can suggest a material that minimizes losses by adsorption, volatilization, or contamination caused by leaching from containers or sampling devices.

2. The analytical chemist can specify cleaning procedures for sampling devices and containers that minimize sample contamination and cross contamination between consecutive samples.

3. The analytical chemist's awareness of analyte-specific properties is useful in selecting the optimum equipment (e.g., choice of sampling devices that minimize agitation for those samples that will be subjected to analysis for volatile compounds).

The final choice of containers and sampling devices will be made jointly by the analytical chemist and the group designing the sampling plan. The factors that will be considered when choosing a sampling device are:

1. Negative contamination: The potential for the measured analyte concentration to be artificially low because of losses from volatilization or adsorption.

2. Positive contamination: The potential for the measured analyte to be artifically high because of leaching or the introduction of foreign matter into the sample by particle fallout or gaseous air contaminants.

3. Cross contamination: A type of positive contamination caused by the introduction of part of one sample into a second sample during sampling, shipping, or storage.

4. Required sample volume for physical and/or chemical analysis.

5. "Ease of use" of the sampling device and containers under the conditions that will be encountered on-site. This includes the ease of shipping to and from the site, ease of deployment, and ease of cleaning.

6. The degree of hazard associated with the deployment of one sampling device versus another.

7. Cost of the sampling device and of the labor for its deployment.

This section describes examples of sampling equipment and suggests potential uses for this equipment. Some of these devices are commercially available, but others will have to be fabricated by the user. The information in this section is general in nature and therefore limited.

Because each sampling situation is unique, the cited equipment and applications may have to be modified to ensure that a representative sample is collected and its physical and chemical integrity are maintained. It is the responsibility of those persons conducting sampling programs to make the appropriate modifications.

Table 9-7 contains examples of sampling equipment and potential applications. It should be noted that these suggested sampling devices may not be applicable to a user's situation due to waste- or site-specific factors. For example, if a waste is highly viscous or if a solid is clay-like, these properties may preclude the use of certain sampling devices. The size and depth of a lagoon or tank, or difficulties associated with accessing the waste, may also preclude use of a given device or require modification of its deployment.

The most important factors to consider when choosing containers for hazardous waste samples are compatibility with the waste, cost, resistance to breakage, and volume. Containers must not distort, rupture, or leak as a result of chemical reactions with consitituents of waste samples. Thus, it is important to have some idea of the properties and composition of the waste. The containers must have adequate wall thickness to withstand handling during sample collection and transport to the laboratory. Containers with wide mouths are often desirable to facilitate transfer of samples from samplers to containers. Also, the containers must be large enough to contain the optimum sample volume.

Containers for collecting and storing hazardous waste samples are usually made of plastic or glass. Plastics that are commonly used to make the containers include high-density or linear polyethylene (LPE), conventional polyethylene, polypropylene, polycarbonate, Teflon FEP (fluorinated ethylene propylene), polyvinyl chloride (PVC), or polymethylpentene. Teflon FEP is almost universally usable due to its chemical inertness and resistance to breakage. However, its high cost severely limits its use. LPE, on the other hand, usually offers the best combination of chemical resistance and low cost when samples are to be analyzed for inorganic parameters.

TABLE 9-7. EXAMPLES OF SAMPLING EQUIPMENT FOR PARTICULAR WASTE TYPES

	Waste location or container								
Waste type	Drum	Sacks and bags	Open-bed truck	Closed-bed truck	Storage tanks or bins	Waste piles	Ponds, lagoons, & pits	Conveyor belt	Pipe
Free-flowing liquids and slurries	Coliwasa	N/A	N/A	Coliwasa	Weighted bottle	N/A	Dipper	N/A	Dipper
Sludges	Trier	N/A	Trier	Trier	Trier	a	a		
Moist powders or granules	Trier	Trier	Trier	Trier	Trier	Trier	Trier	Shovel	Dipper
Dry powders or granules	Thief	Thief	Thief	Thief	a	Thief	Thief	Shovel	Dipper
Sand or packed powders and granules	Auger	Auger	Auger	Auger	Thief	Thief	a	Dipper	Dipper
Large-grained solids	Large Trier	Large Trier	Large Trier	Large Trier	Large Trier	Large Trier	Large Trier	Trier	Dipper

[a]This type of sampling situation can present significant logistical sampling problems, and sampling equipment must be specifically selected or designed based on site and waste conditions. No general statement about appropriate sampling equipment can be made.

Glass containers are relatively inert to most chemicals and can be used to collect and store almost all hazardous waste samples, exept those that contain strong alkali and hydrofluoric acid. Glass soda bottles are suggested due to their low cost and ready availability. Borosilicate glass containers, such as Pyrex and Corex, are more inert and more resistant to breakage than soda glass, but are expensive and not always readily available. Glass containers are generally more fragile and much heavier than plastic containers. Glass or FEP containers must be used for waste samples that will be analyzed for organic compounds.

The containers must have tight, screw-type lids. Plastic bottles are usually provided with screw caps made of the same material as the bottles. Buttress threads are recommended. Cap liners are not usually required for plastic containers. Teflon cap liners should be used with glass containers supplied with rigid plastic screw caps. (These caps are usually provided with waxed paper liners.) Teflon liners may be purchased from plastic specialty supply houses (e.g., Scientific Specialties Service, Inc., P.O. Box 352, Randallstown, Maryland 21133). Other liners that may be suitable are polyethylene, polypropylene, and neoprene plastics.

If the samples are to be submitted for analysis of volatile compounds, the samples must be sealed in air-tight containers.

Prior to sampling, a detailed equipment list should be compiled. This equipment list should be comprehensive and leave nothing to memory. The categories of materials that should be considered are:

1. Personnel equipment, which will include boots, rain gear, disposable coveralls, face masks and cartridges, gloves, etc.

2. Safety equipment, such as portable eyewash stations and a first-aid kit.

3. Field test equipment, such as pH meters and Draeger tube samplers.

4. An ample supply of containers to address the fact that once in the field, the sampling team may want to collect 50% more samples than originally planned or to collect a liquid sample, although the sampling plan had specified solids only.

5. Additional sampling equipment for use if a problem arises, e.g., a tool kit.

6. Shipping and office supplies, such as tape, labels, shipping forms, chain-of-custody forms and seals, field notebooks, random-number tables, scissors, pens, etc.

Composite Liquid Waste Sampler (Coliwasa)

The Coliwasa is a device employed to sample free-flowing liquids and slurries contained in drums, shallow tanks, pits, and similar containers. It is especially useful for sampling wastes that consist of several immiscible liquid phases.

The Coliwasa consists of a glass, plastic, or metal tube equipped with an end closure that can be opened and closed while the tube is submerged in the material to be sampled (refer to Figure 9-9).

Weighted Bottle

This sampler consists of a glass or plastic bottle, sinker, stopper, and a line that is used to lower, raise, and open the bottle. The weighted bottle samples liquids and free-flowing slurries. A weighted bottle with line is built to the specifications in ASTM Methods D270 and E300. Figure 9-10 shows the configuration of a weighted-bottle sampler.

Dipper

The dipper consists of a glass or plastic beaker clamped to the end of a two- or three-piece telescoping aluminum or fiberglass pole that serves as the handle. A dipper samples liquids and free-flowing slurries. Dippers are not available commercially and must be fabricated (Figure 9-11).

Thief

A thief consists of two slotted concentric tubes, usually made of stainless steel or brass. The outer tube has a conical pointed tip that permits the sampler to penetrate the material being sampled. The inner tube is rotated to open and close the sampler. A thief is used to sample dry granules or powdered wastes whose particle diameter is less than one-third the width of the slots. A thief (Figure 9-12) is available at laboratory supply stores.

Trier

A trier consists of a tube cut in half lengthwise with a sharpened tip that allows the sampler to cut into sticky solids and to loosen soil. A trier samples moist or sticky solids with a particle diameter less than one-half the diameter of the trier. Triers 61 to 100 cm long and 1.27 to 2.54 cm in diameter are available at laboratory supply stores. A large trier can be fabricated (see Figure 9-13).

Auger

An auger consists of sharpened spiral blades attached to a hard metal central shaft. An auger samples hard or packed solid wastes or soil. Augers are available at hardware and laboratory supply stores.

Scoops and Shovels

Scoops and shovels are used to sample granular or powdered material in bins, shallow containers, and conveyor belts. Scoops are available at laboratory supply houses. Flat-nosed shovels are available at hardware stores.

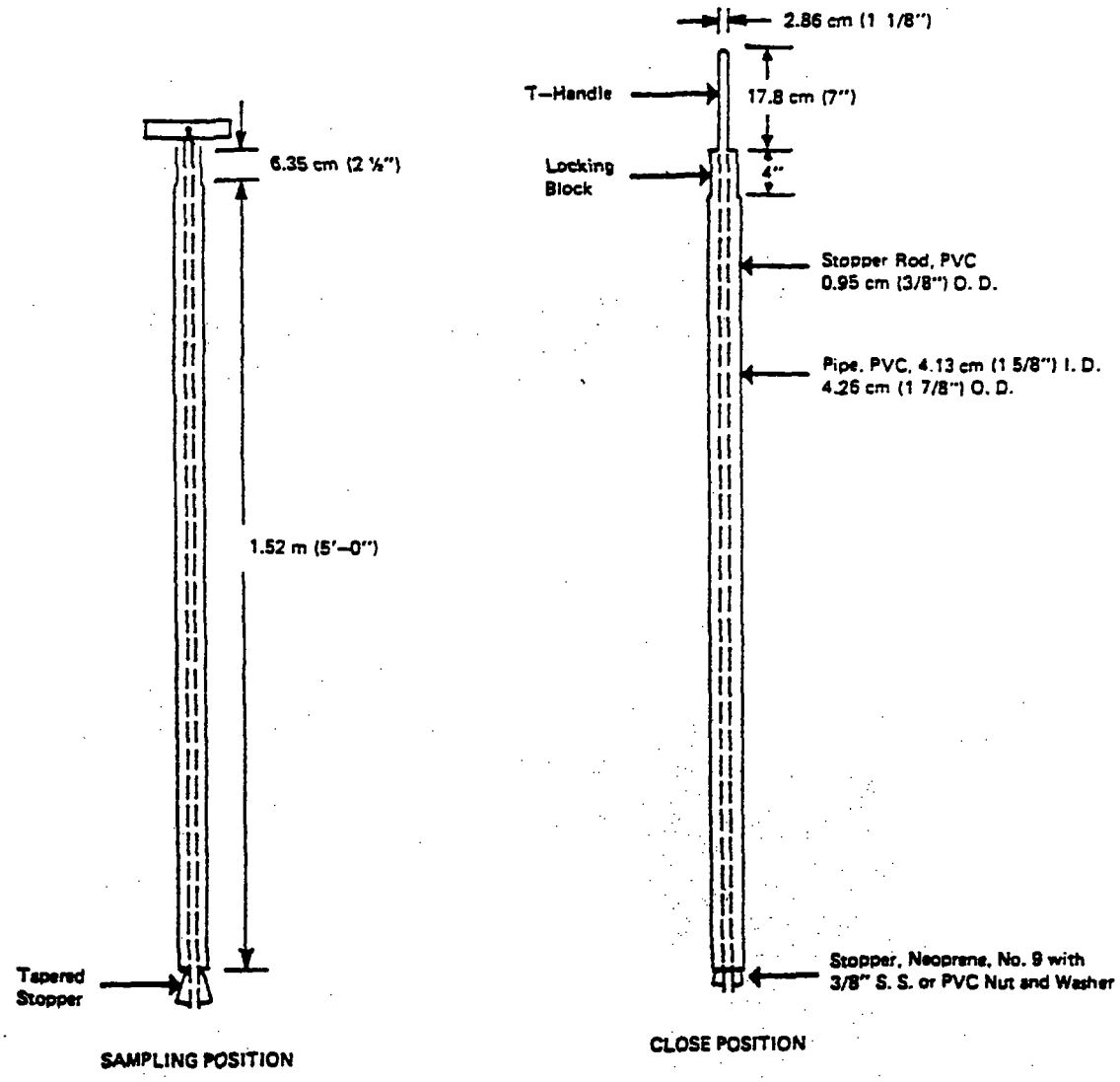


Figure 9-9. Composite liquid waste sampler (Coliwasa).

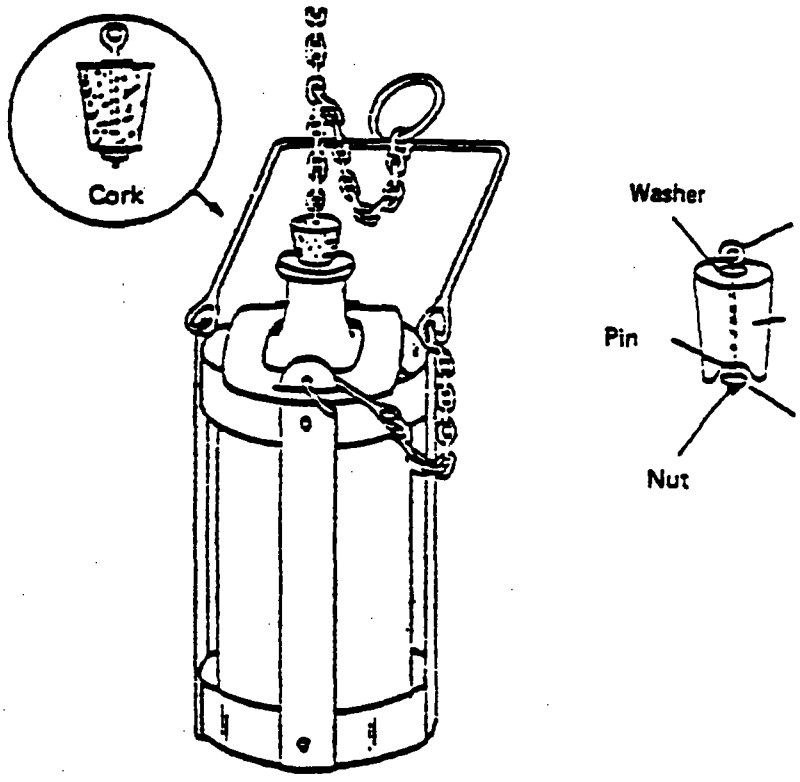


Figure 9-10. Weighted bottle sampler.

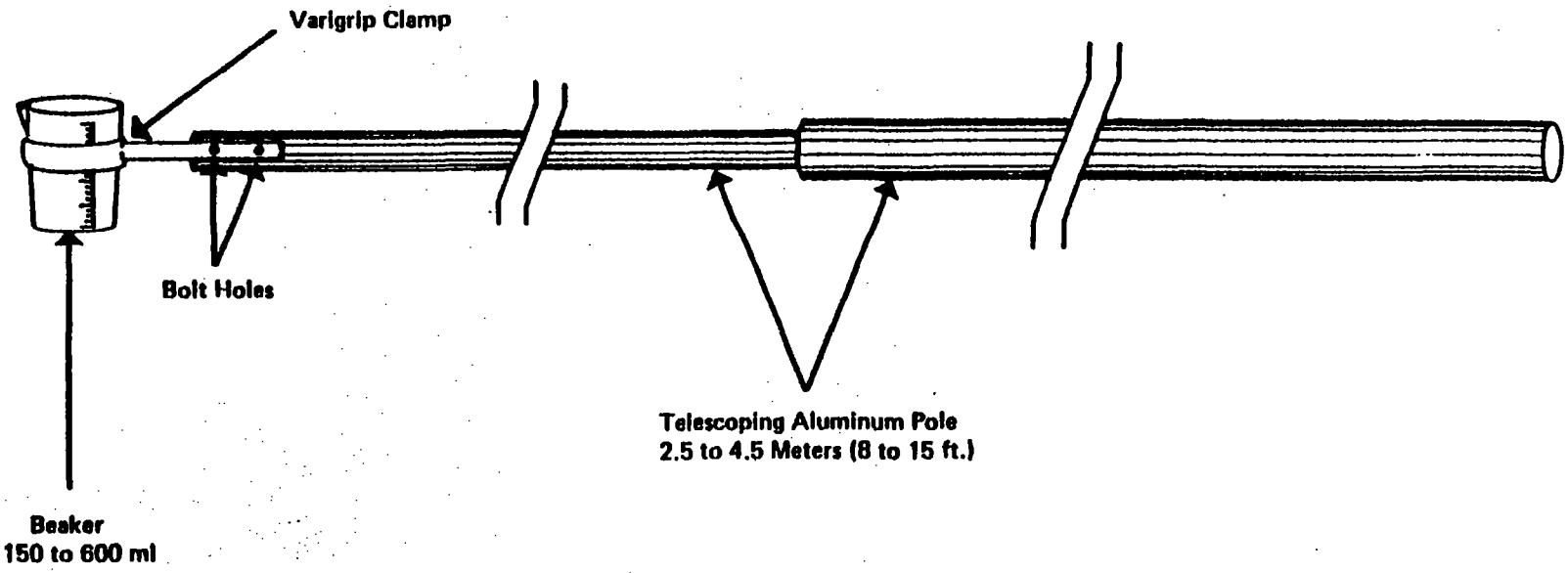


Figure 9-11. Dipper.

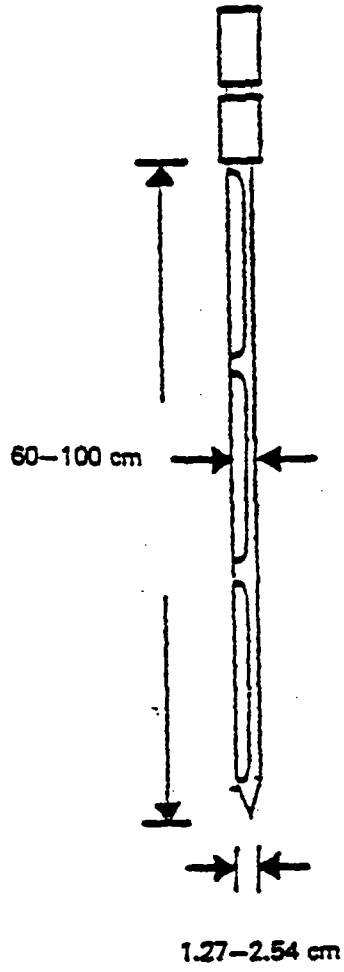


Figure 9-12. Thief sampler.

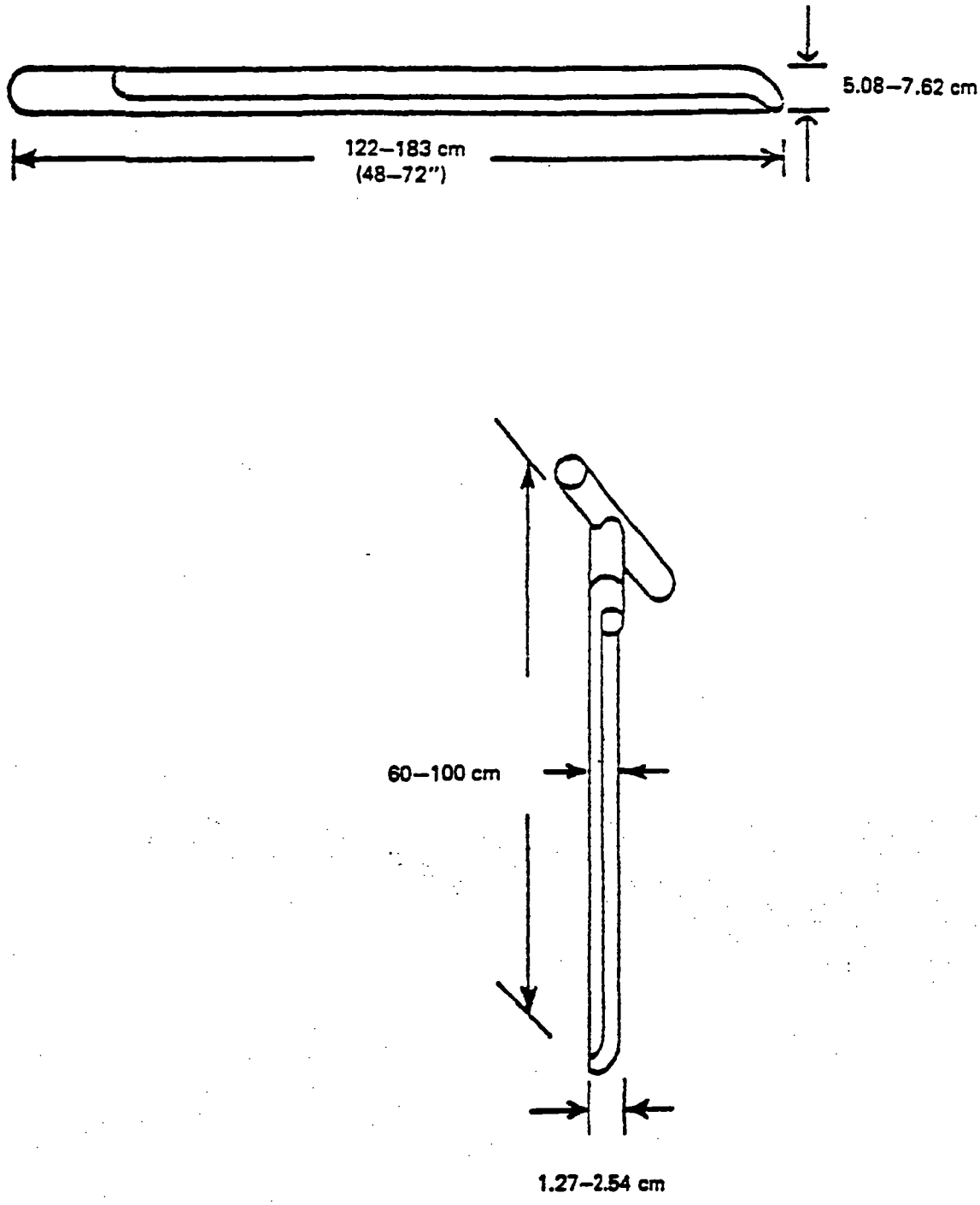


Figure 9-13. Sampling triers.

Bailer

The bailer is employed for sampling well water. It consists of a container attached to a cable that is lowered into the well to retrieve a sample. Bailers can be of various designs. The simplest is a weighted bottle or basally capped length of pipe that fills from the top as it is lowered into the well. Some bailers have a check valve, located at the base, which allows water to enter from the bottom as it is lowered into the well. When the bailer is lifted, the check valve closes, allowing water in the bailer to be brought to the surface. More sophisticated bailers are available that remain open at both ends while being lowered, but can be sealed at both top and bottom by activating a triggering mechanism from the surface. This allows more reliable sampling at discrete depths within a well. Perhaps the best-known bailer of this latter design is the Kemmerer sampler.

Bailers generally provide an excellent means for collecting samples from monitoring wells. They can be constructed from a wide variety of materials compatible with the parameter of interest. Because they are relatively inexpensive, bailers can be easily dedicated to an individual well to minimize cross contamination during sampling. If not dedicated to a well, they can be easily cleaned to prevent cross contamination. Unfortunately, bailers are frequently not suited for well evacuation because of their small volume.

Suction Pumps

As the name implies, suction pumps operate by creating a partial vacuum in a sampling tube. This vacuum allows the pressure exerted by the atmosphere on the water in the well to force water up the tube to the surface. Accordingly, these pumps are located at the surface and require only that a transmission tube be lowered into the well. Unfortunately, their use is limited by their reliance on suction to depths of 20 to 25 ft, depending on the pump. In addition, their use may result in out-gassing of dissolved gases or volatile organics and is therefore limited in many sampling applications. In spite of this, suction methods may provide a suitable means for well evacuation because the water remaining in the well is left reasonably undisturbed.

A variety of pumps that operate on this principle are available, but the ones most commonly suggested for monitoring purposes are the centrifugal and peristaltic pumps. In the centrifugal pump, the fluid is displaced by the action of an impeller rotating inside the pump chamber. This discharges water by centrifugal force. The resulting pressure drop in the chamber creates a suction and causes water to enter the intake pipe in the well. These pumps can provide substantial yields and are readily available and inexpensive. The disadvantages are that they require an external power source and may be difficult to clean between sampling events. In addition, the materials with which these pumps are constructed may frequently be incompatible with certain sample constituents. However, their substantial pumping rates make them suitable for well evacuation.

Peristaltic pumps operate in a manner similar to centrifugal pumps but displace the fluid by mechanical peristalsis. A flexible transmission line is mounted around the perimeter of the pump chamber, and rotating rollers compress the tubing, forcing fluid movement ahead (the peristaltic effect) and inducing suction behind each roller. This design isolates the sample from the moving part of the pump and allows for easy cleaning by removal and replacement of the flexible tubing. Unfortunately, peristaltic pumps are generally capable of providing only relatively low yields. They are, therefore, not ideally suited to well evacuation.

Positive Displacement Pumps

A variety of positive displacement pumps are available for use in withdrawing water from wells. These methods utilize some pumping mechanism, placed in the well, that forces water from the bottom of the well to the surface by some means of positive displacement. This minimizes the potential for aerating or stripping volatile organics from the sample during removal from the well.

The submersible centrifugal pump is one common example of a positive displacement pump. It works in a manner similar to the centrifugal suction lift pump previously described, except that, in this case, both the pump and electric motor are lowered into the well. As the impeller rotates and fluid is brought into the pump, fluid is displaced up the transmission line and out of the well. These pumps are capable of providing a high yield. However, they require an external source of power and are frequently constructed with materials and contain lubricants incompatible with certain sample constituents, particularly organics. They also require considerable equipment and effort to move from well to well. Cleaning between sampling events is difficult as well, and, until recently, they have not been available for well diameters smaller than 3 in.

Piston-driven or reciprocating piston pumps are another example of common positive displacement pumps. These pumps consist of a piston in a submerged cylinder operated by a rod connected to the drive mechanism at the surface. A flap valve or ball-check valve is located immediately above or below the piston cylinder. As the piston is lowered in the cylinder, the check valve opens, and water fills the chamber. On the upstroke, the check valve closes, and water is forced out of the cylinder, up into the transmission line, and to the surface. The transmission line or piston contains a second check valve that closes on the downstroke, preventing water from re-entering the cylinder. These pumps are capable of providing high yields. However, moving these pumps from well to well is difficult, and their use in monitoring programs may require that a pump be dedicated to each well. Many of these pumps may not be constructed with materials compatible with monitoring certain constituents.

A special adaptation of this pump has recently become available for use in ground water monitoring. These piston pumps use compressed gas, rather than a rod connected to a driving mechanism at the surface, to drive the pistons. This provides a much more convenient and portable means for collecting samples from monitoring wells. Compressed-gas pumps provide good yields and can be constructed with materials compatible with many sampling programs.

Another positive displacement pump applicable for monitoring purposes is the gas-operated squeeze pump. This pump was originally developed by R. F. Middleburg of the U.S.G.S. and consequently is referred to as the Middleburg pump. It consists principally of a collapsible membrane inside a long, rigid housing, a compressed gas supply, and appropriate control valves. When the pump is submerged, water enters the collapsible membrane through the bottom check valve. After the membrane has filled, gas pressure is applied to the annular space between the rigid housing and membrane, forcing the water upward through a sampling tube. When the pressure is released, the top check valve prevents the sample from flowing back down the discharge line, and water from the well again enters the pump through the bottom check valve.

Gas-operated squeeze pumps offer a number of advantages for use in ground water monitoring programs. They can be constructed in diameters as small as 1 in. and from a wide variety of materials. They are also relatively portable and are capable of providing a fair range of pumping rates. Most important, the driving gas does not contact the water sample, so that possible contamination or gas stripping does not occur. However, they do require a gas source, and withdrawal of water from substantial depths may require large gas volumes and long pumping cycles.

Jet pumps, a common type of submersible pump used in small domestic water wells, may in some cases be suggested for use in monitoring wells. These pumps operate by injecting water through a pipe down into the well. A venturi device is located at the intake portion of the pump. As the water injected from the surface passes through the constricted portion of the venturi, the velocity increases and pressures decrease according to Bernoulli's principle. If the discharge velocity at the nozzle is great enough, the pressure at this point will be lowered sufficiently to draw water into the venturi assembly through the intake and to bring it to the surface with the original water injected into the well. This additional increment of water is then made available at the surface as the pump's output. Because jet pumps require priming with water and because the water taken from the well mixes with water circulating in the system, they are clearly not applicable to collecting samples for monitoring purposes. For similar reasons, their use is not recommended for well evacuation.

Pressure-Vacuum Lysimeters

The basic construction of pressure-vacuum lysimeters (Wood, 1973), shown in Figure 9-14, consists of a porous ceramic cup, with a bubbling pressure of 1 bar or greater, attached to a short piece of PVC pipe of suitable diameter. Two tubes extend down into the device, as illustrated. Data by Silkworth and Grigal (1981) indicate that, of the two commercially available sampler sizes (2.2 and 4.8 cm diameter), the larger ceramic cup sampler is more reliable, influences water quality less, and yields samples of suitable volume for analysis.

Detailed installation instructions for pressure-vacuum lysimeters are given by Parizek and Lane (1970). Significant modification may be necessary to adapt these instruments to field use when heavy equipment is used. To prevent channelling of contaminated surface water directly to the sampling device, the sampler may be installed in the side wall of an access trench. Because random placement procedures may locate a sampler in the middle of an

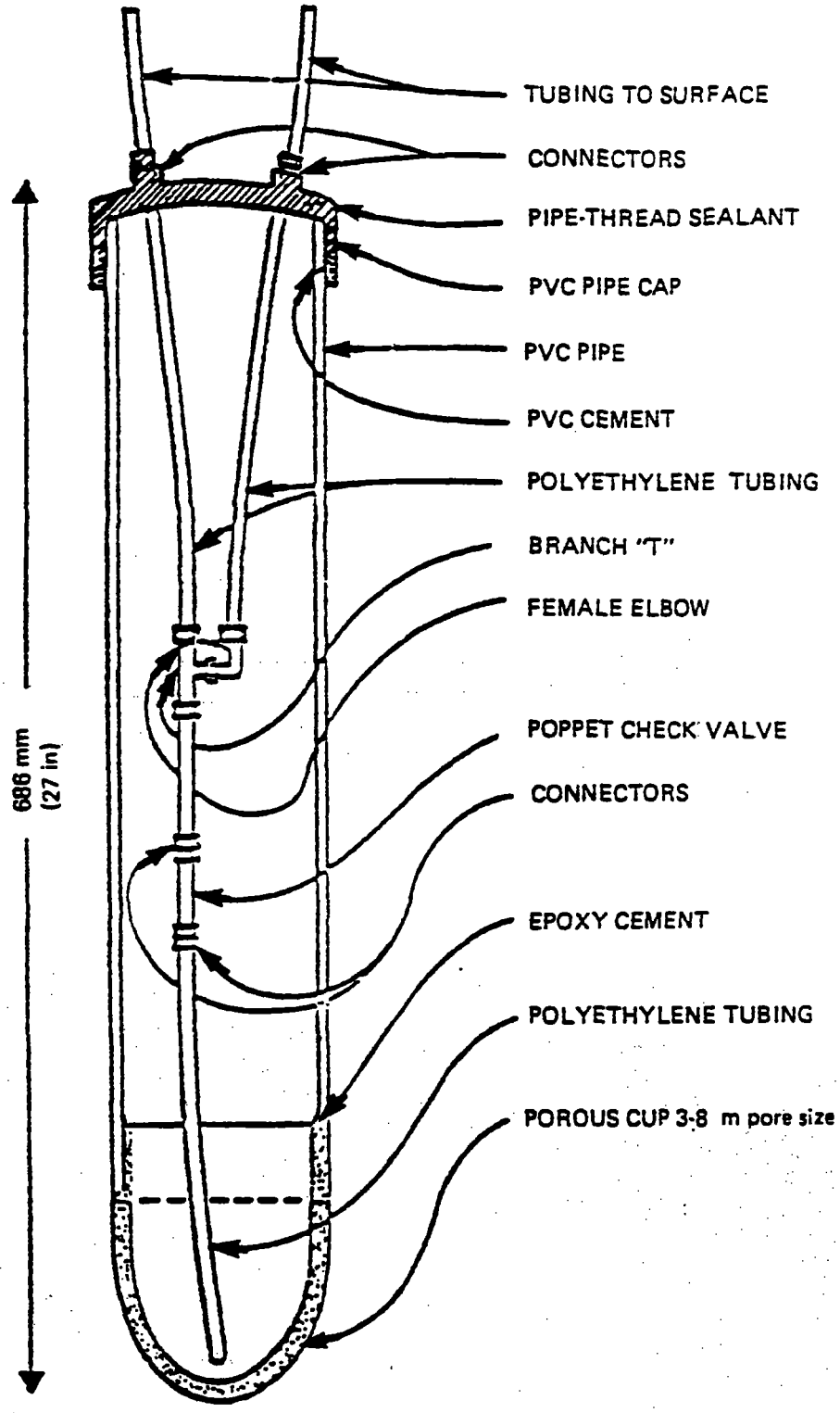


Figure 9-14. One example of a pressure-vacuum lysimeter (Wood, 1973). Reprinted by permission of the American Geophysical Union.

active area, the sample collection tube should be protected at the surface from heavy equipment by a manhole cover, brightly painted steel cage, or other structure. Another problem associated with such sampler placement is that its presence may alter waste management activities (i.e., waste applications, tilling, etc., will avoid the location); therefore, the sampler may not yield representative leachate samples. This problem may be avoided by running the collection tube horizontally underground about 10 m before surfacing.

For sampling after the unit is in place, a vacuum is placed on the system and the tubes are clamped off. Surrounding soil water is drawn into the ceramic cup and up the polyethylene tube. To collect the water sample, the vacuum is released, and one tube is placed in a sample container. Air pressure is applied to the other tube, forcing the liquid up the tube and into the sample container. Preliminary testing should ensure that waste products can pass into the ceramic cup. If sampling for organics, an inert tubing, such as one made of Teflon, should be substituted for the polyethylene pipe to prevent organic contamination.

The major advantages of these sampling devices are that they are easily available, relatively inexpensive to purchase and install, and quite reliable. The major disadvantage is the potential for water quality alterations due to the ceramic cup; this possible problem requires further testing. For a given installation, the device chosen should be specifically tested using solutions containing the soluble hazardous constituents of the waste to be land treated. This device is not recommended for volatiles unless a special trap device is used (Hazardous Waste Land Treatment, SW-874).

Vacuum Extractor

Vacuum extractors were developed by Duke and Haise (1973) to extract moisture from soils above the ground water table. The basic device consists of a stainless steel trough that contains ceramic tubes packed in soil. The unit is sized not to interfere with ambient soil water potentials (Corey, 1974); it is installed at a given depth in the soil with a slight slope toward the collection bottle, which is in the bottom of an adjacent access hole. The system is evacuated and moisture is moved from the adjacent soil into the ceramic tubes and into the collection bottle, from which it can be withdrawn as desired. The advantage of this system is that it yields a quantitative estimate of leachate flux as well as provides a water sample for analysis. The volume of collected leachate per unit area per unit time is an estimate of the downward movement of leachate water at that depth. The major disadvantages to this system are: it is delicate; it requires a trained operator; it estimates leachate quantity somewhat lower than actual field drainage; and it disturbs the soil above the sampler. Further details about the use of the vacuum extractor are given by Trout et al. (1975). Performance of this device when installed in clay soils is generally poor.

Trench Lysimeters

Trench lysimeters are named for the large access trench, or caisson, necessary for operation. Basic installation, as described by Parizek and Lane (1970), involves excavating a rather large trench and shoring up the side walls, taking care to leave open areas so that samplers can be placed in the side walls. Sample trays are imbedded in the side walls and connected by tubing to sample collection containers. The entire trench area is then covered to prevent flooding. One significant danger in using this system is the potential for accumulation of hazardous fumes in the trench, possibly endangering the health and safety of the person collecting the samples.

Trench lysimeters function by intercepting downward-moving water and diverting it into a collection device located at a lower elevation. The intercepting agent may be an open-ended pipe, sheet metal trough, pan, or other similar device. Pans 0.9 to 1.2 m in diameter have been successfully used in the field by Tyler and Thomas (1977). Because there is no vacuum applied to the system, only free water in excess of saturation is sampled. Consequently, samples are plentiful during rainy seasons but are nonexistent during the dry season.

Another variation of this system is to use a funnel filled with clean sand inserted into the sidewall of the trench. Free water will drain into a collection chamber, from which a sample is periodically removed by vacuum. A small sample collection device such as this may be preferable to the large trench because the necessary hole is smaller, so that installation is easier (Figure 9-15).

9.2.2.5 Quality Assurance and Quality Control

Quality assurance (QA) can briefly be defined as the process for ensuring that all data and the decisions based on these data are technically sound, statistically valid, and properly documented. Quality control (QC) procedures are the tools employed to measure the degree to which these quality assurance objectives are met.

A data base cannot be properly evaluated for accuracy and precision unless it is accompanied by quality assurance data. In the case of waste evaluation, these quality assurance data result from the implementation of quality control procedures during sampling and analysis. Quality control requirements for specific analytical methods are given in detail in each method in this manual; in this subsection, quality assurance and quality control procedures for sampling will be discussed.

Quality control procedures that are employed to document the accuracy and precision of sampling are:

1. Trip Blanks: Trip blanks should accompany sample containers to and from the field. These samples can be used to detect any contamination or cross-contamination during handling and transportation.

2. Field Blanks: Field blanks should be collected at specified frequencies, which will vary according to the probability of

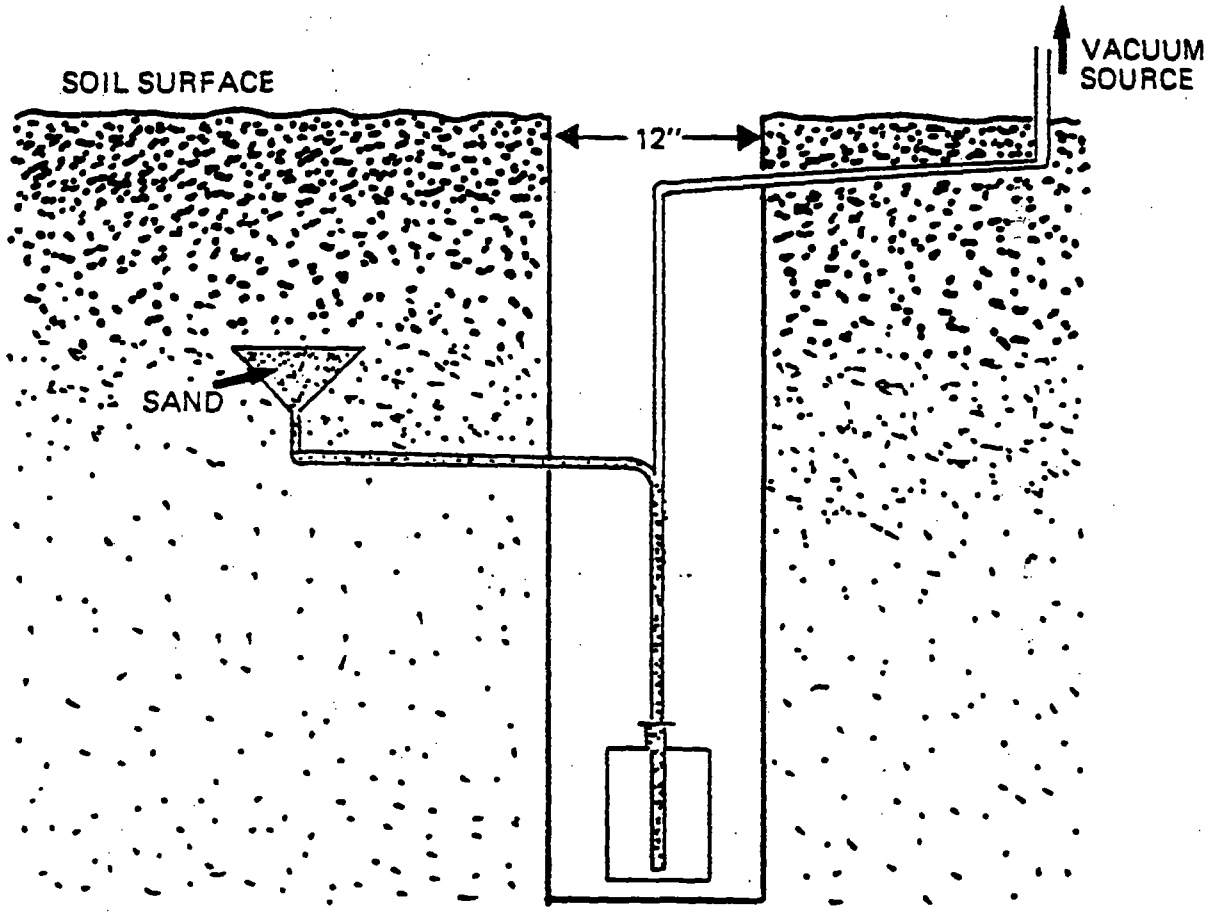


Figure 9-15. Schematic diagram of a sand filled funnel used to collect leachate from the unsaturated zone.

contamination or cross-contamination. Field blanks are often metal- and/or organic-free water aliquots that contact sampling equipment under field conditions and are analyzed to detect any contamination from sampling equipment, cross contamination from previously collected samples, or contamination from conditions during sampling (e.g., airborne contaminants that are not from the waste being sampled).

3. Field Duplicates: Field duplicates are collected at specified frequencies and are employed to document precision. The precision resulting from field duplicates is a function of the variance of waste composition, the variance of the sampling technique, and the variance of the analytical technique.

4. Field Spikes: Field spikes are infrequently used to determine the loss of parameters of interest during sampling and shipment to the laboratories. Because spiking is done in the field, the making of spiked samples or spiked blanks is susceptible to error. In addition, compounds can be lost during spiking, and equipment can be contaminated with spiking solutions. To eliminate these and other problems, some analysts spike blanks or matrices similar to the waste in the laboratory and ship them, along with sample containers, to the field. This approach also has its limitation because the matrix and the handling of the spike are different from those of the actual sample. In all cases, the meaning of a low field-spike recovery is difficult to interpret, and thus, field spikes are not commonly used.

In addition to the above quality control samples, a complete quality assurance program will ensure that standard operating procedures (SOPs) exist for all essential aspects of a sampling effort. SOPs should exist for the following steps in a sampling effort:

1. Definition of objectives (refer to Section 9.2.1).

2. Design of sampling plans (refer to Section 9.2.2).

3. Preparation of containers and equipment (refer to the specific analytical methods).

4. Maintenance, calibration, and cleaning of field equipment (refer to instrument manuals or consult a chemist for cleaning protocols).

5. Sample preservation, packaging, and shipping (refer to the analytical methods and to Section 9.2.2.7).

6. Health and safety protocols (refer to Section 9.2.2.6).

7. Chain-of-custody protocols (refer to Section 9.2.2.7).

In addition to the above protocols, numerous other QA/QC protocols must be employed to document the accuracy of the analytical portion of a waste evaluation program.

9.2.2.6 Health and Safety

Safety and health must also be considered when implementing a sampling plan. A comprehensive health and safety plan has three basic elements: (1) monitoring the health of field personnel; (2) routine safety procedures; and (3) emergency procedures.

Employees who perform field work, as well as those exposed to chemicals in the laboratory, should have a medical examination at the initiation of employment and routinely thereafter. This exam should preferably be performed and evaluated by medical doctors who specialize in industrial medicine. Some examples of parts of a medical examination that ought to be performed are: documentation of medical history; a standard physical exam; pulmonary functions screening; chest X-ray; EKG; urinalysis; and blood chemistry. These procedures are useful to: (1) document the quality of an employee's health at the time of matriculation; (2) ensure the maintenance of good health; and (3) detect early signs of bodily reactions to chemical exposures so they can be treated in a timely fashion. Unscheduled examinations should be performed in the event of an accident, illness, or exposure or suspected exposure to toxic materials.

Regarding safety procedures, personnel should be aware of the common routes of exposure to chemicals (i.e., inhalation, contact, and ingestion) and be instructed in the proper use of safety equipment, such as Draeger tube air samplers to detect air contamination, and in the proper use of protective clothing and respiratory equipment. Protocols should also be defined stating when safety equipment should be employed and designating safe areas where facilities are available for washing, drinking, and eating.

Even when the utmost care is taken, an emergency situation can occur as a result of an unanticipated explosion, electrical hazard, fall, or exposure to a hazardous substance. To minimize the impact of an emergency, field personnel should be aware of basic first aid and have immediate access to a first-aid kit. Phone numbers for both police and the nearest hospital should be obtained and kept by each team member before entering the site. Directions to the nearest hospital should also be obtained so that anyone suffering an injury can be transported quickly for treatment.

9.2.2.7 Chain of Custody

An essential part of any sampling/analytical scheme is ensuring the integrity of the sample from collection to data reporting. The possession and handling of samples should be traceable from the time of collection through analysis and final disposition. This documentation of the history of the sample is referred to as chain of custody.

Chain of custody is necessary if there is <u>any</u> possibility that the analytical data or conclusions based upon analytical data will be used in litigation. In cases where litigation is not involved, many of the chain-of-custody procedures are still useful for routine control of sample flow. The components of chain of custody -- sample seals, a field logbook, chain-of-custody record, and sample analysis request sheet -- and the procedures for their use are described in this section.

A sample is considered is considered to be under a person's custody if it is (1) in a person's physical possession, (2) in view of the person after taking possession, and (3) secured by that person so that no one can tamper with it, or secured by that person in an area that is restricted to authorized personnel. A person who has samples in custody must comply with the following procedures.

(The material presented here briefly summarizes the major aspects of chain of custody. The reader is referred to NEIC Policies and Procedures, EPA-330/9/78/001-R [as revised 1/82], or other manual, as appropriate, for more information.)

Sample labels (Figure 9-16) are necessary to prevent misidentification of samples. Gummed paper labels or tags are adequate and should include at least the following information:

Sample number.
Name of collector.
Date and time of collection.
Place of collection.

Labels should be affixed to sample containers prior to or at the time of sampling and should be filled out at the time of collection.

Sample seals are used to detect unauthorized tampering of samples following sample collection up to the time of analysis. Gummed paper seals may be used for this purpose. The paper seal should include, minimally, the following information:

Sample number. (This number must be identical with the number on the sample label.)
Name of collector.
Date and time of sampling.
Place of collection.

The seal must be attached in such a way that it is necessary to break it in order to open the sample container. (An example of an official sample seal is shown in Figure 9-17.) Seals must be affixed to containers before the samples leave the custody of sampling personnel.

All information pertinent to a field survey or sampling must be recorded in a logbook. This should be bound, preferably with consecutively numbered pages that are 21.6 by 27.9 cm (8-1/2 by 11 in.). At a minimum, entries in the logbook must include the following:

Location of sampling point.
Name and address of field contact.
Producer of waste and address, if different from location.
Type of process producing waste (if known).
Type of waste (e.g., sludge, wastewater).
Suspected waste composition, including concentrations.
Number and volume of sample taken.

Collector _____ Sample No. _____

Place of Collection _____

_____

Date Sampled _____ Time Sampled _____

Field Information _____

_____

_____

Figure 9-16. Example of Sample Label

NAME AND ADDRESS OF ORGANIZATION COLLECTING SAMPLES

Person Collecting Sample _____ Sample No. _____
(signature)

Date Collected _____ Time Collected _____

Place Collected _____

_____

_____

Figure 9-17. Example of Official Sample Seal

Purpose of sampling (e.g., surveillance, contract number).
Description of sampling point and sampling methodology.
Date and time of collection.
Collector's sample identification number(s).
Sample distribution and how transported (e.g., name of laboratory, UPS, Federal Express).
References, such as maps or photographs of the sampling site.
Field observations.
Any field measurements made (e.g., pH, flammability, explosivity).
Signatures of personnel responsible for observations.

Sampling situations vary widely. No general rule can be given as to the extent of information that must be entered in the logbook. A good rule, however, is to record sufficient information so that anyone can reconstruct the sampling without reliance on the collector's memory. The logbook must be stored safely.

To establish the documentation necessary to trace sample possession from the time of collection, a chain-of-custody record should be filled out and should accompany every sample. This record becomes especially important if the sample is to be introduced as evidence in a court litigation. (A chain-of-custody record is illustrated in Figure 9-18.)

The record should contain, minimally, the following information:

Sample number.
Signature of collector.
Date and time of collection.
Place and address of collection.
Waste type.
Signature of persons involved in the chain of possession.
Inclusive dates of possession.

The sample analysis request sheet (Figure 9-19) is intended to accompany the sample on delivery to the laboratory. The field portion of this form is completed by the person collecting the sample and should include most of the pertinent information noted in the logbook. The laboratory portion of this form is intended to be completed by laboratory personnel and to include, minimally:

Name of person receiving the sample.
Laboratory sample number.
Date and time of sample receipt.
Sample allocation.
Analyses to be performed.

The sample should be delivered to the laboratory for analysis as soon as practicable -- usually within 1 or 2 days after sampling. The sample must be accompanied by the chain-of-custody record (Figure 9-18) and by a sample analysis request sheet (Figure 9-19). The sample must be delivered to the person in the laboratory authorized to receive samples (often referred to as the sample custodian).

CHAIN OF CUSTODY RECORD

Proj No.	Project Name												
Samplers (Signature)													
Sta. No.	Date	Time	Comp.	Grab	Station Location	No. of Containers							Remarks

Relinquished by: (Signature)	Date Time	Received by: (Signature)	Relinquished by: (Signature)	Date Time	Received by: (Signature)
Relinquished by: (Signature)	Date Time	Received by: (Signature)	Relinquished by: (Signature)	Date Time	Received by: (Signature)
Relinquished by: (Signature)	Date Time	Received for Laboratory by: (Signature)		Remarks	

Figure 9-18.

SAMPLING ANALYSIS REQUEST

Part I: Field Section

Collector _____ Date Sampled _____ Time _____ hours

Affiliation of Sampler _____

Address _____
number street city state zip

Telephone ( ) _____ Company Contact _____

LABORATORY SAMPLE NUMBER	COLLECTOR'S SAMPLE NO.	TYPE OF SAMPLE*	FIELD INFORMATION**

Analysis Requested _____

_____

_____

Special Handling and/or Storage _____

_____

PART II: LABORATORY SECTION**

Received by _____ Title _____ Date _____

Analysis Required _____

_____

* Indicate whether sample is soil, sludge, etc.
**Use back of page for additional information relative to sample location.

Figure 9-19. Example of hazardous waste sample analysis sheet.

Any material that is identified in the DOT Hazardous Material Table (49 CFR 172.101) must be transported as prescribed in the table. All other hazardous waste samples must be transported as follows:

1. Collect sample in a 16-oz or smaller glass or polyethylene container with nonmetallic Teflon-lined screw cap. For liquids, allow sufficient air space (approximately 10% by volume) so that the container is not full at 54°C (130°F). If collecting a solid material, the container plus contents should not exceed 1 lb net weight. If sampling for volatile organic analysis, fill VOA container to septum but place the VOA container inside a 16-oz or smaller container so that the required air space may be provided. Large quantities, up to 3.785 liters (1 gal), may be collected if the sample's flash point is 23°C (75°F) or higher. In this case, the flash point must be marked on the outside container (e.g., carton or cooler), and shipping papers should state that "Flash point is 73°F or higher."

2. Seal sample and place in a 4-mil-thick polyethylene bag, one sample per bag.

3. Place sealed bag inside a metal can with noncombustible, absorbent cushioning material (e.g., vermiculite or earth) to prevent breakage, one bag per can. Pressure-close the can and use clips, tape, or other positive means to hold the lid securely.

4. Mark the can with:

   Name and address of originator.
   "Flammable Liquid, N.O.S. UN 1993."
   (or, "Flammable Solid, N.O.S. UN 1325".)

NOTE: UN numbers are now required in proper shipping names.

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5. Place one or more metal cans in a strong outside container such as a picnic cooler or fiberboard box. Preservatives are not used for hazardous waste site samples.

6. Prepare for shipping: The words "Flammable Liquid, N.O.S. UN 1993" or "Flammable Solid, N.O.S. UN 1325"; "Cargo Aircraft Only" (if more than 1 qt net per outside package); "Limited Quantity" or "Ltd. Qty."; "Laboratory Samples"; "Net Weight ___" or "Net Volume ___" (of hazardous contents) should be indicated on shipping papers and on the outside of the outside shipping container. The words "This Side Up" or "This End Up" should also be on container. Sign the shipper certification.

7. Stand by for possible carrier requests to open outside containers for inspection or to modify packaging. (It is wise to contact carrier before packing to ascertain local packaging requirements.) Remain in the departure area until the carrier vehicle (aircraft, truck, etc.) is on its way.

At the laboratory, a sample custodian should be assigned to receive the samples. Upon receipt of a sample, the custodian should inspect the condition of the sample and the sample seal, reconcile the information on the sample label and seal against that on the chain-of-custody record, assign a laboratory number, log in the sample in the laboratory logbook, and store it in a secured sample storage room or cabinet until it is assigned to an analyst for analysis.

The sample custodian should inspect the sample for any leakage from the container. A leaky container containing a multiphase sample should not be accepted for analysis. This sample will no longer be a representative sample. If the sample is contained in a plastic bottle and the container walls show that the sample is under pressure or releasing gases, the sample should be treated with caution because it may be explosive or release extremely poisonous gases. The custodian should examine whether the sample seal is intact or broken, because a broken seal may mean sample tampering and would make analysis results inadmissible as evidence in court. Any discrepancies between the information on the sample label and seal and the information that is on the chain-of-custody record and the sample analysis request sheet should be resolved before the sample is assigned for analysis. This effort might require communication with the sample collector. Results of the inspection should be noted on the sample analysis request sheet and on the laboratory sample logbook.

Incoming samples usually carry the inspector's or collector's identification numbers. To identify these samples further, the laboratory should assign its own identification numbers, which normally are given consecutively. Each sample should be marked with the assigned laboratory number. This number is correspondingly recorded on a laboratory sample log book along with the information describing the sample. The sample information is copied from the sample analysis request sheet and cross-checked against that on the sample label.

In most cases, the laboratory supervisor assigns the sample for analysis. The supervisor should review the information on the sample analysis request sheet, which now includes inspection notes recorded by the laboratory sample custodian. The technician assigned to analysis should record in the laboratory notebook the identifying information about the sample, the date of receipt, and other pertinent information. This record should also include the subsequent testing data and calculations. The sample may have to be split with other laboratories in order to obtain all the necessary analytical information. In this case, the same type of chain-of-custody procedures must be employed while the sample is being transported and at the other laboratory.

Once the sample has been received in the laboratory, the supervisor or his/her assignee is responsible for its care and custody. That person should be prepared to testify that the sample was in his/her possession or secured in the laboratory at all times, from the moment it was received from the custodian until the analyses were performed.

9.2.3 Sample Plan Implementation

Prior to implementing a sampling plan, it is often strategic to walk through the sampling plan mentally, starting with the preparation of equipment until the time when samples are received at the laboratory. This mental excursion should be in as much detail as can be imagined, because the small details are the ones most frequently overlooked. By employing this technique, items not included on the equipment list may be discovered, as well as any major oversight that could cause the sampling effort to fail. During this review of the sampling plan, an attempt should be made to anticipate what could go wrong. A solution to anticipated problems should be found, and, if necessary, materials needed for solving these problems should be added to the equipment list.

The remainder of this section discusses examples of sampling strategies for different situations that may be encountered.

Containers

Prior to discussing the sampling of containers, the term must be defined. The term container, as used here, refers to receptacles that are designed for transporting materials, e.g., drums and other smaller receptacles, as opposed to stationary tanks. Weighted bottles, Coliwasas, drum thiefs, or triers are the sampling devices that are chosen for the sampling of containers. (See Section 9.2.2.4 for a full discussion of sampling equipment.)

The sampling strategy for containers varies according to (1) the number of containers to be sampled and (2) access to the containers. Ideally, if the waste is contained in several containers, every container will be sampled. If this is not possible due to the large number of containers or to cost factors, a subset of individual containers must be randomly selected for sampling. This can be done by assigning each container a number and then randomly choosing a set of numbers for sampling.

Access to a container will affect the number of samples that can be taken from the container and the location within the container from which samples can be taken. Ideally, several samples should be taken from locations displaced both vertically and horizontally throughout the waste. The number of samples required for reliable sampling will vary depending on the distribution of the waste components in the container. At a minimum with an unknown waste, a sufficient number and distribution of samples should be taken to address any possible vertical anomalies in the waste. This is because contained wastes have a much greater tendency to be nonrandomly heterogeneous in a vertical rather than a horizontal direction due to (1) settling of solids and the denser phases of liquids and (2) variation in the content of the waste as it enters the container. Bags, paper drums, and open-headed steel drums (of which the entire top can be removed) generally do not restrict access to the waste and therefore do not limit sampling.

When access to a container is unlimited, a useful strategy for obtaining a representative set of samples is a three-dimensional simple random sampling strategy in which the container is divided by constructing an imaginary three-dimensional grid (see Figure 9-20), as follows. First, the top surface of the waste is divided into a grid whose sections either approximate the size of the sampling device or are larger than the sampling device if the container is large. (Cylindrical containers can be divided into imaginary concentric circles, which are then further divided into grids of equal size.) Each section is assigned a number. The height of the container is then divided into imaginary levels that are at least as large as the vertical space required by the chosen sampling device. These imaginary levels are then assigned numbers. Specific levels and grid locations are then selected for sampling using a random-number table or random-number generator. (An alternative means of choosing random sampling locations using circumference and diameter dimensions is discussed in Section 9.2.2.1.)

Another appropriate sampling approach is the two-dimensional simple random sampling strategy, which can usually yield a more precise sampling when fewer samples are collected. This strategy involves (1) dividing the top surface of the waste into an imaginary grid as in the three-dimensional strategy, (2) selecting grid sections for sampling using random-number tables or random-number generators, and (3) sampling each selected grid point in a vertical manner along the entire length from top to bottom using a sampling device such as a drum thief or Coliwasa.

Some containers, such as drums with bung openings, limit access to the contained waste and restrict sampling to a single vertical plane. Samples taken in this manner can be considered representative of the entire container only if the waste is known to be homogeneous or if no horizontal stratification has occurred. Precautions must be taken when sampling any type of steel drum because the drum may explode or expel gases and/or pressurized liquids. An EPA/NEIC manual, "Safety Manual for Hazardous Waste Site Investigation," addresses these safety precautions.

Tanks

Tanks are essentially large containers. The considerations involved in sampling tanks are therefore similar to those for sampling containers. As with containers, the goal of sampling tanks is to acquire a sufficient number of samples from different locations within the waste to provide analytical data that are representative of the entire tank contents.

The accessibility of the tank contents will affect the sampling methodology. If the tank is an open one, allowing unrestricted access, then usually a representative set of samples is best obtained using the three-dimensional simple random sampling strategy, as described for containers (see also Section 9.2.2.1). This strategy involves dividing the tank contents into an imaginary three-dimensional grid. As a first step, the top surface of the waste is divided into a grid whose sections either approximate the size of the sampling device or are larger than the sampling device if the tank is large.

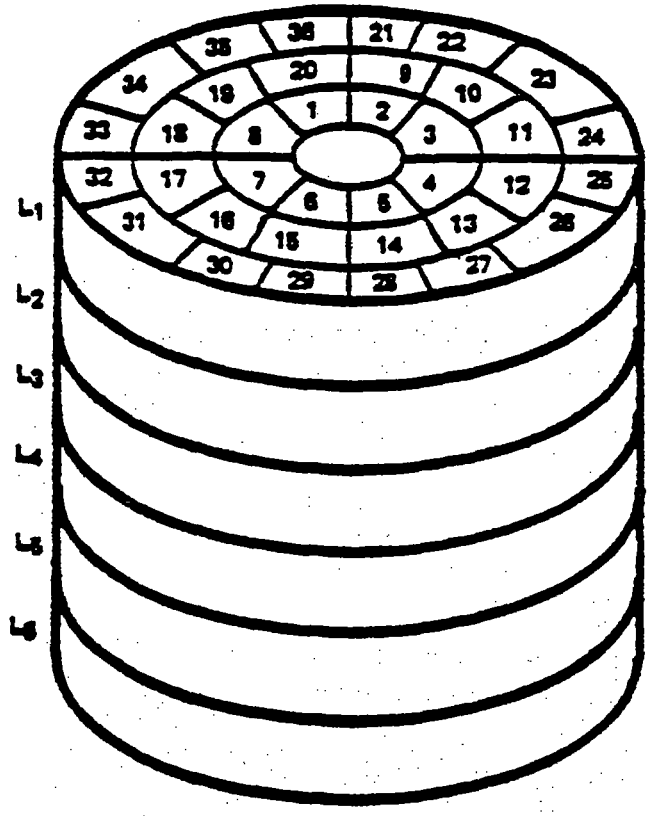

Figure 9-20. Container divided into an imaginary three-dimensional grid.

(Cylindrical tanks can be divided into imaginary concentric circles, which are then further divided into grids of equal size.) Each section is assigned a number. The height of the tank is then divided into imaginary levels that are at least as large as the vertical space required by the chosen sampling device. These imaginary levels are assigned numbers. Specific levels and grid locations are then selected for sampling using a random-number table or random-number generator.

A less comprehensive sampling approach may be appropriate if information regarding the distribution of waste components is known or assumed (e.g., if vertical compositing will yield a representative sample). In such cases, a two-dimensional simple random sampling strategy may be appropriate. In this strategy, the top surface of the waste is divided into an imaginary grid; grid sections are selected using random-number tables or random-number generators; and each selected grid point is then sampled in a vertical manner along the entire length from top to bottom using a sampling device such as a weighted bottle, a drum thief, or Coliwasa. If the waste is known to consist of two or more discrete strata, a more precise representation of the tank contents can be obtained by using a stratified random sampling strategy, i.e., by sampling each stratum separately using the two- or three-dimensional simple random sampling strategy.

Some tanks permit only limited access to their contents, which restricts the locations within the tank from which samples can be taken. If sampling is restricted, the sampling strategy must, at a minimum, take sufficient samples to address the potential vertical anomalies in the waste in order to be considered representative. This is because contained wastes tend to display vertical, rather than horizontal, nonrandom heterogeneity due to settling of suspended solids or denser liquid phases. If access restricts sampling to a portion of the tank contents (e.g., in an open tank, the size of the tank may restrict sampling to the perimeter of the tank; in a closed tank, the only access to the waste may be through inspection ports), then the resulting analytical data will be deemed representative only of the accessed area, not of the entire tank contents unless the tank contents are known to be homogeneous.

If a limited access tank is to be sampled, and little is known about the distribution of components within the waste, a set of samples that is representative of the entire tank contents can be obtained by taking a series of samples as the tank contents are being drained. This should be done in a simple random manner by estimating how long it will take to drain the tank and then randomly selecting times during drainage for sampling.

The most appropriate type of sampling device for tanks depends on the tank parameters. In general, subsurface samplers (i.e., pond samplers) are used for shallow tanks, and weighted bottles are usually employed for tanks deeper than 5 ft. Dippers are useful for sampling pipe effluents.

Waste Piles

In waste piles, the accessibility of waste for sampling is usually a function of pile size, a key factor in the design of a sampling strategy for a waste pile. Ideally, piles containing unknown wastes should be sampled using a three-dimensional simple random sampling strategy. This strategy can be employed only if all points within the pile can be accessed. In such cases, the pile should be divided into a three-dimensional grid system, the grid sections assigned numbers, and the sampling points then chosen using random-number tables or random-number generators.

If sampling is limited to certain portions of the pile, then the collected sample will be representative only of those portions, unless the waste is known to be homogeneous.

In cases where the size of a pile impedes access to the waste, a set of samples that are representative of the entire pile can be obtained with a minimum of effort by scheduling sampling to coincide with pile removal. The number of truckloads needed to remove the pile should be estimated and the truckloads randomly chosen for sampling.

The sampling devices most commonly used for small piles are thiefs, triers, and shovels. Excavation equipment, such as backhoes, can be useful for sampling medium-sized piles.

Landfills and Lagoons

Landfills contain primarily solid waste, whereas lagooned waste may range from liquids to dried sludge residues. Lagooned waste that is either liquid or semisolid is often best sampled using the methods recommended for large tanks. Usually, solid wastes contained in a landfill or lagoon are best sampled using the three-dimensional random sampling strategy.

The three-dimensional random sampling strategy involves establishing an imaginary three-dimensional grid of sampling points in the waste and then using random-number tables or random-number generators to select points for sampling. In the case of landfills and lagoons, the grid is established using a survey or map of the area. The map is divided into two two-dimensional grids with sections of equal size. (An alternative way of choosing random sampling locations is presented in the second example described in Section 9.2.2.1.) These sections are then assigned numbers sequentially.

Next, the depth to which sampling will take place is determined and subdivided into equal levels, which are also sequentially numbered. (The lowest sampling depth will vary from landfill to landfill. Usually, sampling extends to the interface of the fill and the natural soils. If soil contamination is suspected, sampling may extend into the natural soil.) The horizontal and vertical sampling coordinates are then selected using random-number tables or random-number generators. If some information is known about the nature of the waste, then a modified three-dimensional strategy may be more appropriate. For example, if the landfill consists of several cells, a more precise measurement may be obtained by considering each cell as a stratum and employing a stratified three-dimensional random sampling strategy (see Section 9.1).

Hollow-stem augers combined with split-spoon samplers are frequently appropriate for sampling landfills. Water-driven or water-rinsed coring equipment should not be used for sampling because the water can rinse chemical components from the sample. Excavation equipment, such as backhoes, may be useful in obtaining samples at various depths; the resulting holes may be useful for viewing and recording the contents of the landfill.

9.2.4 Sample Compositing

The compositing of samples, is usually done for cost-saving reasons, involves the combining of a number of samples or aliquots of a number of samples collected from the same waste. The disadvantage of sample compositing is the loss of concentration variance data, whereas the advantage is that, for a given analytical cost, a more representative (i.e., more accurate) sample is obtained.

It is usually most expedient and cost effective to collect component samples in the field and to composite aliquots of each sample later in the laboratory. Then, if after reviewing the data any questions arise, the samples can be recomposited in a different combination, or each component sample can be analyzed separately to determine better the variation of waste composition over time and space, or to determine better the precision of an average number. The fact that this recompositing of samples can occur without the need to resample often results in a substantial cost savings.

To ensure that recompositing can be done at a later date, it is essential to collect enough sample volume in the field so that, under normal circumstances, enough component sample will remain following compositing to allow for a different compositing scheme or even for an analysis of the component samples themselves.

The actual compositing of samples requires the homogenization of all component samples to ensure that a representative subsample is aliquoted. The homogenization procedure, and the containers and equipment used for compositing, will vary according to the type of waste being composited and the parameters to be measured. Likewise, the composite sample itself will be homogenized prior to the subsampling of analytical aliquots.

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7

AN INTERNATIONAL PERSPECTIVE ON CHARACTERISATION AND MANAGEMENT OF RESIDUES FROM MUNICIPAL SOLID WASTE INCINERATION

SUMMARY REPORT

DECEMBER 1994

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4. RESIDUE SAMPLING AND CHARACTERISATION METHODS

Considerable confusion has been created by the apparently conflicting residue characterisation data available in the literature. Detailed examination of that information suggests that some of the discrepancies may result from the use of different sampling and analytical techniques. Variations in these techniques have been shown to significantly affect the results and conclusions obtained from the studies. In some cases, additional difficulties have arisen from misinterpretation of the analytical results. Too often, ash studies have suffered from "snap shot" sampling plans that do not provide a true estimate or value of a characteristic. A sampling scheme should be designed to compensate for variability and identify the inherent noise and overlapping cycles so that a "true" estimate or value of a time-dependent characteristic can be obtained. One of the objectives of the IAWG work was to recommend a uniform suite of sampling and analytical tools to minimize the experimental differences between studies. This section focuses on some of the issues identified during the study and provides a synopsis of the resulting recommendations.

Residue Heterogeneity and Variability

As noted in previous sections, it is important to consider the influence of waste stream variations on residue characteristics, including:

- differing mixes of residential, commercial and light industry waste created by pick-up schedules;
- seasonal variations in waste including changes in the proportion of yard and garden waste; or,
- changes in burning characteristics attributable to weather conditions (wet vs. dry waste).

Thus residue properties can vary over short intervals in response to the waste feed and the variability during short intervals (less than one day) can be as great as composite variability over longer intervals (e.g., weeks or months). In addition, complex interactions between the incinerator operating conditions and mechanical operating cycles will further influence the residue characteristics. For example, facility design can influence the level of burnout achieved and the extent of particulate carry-over from the combustion chamber to the APC system. Moreover, timed cycles within the incinerator facility, such as boiler tube rapping or soot blowing, APC cleaning cycles, ash discharge conveyor operation and hopper evacuation will invariably influence the residue characteristics at any one point in time, i.e., sampling before, during or shortly after these cyclical processes will produce different results.

All of these factors need to be considered when developing a sampling strategy for ash which will generate samples that are "representative". Defining the variability of residue streams is made more difficult by their heterogeneous nature. Both bottom ash and combined ash pose an extreme challenge because a wide range of particle sizes and types are present in sampling, the resulting sample still must be size-reduced and sub-sampled in a manner that ensures that it is representative.

The chemical heterogeneity of bottom ash is usually much larger that the heterogeneity of the physical properties. This is caused by the presence of individual particles of widely different composition even after thorough sample particle size reduction and sample homogenization (e.g., pure metal particles). This is appar-

ent from much larger relative standard deviations (RSD) as a function of total concentration, than would be expected from analytical variation.

Most sampling programs initially involve intensive sampling efforts to establish the range of variability for chemical, physical and engineering properties. Once these boundaries are established, sampling frequencies can be dramatically reduced and surrogate parameters such as acid neutralizing capacity (ANC) and loss on ignition (LOI) can be used to estimate residue quality.

Sampling Protocols

Recommendations for sampling programs include consideration of where and when to take samples, the most appropriate sampling methods, the number and size of sample increments, and sample handling and storage protocols. The purpose of sampling can vary considerably. Sampling for regulatory purposes aims to establish average residue characteristics, whereas research often seeks to clarify the effects of specific operational interventions, including the factors listed above. Regardless, all sampling should follow the same general approach to minimise variability:

- Document the cyclical operating procedures that can influence the residue stream to be sampled;
- Select a sampling period that incorporates the variations documented above and the time interval that the sample is intended to represent. This period is used to generate a composite sample. It may be an 8 hour shift composite, a daily composite, a weekly composite, or an amount accumulated in a roll-off container, etc;
- Select a sampling location and construct a suitable sampling device. The sampling device should be capable of collecting the full range of particle sizes anticipated for the residue stream. Therefore, the nominal sampler dimension should be at least 2.5 times the largest particle size anticipated (e.g., 125 mm for sorted bottom ash and smaller for other streams). A specific caution is that only pile sampling is recommended for combined ash to minimize the effects of typically poor mixing of bottom ash with APC residues;
- Obtain a composite sample by taking a minimum of 10 increments from the residue stream, however, it is preferable to collect 24 increments. A minimum increment size of 10 kg is recommended for bottom ash or combined ash, while smaller increments (e.g., 1 kg) are considered satisfactory for the other residue streams. During the sample period, increments should be collected at regular intervals over the total time or mass intended to be characterised. In the case of the smaller volume residue streams, it may be preferable to collect all the material produced over the time-frame of interest and core this material to obtain the increments;
- Composite samples of bottom ash should be screened to remove the plus 50 mm material. The plus 50 mm material should be characterised as clinker or metal and weighed. The minus 50 mm material should be sub-sampled, using appropriate techniques (e.g., core or cone and quarter), to provide two 20 litre samples. The oversize clinker should be reduced in size to pass a 50 mm screen. This step will assist in determin-

ing the amount of metal in the clinker. The size reduced material should be retained in a separate container. All other composite samples should be split into two samples and stored and shipped in airtight containers to prevent moisture migration into the material. At the laboratory, material may be either stored at 4°C or dried at 60°C depending on the type of analyses to be carried out.

Laboratory sub-sampling, size reduction and sample preparation steps are usually required prior to analysis. As noted above, for many analyses it may be appropriate to dry bottom ash before further sub-sampling occurs. These sub-sampling and sample preparation stages should follow standard laboratory practices. The physical and chemical characterisation methods are outlined later in this report.

Sampling Documentation

The reporting of test results for residue samples should provide:

- a complete description of the methods used to take the samples, including the type of increments, timing or spacing of increments, number and weight of increments, and, methods of creating gross samples;
- a description of the sample storage procedures; and,
- a description of laboratory methods including any screening, separation, and, mixing procedures. Depending on the type of sampling (detailed characterisation, regulatory, or research), these daily composites may be collected seven days a week, once per month or once per quarter year.

In addition, the following information should be compiled when possible, to assist in developing a more useful database on the relationship of physical and chemical properties of residues to other factors:

- general composition of the waste materials being burned (e.g., residential, commercial or mixed), including the types of waste received or processed at the facility on the dates of sampling, and any waste composition analyses that are available;
- designation and description of the incinerator units and any other specific equipment within the facility which contributed material to the residue sampled, including the heat recovery, pollution control and quenching equipment;
- description of the operating conditions of the specified equipment prior to, and during collection of the sample, including material throughput rates, material discharge frequencies, quench water flow rates and gas stream temperatures.
- description of the length of time that the ash has been exposed to air or weather prior to sampling, or whether or not it has been subjected to particle size reduction.

4.2 CHEMICAL CHARACTERISATION METHODS

Determining the intrinsic properties of the various ash streams is essential to the development of management strategies. The chemical properties of the residues are of major importance since they govern the potential for the material to interact with the environment. The chemical analysis of residue streams is com-

plicated by the complex matrix of the residues, including a significant fraction which contains alumino-silicate based compounds. Consequently, specific techniques are required to avoid interferences and generate accurate data.

Loss on Ignition

Loss on ignition (LOI) can be used as a surrogate parameter for total carbon content of bottom ash and combustion efficiency. LOI is determined based on the mass loss of a dry sample (105°C) upon exposure to 550°C for at least one hour. LOI is not a valid surrogate parameter for total carbon content in APC residues because the 550°C temperature liberates water and other condensation products sorbed onto the individual particles. This results in LOI values that are generally greater than the total carbon content for APC residues.

pH and Acid Neutralisation Capacity

Measurement of residue pH, alkalinity, and acid neutralisation capacity are important considerations when developing management scenarios. The acid neutralisation capacity test is recommended to provide all of this information by exposing the residues to varying quantities of HNO_3 (from 0 to 2 or 4 milliequivalents of acid per gram of ash) to manipulate the pH over the range of 2 - 13. The extracts are then analyzed for elemental composition and plotted against the corresponding pH.

Elemental Composition

Many methods previously recommended for "total" elemental analysis of solid samples results in only a partial recovery of specific elements or species in MSW incinerator residues. For example, nitric acid digestion, as recommended in many regulatory protocols, may result in underestimation of Al, Cr, Pb and Zn by as much as 40 - 80%. Non-destructive total analysis techniques (e.g., X-ray fluorescence, neutron activation analysis) or digestions which result in total sample dissolution (e.g., sequential nitric/perchloric/hydrofluoric acid digestions) are recommended for quantification of trace metals. Alkali fusion techniques are recommended as preparation techniques for analysis of Cl, Br, F, and SO_4.

Chemical Speciation Methods

Understanding and modelling residue leaching behaviour, long-term geochemical stability and aging reactions, as well as response to many treatment processes requires a sound understanding of the speciation of elements in the residues. Speciation is defined as the valence state of an element (i.e. Cr^{3-} or Cr^{6+}), the amorphous or mineral phase in which the element resides, and the physical particle or assemblage of phases in which the minerals exist.

A number of preparation methods are available to examine ash residues, concentrate phases, or selectively remove phases from the ash so as to allow the use of analytical spectroscopy methods to characterise the speciation. Analytical spectroscopy methods should be used to both characterise speciation in the bulk phase and at the surface of the ash particle where leaching is initiated. Some preferred methods include x-ray powder diffraction and x-ray photoelectron spectroscopy. These methods, when used in conjunction with geochemical modelling of leaching, are valuable

analytical tools in understanding leaching, geochemical stability, aging, and responses to stabilization treatment.

4.3 PHYSICAL CHARACTERISATION METHODS

The physical properties of the residue streams have a direct bearing on their handling, their potential for specific utilisation applications, and steps that may be required for the safe disposal of the material. The following parameters are provided to assist with the selection of a protocol relevant to the intended application. They are based primarily upon traditional geotechnical analytical procedures, and specific protocols along with their interpretation are discussed in the main document.

Visual examination of the material provides an indication of the extent of processing required to make the ash suitable for use and can provide initial information on the relative efficiency of the combustion process. Particle size distribution is generally determined by sieve analyses, although wet sieving of APC residues is not recommended because of the large fraction of water soluble material in these residues. The data can be related to the properties of shear strength, bearing capacity, permeability, workability, dusting and frost susceptibility. The absorption test provides another indication of potential frost susceptibility. Aggregates with a high absorptive capacity exhibit greater freeze thaw susceptibility. Hydraulic conductivity is an important parameter in determining the potential leachate flow in a disposed ash fill and for forecasting the frost susceptibility and drainage properties of residues.

Density measurements, including bulk density, dry density and specific density are important parameters in assessing the homogeneity of the material, the porosity of the particles, the bulk pore volume and the degree of compaction that can be achieved. The use of standard methods for these parameters are considered applicable to incinerator residues. The water content of a material relates to achievable field compaction levels as well as internal stability and stiffness.

Compactability using Proctor compaction is used to determine the moisture and compaction levels necessary to achieve maximum compacted densities in the field. It is also related to the internal stiffness and stability of the material. Moisture contents are important for certain construction applications where there are specified limits on water content, i.e., Portland cement concrete and asphaltic concrete applications.

Strength and strength development tests are used to determine the inclination of a landfill slope, the bearing capacity of fill built up with residues and the durability of cementitious material. These are important issues not only for disposal situations but also for the use of the materials. In addition, bearing capacity relates to the shearing resistance of the material, particularly with respect to roadway construction. Durability relates to the ability of the material to withstand weathering without disintegrating. Freeze-thaw testing or soundness tests coupled with abrasion tests are typically used.

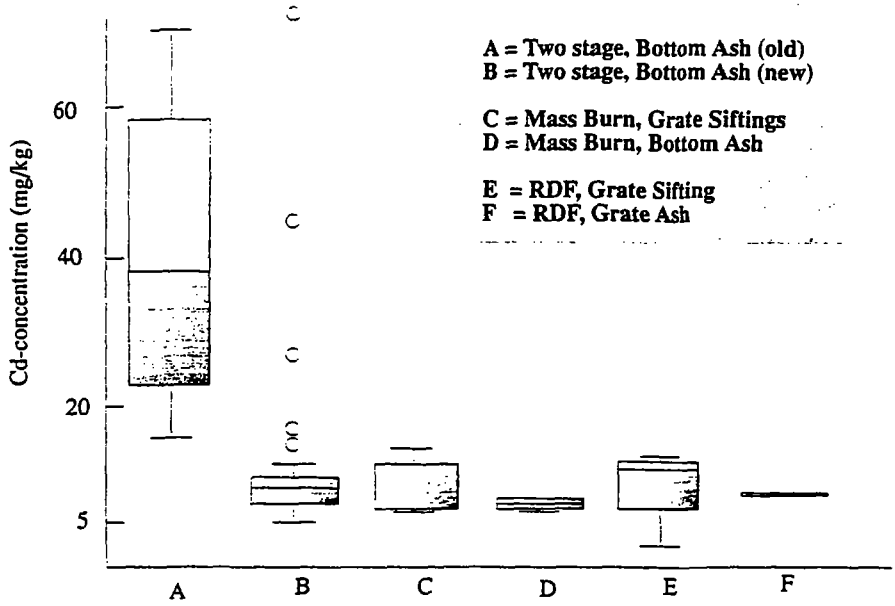
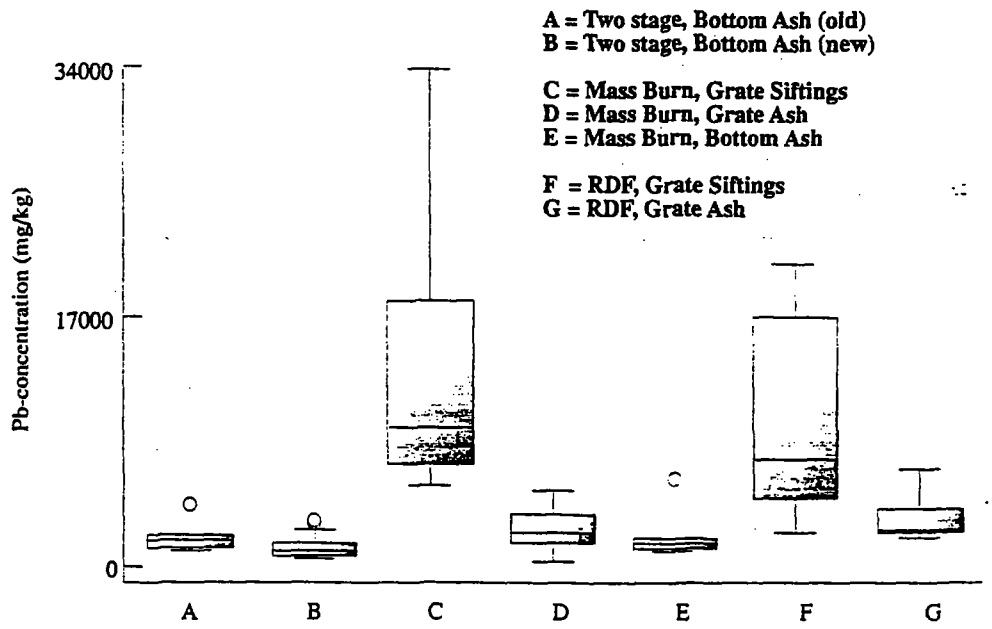


Figure 5.1 Comparison of Cadmium Concentrations in Bottom Ash, Grate Ash and Grate Siftings from Different Incinerator Designs.

Figure 5.2 Comparison of Lead Concentrations in Bottom Ash, Grate Ash and Grate Siftings from Different Incinerator Designs.



6. LEACHING

Leaching is generically defined as the dissolution of a soluble constituent from a solid phase into a solvent. Accumulated dissolved constituents in the leachant eventually comprise a leachate. The relative rate at which leaching occurs, as well as the strength of the leachate are of interest for proper ash management because leaching is a primary pathway through which environmental impact may occur. Numerous types of leaching tests have been used to predict leaching behaviour, or more correctly, specific aspects of leaching behaviour. However, the application of most leaching data has become a contentious issue, due to a misunderstanding of the objectives of the individual leach tests, and hence misinterpretation of the data. By examining some of the fundamental processes and reactions which can occur during leaching, the relationship between leaching and leaching tests can be placed into perspective.

6.1 LEACHING FUNDAMENTALS

The primary mechanisms of contaminant release from untreated residues can be different from those controlling release from "treated" residues or products containing incinerator residues. Figure 6.1 depicts the different contaminant release mechanisms in advective (fluid percolation through untreated residue) and diffusive (fluid flow around treated residue) transport scenarios. Contaminant release from untreated residues primarily is the result of percolation through the granular residues and therefore is usually dominated by solubility-controlled release. Solubility-controlled release can be described as leachate composition dictated by the partial dissolution of mineral phases that reach chemical equilibrium with the leachant. The flow of liquid past granular material enhances contact

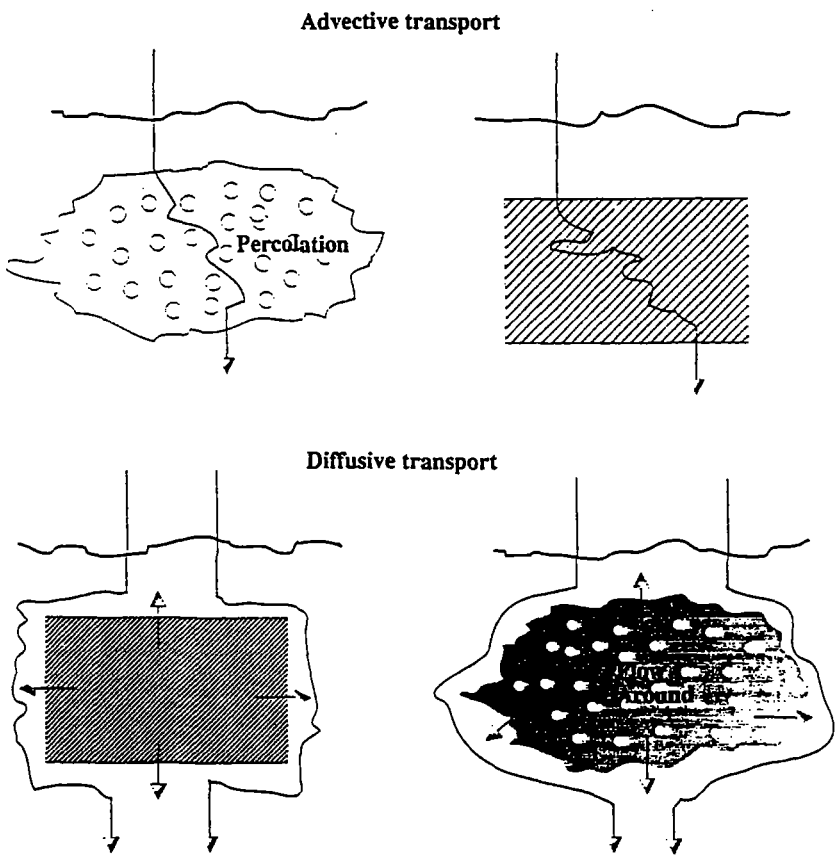


Figure 6.1 Comparison of Contaminant Release from Advective and Diffusive Transport Scenarios.

of the leachant with the solid phase, allowing chemical equilibrium to be attained. In some special instances, very soluble mineral phases can completely dissolve, resulting in the leachate composition being dictated by the available amount of the elemental compound present in the solid. This is termed availability-controlled release. Conversely, contaminant release from "treated" residues can be dominated either by percolation, or more frequently by diffusion-controlled release. Diffusion-controlled release can be described as leachate composition dictated by the extremely slow release of elemental compounds into the leachant via diffusion. It occurs when a product is either monolithic, or a granular material which has a low permeability such that it behaves as a monolith. In these instances, liquid flow is predominantly around, rather than through, the material. Hence the primary liquid-solid phase contact occurs only at the exterior boundaries of the monolith where chemical equilibrium is generally not attained. The leaching behaviour from monoliths is described in more detail later in this section.

Prior to modelling leaching, fundamental knowledge of the physical and chemical processes are required (Figure 6.2), including:

- particle morphology;
- leachant/particle hydrodynamics;
- reaction type (equilibrium versus kinetic);
- element speciation;
- influences of pH, pE (or Eh) and complexing ligands;
- sorption; and
- the role of liquid-to solid (L/S) ratio and time.

The physical aspects of leaching specifically relate to the fluid interactions

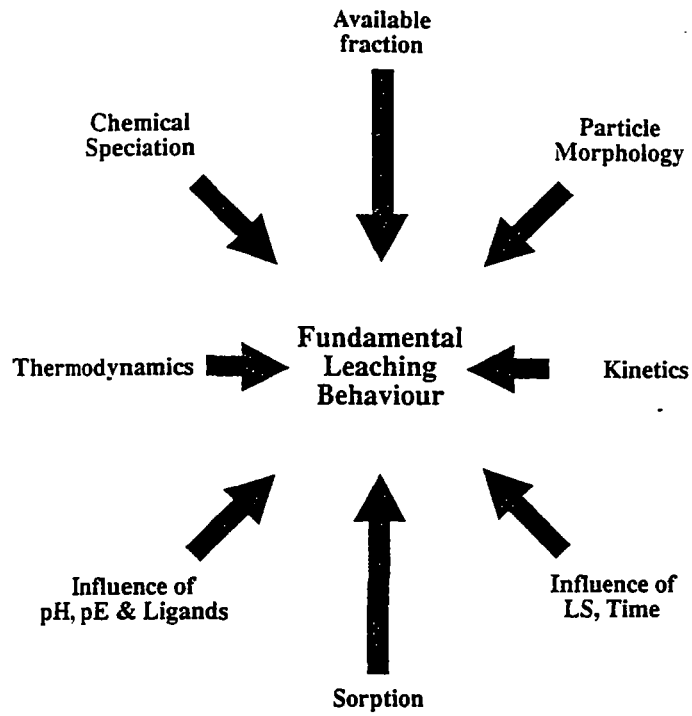


Figure 6.2 Factors Which Influence Fundamental Leaching Behaviour of Residues.

between the solid phase and leachant flowing past it. Since incinerator ash consists of discrete particles with varying sizes, geometries, internal porosities and even different pore diameter distributions, the rate of leaching will be limited by diffusional mass transfer inside the particle. Furthermore, the rate of dissolution of readily soluble phases can be limited by the relative fluid velocity past the solid/liquid boundary layers external to the particle, which in turn is dependent on the hydraulic conductivity of the ash. Consequently, these physical factors will influence whether the chemical equilibrium at the local level (i.e., at the particle surface) is attained for many of the equilibrium-based processes which occur during leaching (dissolution, precipitation, complexation, sorption/desorption). The approach used to describe these types of equilibrium reactions relies on a thermodynamic-based geochemical system that considers properties such as ionic strength, ion activity, electro-neutrality, and equilibrium

expressions derived from Gibb's free energies.

The chemical aspects of leaching include those processes which occur between the solid phase and the leachant (i.e., dissolution, precipitation, sorption) as well as within the leachate itself (complexation). Solubility-controlled leaching therefore results in saturated solutions where equilibrium has been attained between the solid and liquid phases. Availability-controlled leaching results in the total amount of an elemental compound available for leaching in a solid phase being released into the leachate.

Release as a Function of Time

Time is another important consideration with respect to leaching. Many chemical reactions (e.g., the dissolution of solid metal salts) are rapid enough that they can attain equilibrium relatively quickly (i.e., seconds to hours). Conversely, some reactions (i.e., dissolution of silicon from glassy phases) proceed at very slow rates (years to centuries) and may never reach equilibrium under normal leaching conditions. Furthermore, the rate of some reactions may be limited by the supply of a reactant, such as CO_2 (from the air or biological activity) for carbonate formation.

It is important to relate the leaching over time to the L/S ratio. The L/S ratio is defined as the volume of leachant applied to the solid residue, expressed as L/kg. This concept can be used for data from laboratory batch leach tests (L/S ratios typically between 6 and 100:1), cumulative batch tests (L/S ratios usually in increments of 10 to 20:1), or column and lysimeter test (L/S ratios usually up to 5:1). The latter tests most closely approximate the conditions observed in a disposal site, whereas the rate of leachant application is accelerated relative to in-situ conditions during the different batch tests.

Solubility-Controlled Release

Solubility-controlled leaching usually occurs at low L/S ratios (e.g., less than 20) for

- metal ions, such as Cd, at pH greater than 4.5;
- amphoteric metals, such as Pb, between a pH of 4.5 and 12; and
- oxy-anions, such as MoO_4^{-3}, at a pH less than 7.

The specific L/S ratio and pH range for solubility control is generally determined by the mineral solid phase in which an element resides. Solubility-controlled leaching can be determined by determining if the leachate concentration of an element changes as a function of pH. The final solution pH is the most significant variable influencing the leachate concentration of specific elements which are solubility-controlled. Consequently, the data generated from leach tests can vary by several orders of magnitude for some elements, depending on the pH of leachate. The solubility of Na, K, Cl and Br is independent of pH.

The presence of complexing agents in solution may also significantly increase the solubility of certain elements. The most common complexing agents present in ash are chloride and organic acids. For example, increased Cd solubility from APC residues compared to bottom ash may be influenced by the high chloride concentration in APC residues (Figure 6.3).

The leaching behaviour of individual elements tends to follow a similar pattern of solubility across the pH range of 4 - 12, irrespective of the type of ash. Moreover, groups of elements will exhibit pH dependent-solubility behaviour which is specific to that group of elements, e.g., metals compared to oxy-anions. The release versus pH curve presented in Figure 6.4 includes confidence limits for data based on the standard deviation within a small pH interval. These plots indicate that ash samples which

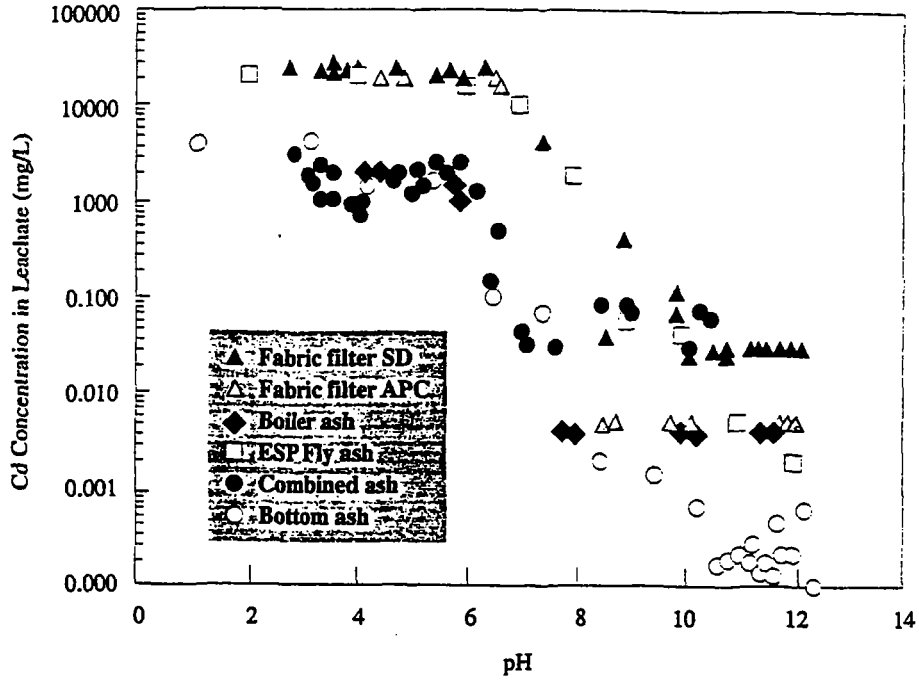


Figure 6.3 Comparison of Relative Solubilities of Cadmium from Different Incinerator Residues.

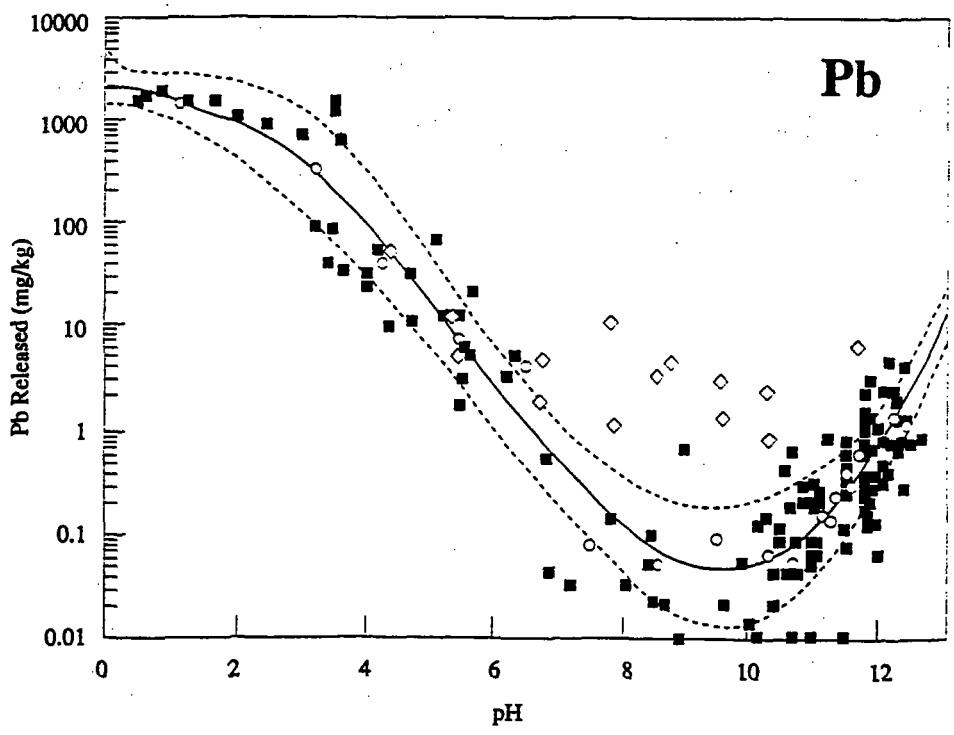


Figure 6.4 The Release of Lead From Bottom Ash as a Function of pH.

The potential release of an element is evaluated based on the element's total availability. The release rate is assessed based on diffusion estimates using measured effective diffusion coefficients and the release potential. Release mechanisms, effective diffusion coefficients, tortuosity (physical retardation factors), and chemical retardation factors are generally estimated using data from tank leaching tests on monoliths, in conjunction with data from an total availability leach test. Physical retardation factors are primarily related to the product pore structure and the density of the material, whereas the chemical retention factors (involving the sorption or coprecipitation of elements on solid surfaces) are primarily related to the interaction of the pH of pore water, acid neutralisation capacity of the solid phase and the solubility of individual elements as a function of pH.

The total availability of constituents from "treated" residues can be decreased by treatment with product additives that fill micropores and coat surfaces with hydrophobic materials, or chemically respeciate the metals. Dilution can also occur when MSW incinerator residues represent only a limited fraction of the product material. Examples of significant dilution effects include partial substitution of grate ash for aggregate in cement or asphalt materials. In these cases, the grate ash may represent from less than 10 to more than 50 wt% of the final material.

Geochemical Modelling

All of the fundamental processes discussed above can be modelled using appropriate leaching data and speciation modelling. Modelling can be a useful predictive tool which offers a number of advantages to both the regulator and scientist. Once fundamental processes such as dissolution, sorption, and solution phase complexation can be modelled, leaching behaviour under unique disposal scenarios (i.e. co-disposal) or under special treatment processes (i.e. chemical stabilization) can be described. Further, it is possible to use the model to predict behaviour in the future. Two approaches have been used to date. These include the geochemical thermodynamic equilibrium approach or the dynamic multicomponent leaching model. Special attention should be paid to the fact that ash in a disposal site or utilisation application generally does not remain under saturated conditions.

The computer-based geochemical thermodynamic equilibrium models used to date, such as MINTEQA2, GEOCHEM, PHREEQUE, SOLTEQ, EQ3/EQ6, and SOLMINEQ, hold promise for further understanding of leaching and predicting leaching behaviour. Caution is still needed in recognizing that some leaching processes are not equilibrium-based. Further, careful selection of solubility products is needed. The role of sorption, as well as the selection of appropriate sorption modelling techniques, requires further work.

6.2 LEACHING TESTS

There are many different leaching tests that can be employed, preferably in conjunction with one another, to adequately describe leaching processes. They are broadly classified as extraction tests (no leachant renewal) and dynamic tests (leachant renewal). Extraction tests are further classified as pH controlled, non-pH controlled, complexation and low LS tests. Dynamic tests are further clas-

Table 6.1. Tests for granular materials

Extraction tests

Region pH 4 -5	pH 5 - 6	Matrix Dictated	Complexation	Low LS
TCLP	Swiss TVA	DIN 38414 S4	MBLP (synth.)	MBLP
EPtox		AFNOR X-31-210	(California WET)	Modified DIN
Availability test (NEN 7341)		Canada EE		WisconcinSLT
California WET		MCC-3C (Canada)		
Ontario LEP		ASTM D 3987		
Quebec QRsQ		ILT-13		

Dynamic tests

Serial Batch (low LS)	Serial Batch LS>10	Percolation or flow through tests
UHHamburg	NF-X31-210	NEN 7343 (NVN2508) Column up flow
WRU	WRU	ASTM Column up flow
	ASTM D4793-88	Column Germany (pH static)
	NEN 7349 (NVN 2508)	Lysimeter tests
	MEP method 1320	
	Sweden ENA	
	MWEP	

Static tests	Speciation Methods
MCC-1	Sequential Chemical Extraction
MCC-2	pH stat procedures
Compacted granular tank leach test (Rutgers/ECN)	

sified as serial, batch tests with concentration build-up and high-LS or flow-through. Each of these tests has different objectives and underlying assumptions. Leaching tests from various countries are compiled in Table 6.1 according to the following broad categories: extraction tests, dynamic tests, static tests and speciation methods.

Because of the diversity of tests, it is difficult, and inaccurate, to compare the data directly without first transforming the data into the mass of an element released per mass of dry ash (mg/kg) based on the final leachate pH in batch tests. Release is calculated by multiplying the concentration of an element in the leachate by the L/S ratio.

When the results from current regulatory tests (TCLP, DIN, AFNOR, TVA, NEN) are plotted as release against pH, the data generally fits the pH/solubility curves for the specific element (Figure 6.6). This indicates that the release of elements during regulatory leach tests is primarily solubility-controlled, and that the release can be influenced by changes in ash alkalinity when the extraction final pH is not specified. The California WET test is

generate data falling outside the confidence limits represents ash exhibiting significantly different leaching characteristics than typical ashes, and that these samples should be examined more closely to try to ascertain the reason for the differences.

Availability-Controlled Release

The transition from solubility-controlled leaching to availability-controlled leaching can be observed in leaching data presented as the release of a constituent as function of pH at a constant L/S ratio. This transition is indicated by a constant solution concentration with decreasing pH (typically less than 4). Availability-controlled leaching occurs when the maximum quantity of a specific element or species that can leach is released into solution. The resulting solution (leachate) is at a concentration less than the saturation condition for the element or species of interest. This condition can be achieved through use of high L/S ratios (e.g., greater than or equal to 100), strong complexing agents (e.g., citric acid, EDTA), acidic final pH (pH less than or equal to 4) or, for amphoteric elements alkaline final pH (pH greater than 11). The specific liquid-to-solid ratio, pH domain, or, concentration of complexing agent for availability control is determined by the element or species of interest and the solubility of that element at the leaching conditions. The quantitative release of a specific element for a specific ash sample is generally independent of ash type or origin. The exception is Pb from APC residues, which often shows a maximum availability at pH greater than 11.

The total availability of specific elemental compounds is a fraction of the total concentration present in the ash and may be significantly different for different ash types. For example, the total availability of Cu and Pb is significantly greater for grate siftings than grate ash, whereas the total availability of Cd, Zn, Cl, Br and SO_4 from APC residues is generally higher than from the other ash streams. This total availability data should also be placed into context with the total mass of an element present in the different ash streams. For example:

- if the total amount of Pb available for leaching from all ash streams is about 145 grams of Pb per tonne of MSW, the equivalent of 45 g/tonne of MSW could be available from the grate ash, 70 g/tonne of MSW from the grate siftings, 0.3 g/tonne of MSW from the boiler ash, and 30 g/tonne of MSW from the APC residues.
- if the total amount of Cd available for leaching from all ash streams is about 6 kg/tonne MSW, the equivalent of 0.8 grams of MSW could be available from the grate ash, less than 0.001 grams from the grate siftings, 0.03 g from the boiler ash, and 5 grams from the APC residues.

Leaching of Treated or Utilised Residues

As mentioned earlier, diffusion and surface dissolution are the primary mechanisms by which contaminants are released from monolithic materials. Consequently, evaluating the performance of treated residue requires a somewhat different approach than that used for granular material. Although solubility as a function of pH is still a major controlling factor, the potential for release of a contaminant and the rate at which the contaminant is released is important as well.

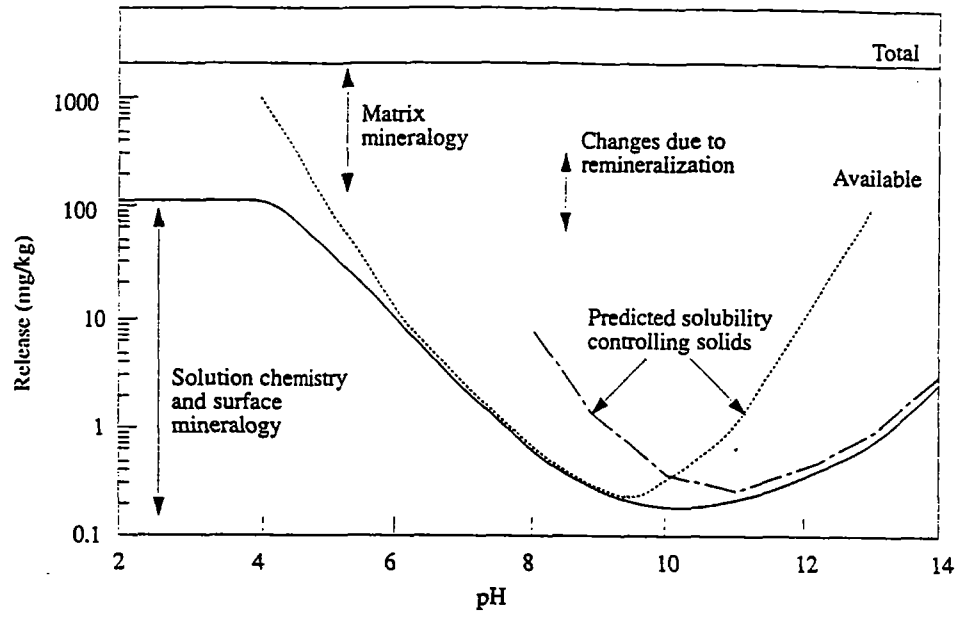


Figure 6.5 A Generic Comparison of Total Chemical Composition, Total Available Composition and pH Dependent Leaching.

an exception to pH-dependent solubility, since the citric acid used in the test results in availability-controlled leaching.

Because leaching behaviour can change dramatically over time and under different leaching conditions, it is recommended that more than one test (i.e., more than one type of extract analysis) be used to provide the information necessary to characterise the potential leaching behaviour. A general evaluation framework, or a unified approach to leaching, includes use of the total elemental composition, a total availability leaching test and pH-dependent leaching to provide reference levels for comparison (Figure 6.5). It is suggested that a series of basic characterisation leaching tests be selected, including determination of:

- the total availability for leaching;
- the elemental solubility as a function of pH; and
- the effect of increased L/S ratio or time on cumulative release.

With respect to the last set of issues, cumulative release (mg/kg) is related to the cumulative L/S ratio in cumulative batch, column or lysimeter tests. Column leaching tests are generally used to assess the release of elements or species as a function of time. The release of elements into the leachate under most environmental exposure scenarios are generally solubility-controlled. Therefore, like most leaching data, column leaching test results should be presented as release (mg/kg of ash) as a function of L/S ratio, to permit comparison to batch leaching test results (see Figure 6.6). The pH should also be monitored. The protocol might also include tests which are designed to better simulate the anticipated environmental conditions which might prevail in the repository, i.e., account for oxidising or reducing conditions, the presence of organic acids, etc.

Changes in pH as a function of L/S ratios may have significant effects on solubility, and therefore release, at L/S ratios of less than 1. For example, although the initial pH of leachate from laboratory column studies with APC residues may be neutral to moderately alkaline, the pH will rapidly increase, even at L/S ratios less than 1. This can result in the release of relatively insoluble elements. This specific effect has been observed for ESP ash, and wet, dry and semi-dry scrubber residues. Thus, it is important to indicate the leachate pH and acid neutralisation capacity curve for column leach test results.

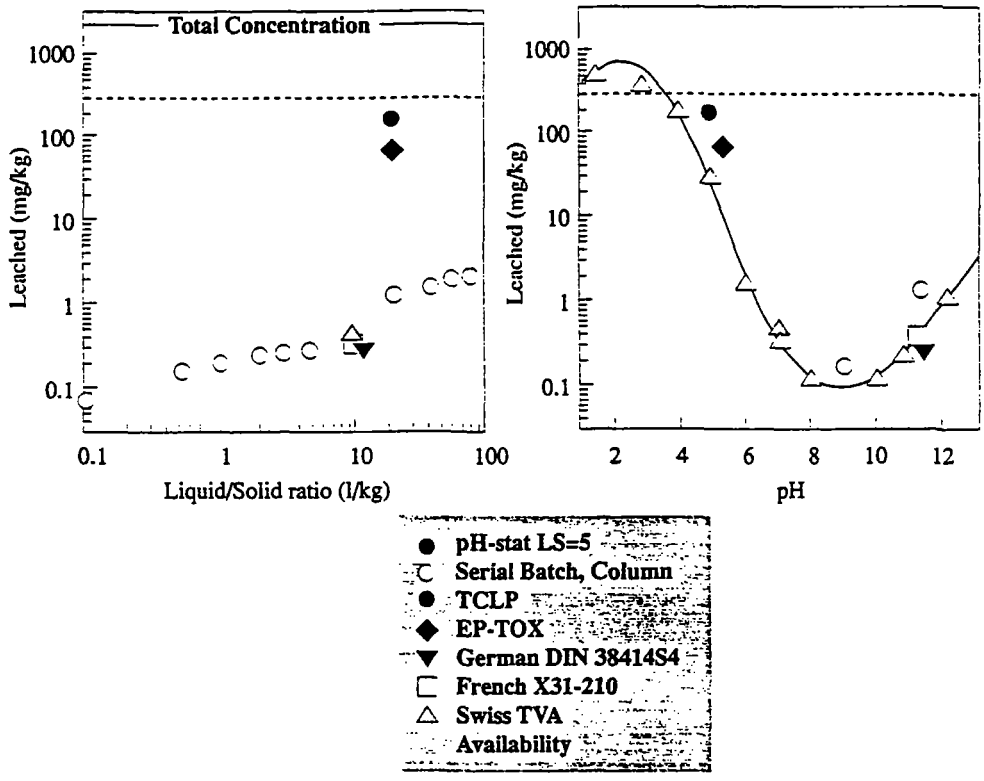


Figure 6.6 Release as a Function of pH and L/S Ratio for Different Leaching Tests. (Unified Approach)

The distinction between the wash out of very soluble phases (e.g. NaCl) versus solubility-controlled leaching of elements during column leaching tests can be discerned by plotting the cumulative release of the specific elements as a function of L/S ratio. This distinction can be derived from the slope of the cumulative release curve:

- wash out initially results in a slope greater than or equal to 1 followed by a slope of 0. Very soluble ions typically follow this pattern; and
- solubility control results in a slope of 1. Elements or species whose solubility is strongly dependent on pH typically follow this pattern.

Elemental compounds species which are the primary components of residues will generally control the release of trace species (e.g., Pb, Cd, etc.) by influencing the leachate composition and final pH. Therefore, major elements present in the residues being tested should be analyzed, in addition to the trace elements of interest. These parameters include Ca, Na, K, Cl, SO_4, CO_3, the total dissolved solids (TDS) content and total organic carbon (TOC) content. The final extract pH and alkalinity should also be determined to assist with estimating the concentration of carbonate and bi-carbonate in the leachate.

Caution should be exercised when estimating the release of elements when solubility is controlled by a second species which may be released or washed out at a lower L/S ratio. This may be the case for Ca, Cd, Ba, Cu and SO_4, with some specific examples being:

- the control of Cd solubility by the concentration of Cl;
- the control of Cu solubility by the concentration of dissolved organic carbon; and
- the control of Ba solubility by the concentration of SO_4.

The selection of leaching tests should also distinguish between testing for detailed characterisation to understand the underlying release behaviour and testing for quality control. Three categories or levels of testing can be defined:

- "Basic characterisation" tests as defined previously.
- "Compliance" tests are used to determine whether the waste com-

plies with specific reference values (i.e., regulatory tests). The tests focus on specific variables and leaching behaviour identified by some of the basic characterisation tests, however, it is important to initially characterise the leaching behaviour of the ash prior to conducting quality control tests, to better define the statistically valid "normal" range of data which could be anticipated. Since the acid neutralisation capacities of ash vary, the endpoint pH's will also vary. Hence, measuring the contaminant release in a pH region characterised by a steep release slope, may not generate directly reproducible results, but may fall within the statistically defined pH dependent leaching behaviour.

- "On-site verification" tests are used as a rapid check to confirm that the waste is the same as that which has been subjected to the compliance test(s).

Comparison of Laboratory to Field Data

The release of specific elements or compounds into leachates over a given pH range from field sampling and lysimeter studies have been shown to be similar to laboratory leaching data (Figures 6.7 and 6.8). This indicates that the solubility-controlling phases in the field are not significantly different from those in the laboratory when pH and redox effects are taken into account. Consequently, if the pH of the leaching environment is known, the concentration of elements which are solubility-controlled can be estimated for field leachates based on pH/solubility curves.

Cumulative release of specific elements under field conditions can be estimated based on knowledge of the unified pH curve, total availability, anticipated pH in the field and the anticipated L/S ratio in the field. These estimates can be refined further if the extent and effects of reducing conditions in the field are known. The release of elements under unsaturated conditions is more difficult to model. The leachate production is dependent on climatic conditions such as temperature variations and dry and rainy periods. This means that during some periods, at least in thinner layers such as in roads, the leaching may be dominated by percolation while at other times it may be dominated by diffusion.

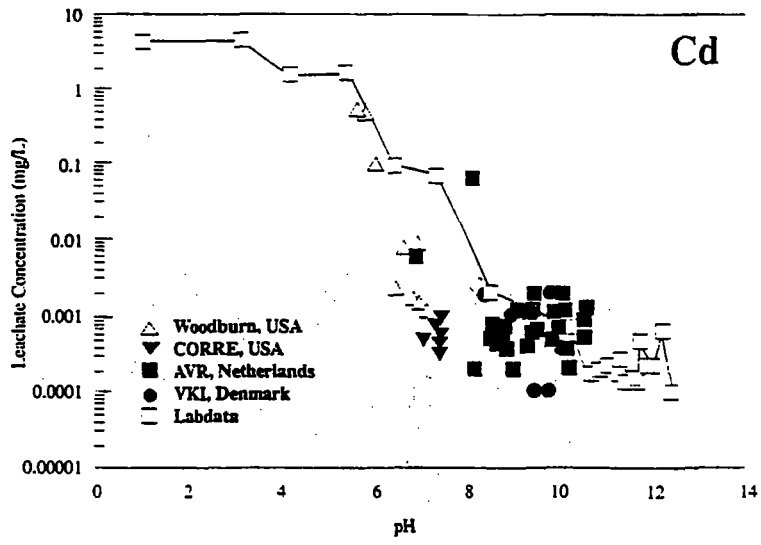


Figure 6.7 Comparison of Cadmium Solubility from Laboratory and Field Studies as a Function of pH.

Aging or weathering of ash generally results in a decrease in the observed pH of leachates from alkaline towards neutral pH. This phenomenon is the result of uptake of atmospheric or biologically generated carbon dioxide and self-neutralisation of the ash due to matrix reactions. This change in leachate pH results in decreased

solubility of many elements of interest and consequently decreased release at low L/S ratios.

Leaching Tests for "Treated" Residues

Monolith leach tests (tank leaching) should be used to determine the effective diffusion coefficients, physical retardation factors and chemical retardation factors for monolithic or "treated" residues and products. The durability of the material should also be evaluated.

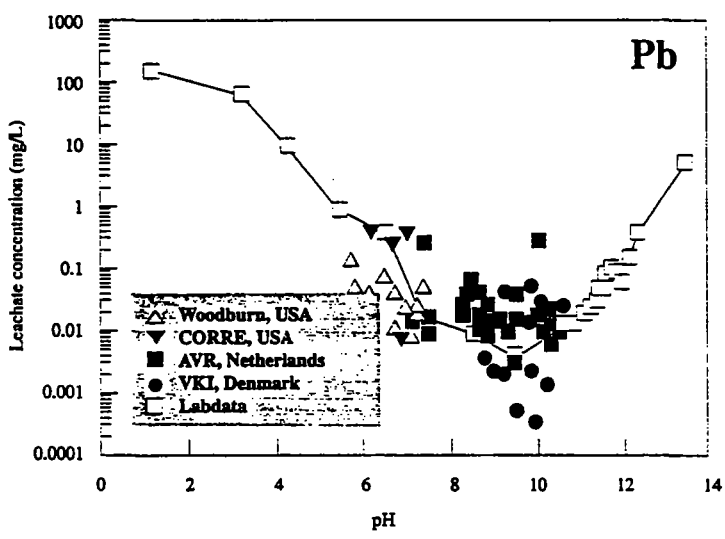


Figure 6.8 Comparison of Lead Solubility from Laboratory and Field Studies as a Function of pH.

Application of the monolith leach test for estimation of contaminant release rates assumes that contaminant concentrations in the extract solution are dilute and do not approach contaminant solubility limits. This assumption may not be true when the residue content in the product being tested is high, and leaching results should be evaluated to ensure that this test criteria is met. Increasing the liquid to surface area ratios generally ensure that there are no solubility limitations. The compacted granular leach test, which is similar to the monolithic leach test, is an applicable tool for estimation of contaminant release rates for material compacted in place to a low permeability during use or disposal, or to evaluate the effectiveness of treatment processes.

With respect to the interpretation of data from these tests, the total availability of elements (NEN 7341 test) in the treated residues and products should be determined to help assess the driving force for diffusion and the rate of diffusion-controlled release. This data can then be used in conjunction with the monolithic leach test data to calculate the effective diffusion coefficients. The total availability data is recommended instead of the total elemental concentration since the latter can result in under estimating the diffusion coefficient by up to two orders of magnitude. This is also true for the leachability index resulting from ANS 16.1 testing protocols.

EPA REGULATIONS FOR HAZARDOUS WASTE GENERATORS

(40 CFR 262; 45 FR 33142, May 19, 1980; Revised through July 1, 1991; amended at 56 FR 43705, Sept. 4, 1991; 57 FR 37263, Aug. 18, 1992; 58 FR 34370, June 25, 1993; 59 FR 62923, Dec. 6, 1994)

[*Editor's note:* Part 262 was originally promulgated at 45 FR 12732, Feb. 26, 1980.

EPA's policy outlining the use of technology-based standards over risk-based screening levels for land disposal of hazardous wastes is published in Environment Reporter — Federal Laws/Index — 1, p. 21:5061.

The Environmental Protection Agency June 25, 1993 (58 FR 34369 removed existing Office of Management and Budget (OMB) control numbers assigned to affected sections in Title 40. A new part listing current OMB control numbers (40 CFR 9) was issued by the agency May 10, 1993 (58 FR 27472) and is published in Federal Regulations—1, p. 101:0701.]

TITLE 40—PROTECTION OF ENVIRONMENT

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER I—SOLID WASTES

PART 262—STANDARDS APPLICABLE TO GENERATORS OF HAZARDOUS WASTE

Authority: 42 U.S.C. 6906, 6912, 6922(a), 6923, 6924, 6925, 6937, and 6938, unless otherwise noted.

[Amended at 56 FR 43705, Sept. 4, 1991; 57 FR 37263, Aug. 18, 1992; 59 FR 62923, Dec. 6, 1994]

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Appendix To Part 262—Uniform Hazardous Waste Manifest And Instructions (EPA Forms 8700-22 And 8700-22A And Their Instructions)

Subpart A—General

§262.10 Purpose, scope, and applicability.

(a) These regulations establish standards for generators of hazardous waste.

(b) A generator who treats, stores, or disposes of hazardous waste on-site must only comply with the following sections of this part with respect to that waste: Section 262.11 for determining whether or not he has a hazardous waste, §262.12 for obtaining an EPA identification number, §262.34 for accumulation of hazardous waste, §262.40 (c) and (d) for recordkeeping, §262.43 for additional reporting, and if applicable, §262.70 for farmers.

(c) Any person who imports hazardous waste into the United States must comply with the standards applicable to generators established in this part.

(d) A farmer who generates waste pesticides which are hazardous waste and who complies with all of the requirements of §262.70 is not required to comply with other standards in this part or 40 CFR parts 270, 264, 265, or 268 with respect to such pesticides.

(e) A person who generates a hazardous waste as defined by 40 CFR part 261 is subject to the compliance requirements and penalties prescribed in section 3008 of the Act if he does not comply with the requirements of this part.

(f) An owner or operator who initiates a shipment of hazardous waste from a treatment, storage, or disposal facility must comply with the generator standards established in this part.

NOTE 1: The provisions of §262.34 are applicable to the on-site accumulation of hazardous waste by generators. Therefore, the provisions of §262.34 only apply to owners or operators who are shipping hazardous waste which they generated at that facility.

NOTE 2: A generator who treats, stores, or disposes of hazardous waste on-site must comply with the applicable standards and permit requirements set forth in 40 CFR parts 264, 265, 266, 268, and 270.

[Sec. 262.10(f)]

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§262.11 Hazardous waste determination.

A person who generates a solid waste, as defined in 40 CFR 261.2, must determine if that waste is a hazardous waste using the following method:

(a) He should first determine if the waste is excluded from regulation under 40 CFR 261.4.

(b) He must then determine if the waste is listed as a hazardous waste in subpart D of 40 CFR part 261.

NOTE: Even if the waste is listed, the generator still has an opportunity under 40 CFR 260.22 to demonstrate to the Administrator that the waste from his particular facility or operation is not a hazardous waste.

(c) For purposes of compliance with 40 CFR part 268, or if the waste is not listed in subpart D of 40 CFR part 261, the generator must then determine whether the waste is identified in subpart C of 40 CFR part 261 by either:

(1) Testing the waste according to the methods set forth in subpart C of 40 CFR part 261, or according to an equivalent method approved by the Administrator under 40 CFR 260.21; or

(2) Applying knowledge of the hazard characteristic of the waste in light of the materials or the processes used.

(d) If the waste is determined to be hazardous, the generator must refer to parts 264, 265, 268 of this chapter for possible exclusions or restrictions pertaining to management of his specific waste.

§262.12 EPA identification numbers.

(a) A generator must not treat, store, dispose of, transport, or offer for transportation, hazardous waste without having received an EPA identification number from the Administrator.

(b) A generator who has not received an EPA identification number may obtain one by applying to the Administrator using EPA form 8700-12. Upon receiving the request the Administrator will assign an EPA identification number to the generator.

(c) A generator must not offer his hazardous waste to transporters or to treatment, storage, or disposal facilities that have not received an EPA identification number.

Subpart B—The Manifest

§262.20 General requirements.

(a) A generator who transports, or offers for transportation, hazardous waste for offsite treatment, storage, or disposal must prepare a Manifest OMB control number 2050-0039 on EPA form 8700-22, and, if necessary, EPA form 8700-22A, according to the instructions included in the appendix to part 262.

(b) A generator must designate on the manifest one facility which is permitted to handle the waste described on the manifest.

(c) A generator may also designate on the manifest one alternate facility which is permitted to handle his waste in the event an emergency prevents delivery of the waste to the primary designated facility.

(d) If the transporter is unable to deliver the hazardous waste to the designated facility or the alternate facility, the generator must either designate another facility or instruct the transporter to return the waste.

(e) The requirements of this subpart do not apply to hazardous waste produced by generators of greater than 100 kg but less than 1000 kg in a calendar month where:

(1) The waste is reclaimed under a contractual agreement pursuant to which:

(i) The type of waste and frequency of shipments are specified in the agreement;

(ii) The vehicle used to transport the waste to the recycling facility and to deliver regenerated material back to the generator is owned and operated by the reclaimer of the waste; and

(2) The generator maintains a copy of the reclamation agreement in his files for a period of at least three years after termination or expiration of the agreement.

§262.21 Acquisition of manifests.

(a) If the State to which the shipment is manifested (consignment State) supplies the manifest and requires its use, then the generator must use that manifest.

(b) If the consignment State does not supply the manifest, but the State in which the generator is located (generator State) supplies the manifest and requires its use, then the generator must use that State's manifest.

(c) If neither the generator State nor the consignment State supplies the manifest, then the generator may obtain the manifest from any source.

§262.22 Number of copies.

The manifest consists of at least the number of copies which will provide the generator, each transporter, and the owner or operator of the designated facility with one copy each for their records and another copy to be returned to the generator.

§262.23 Use of the manifest.

(a) The generator must:

(1) Sign the manifest certification by hand; and

(2) Obtain the handwritten signature of the initial transporter and date of acceptance on the manifest; and

(3) Retain one copy, in accordance with §262.40(a).

(b) The generator must give the transporter the remaining copies of the manifest.

(c) For shipments of hazardous waste within the United States solely by water (bulk shipments only), the generator must send three copies of the manifest dated and signed in accordance with this section to the owner or operator of the designated facility or the last water (bulk shipment) transporter to handle the waste in the United States if exported by water. Copies of the manifest are not required for each transporter.

(d) For rail shipments of hazardous waste within the United States which originate at the site of generation, the generator must send at least three copies of the manifest dated and signed in accordance with this section to:

(1) The next non-rail transporter, if any; or

(2) The designated facility if transported solely by rail; or

(3) The last rail transporter to handle the waste in the United States if exported by rail.

(e) For shipments of hazardous waste to a designated facility in an authorized State which has not yet obtained authorization to regulate that particular waste as hazardous, the generator must assure that the designated facility agrees to sign and return the manifest to the generator, and that any out-of-state transporter signs and forwards the manifest to the designated facility.

NOTE: See §263.20(e) and (f) for special provisions for rail or water (bulk shipment) transporters.

Subpart C—Pre-Transport Requirements

§262.30 Packaging.

Before transporting hazardous waste or offering hazardous waste for transportation off-site, a generator must package the waste in accordance with the applicable Department of Transportation regulations on packaging under 49 CFR parts 173, 178, and 179.

[Sec. 262.30]

(ii) No more than 2.5 centimeters (one inch) of residue remain on the bottom of the container or inner liner, *or*

(iii) (A) No more than 3 percent by weight of the total capacity of the container remains in the container or inner liner if the container is less than or equal to 110 gallons in size, or

(B) No more than 0.3 percent by weight of the total capacity of the container remains in the container or inner liner if the container is greater than 110 gallons in size.

(2) A container that has held a hazardous waste that is a compressed gas is empty when the pressure in the container approaches atmospheric.

(3) A container or an inner liner removed from a container that has held an acute hazardous waste listed in §§261.31, 261.32, or 261.33(e) is empty if:

(i) The container or inner liner has been triple rinsed using a solvent capable of removing the commercial chemical product or manufacturing chemical intermediate;

(ii) The container or inner liner has been cleaned by another method that has been shown in the scientific literature, or by tests conducted by the generator, to achieve equivalent removal; or

(iii) In the case of a container, the inner liner that prevented contact of the commercial chemical product or manufacturing chemical intermediate with the container, has been removed.

261.8 PCB wastes regulated under Toxic Substance Control Act.

The disposal of PCB-containing dielectric fluid and electric equipment containing such fluid authorized for use and regulated under part 761 of this chapter and that are hazardous only because they fail the test for the Toxicity Characteristic (Hazardous Waste Codes D018 through D043 only) are exempt from regulation under parts 261 through 265, and parts 268, 270, and 124 of this chapter, and the notification requirements of section 3010 of RCRA.

Subpart B—Criteria for Identifying the Characteristics of Hazardous Waste and for Listing Hazardous Waste

§261.10 Criteria for identifying the characteristics of hazardous waste.

(a) The Administrator shall identify and define a characteristic of hazardous waste in subpart C only upon determining that:

(1) A solid waste that exhibits the characteristic may:

(i) Cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or

(ii) Pose a substantial present or potential hazard to human health or the environment when it is improperly treated, stored, transported, disposed of or otherwise managed; and

(2) The characteristic can be:

(i) Measured by an available standardized test method which is reasonably within the capability of generators of solid waste or private sector laboratories that are available to serve generators of solid waste; or

(ii) Reasonably detected by generators of solid waste through their knowledge of their waste.

§261.11 Criteria for listing hazardous waste.

(a) The Administrator shall list a solid waste as a hazardous waste only upon determining that the solid waste meets one of the following criteria:

(1) It exhibits any of the characteristics of hazardous waste identified in subpart C.

(2) It has been found to be fatal to humans in low doses or, in the absence of data on human toxicity, it has been shown in studies to have an oral LD 50 toxicity (rat) of less than 50 milligrams per kilogram, an inhalation LC 50 toxicity (rat) of less than 2 milligrams per liter, or a dermal LD 50 toxicity (rabbit) of less than 200 milligrams per kilogram or is otherwise capable of causing or significantly contributing to an increase in serious irreversible, or incapacitating reversible, illness. (Waste listed in accordance with these criteria will be designated Acute Hazardous Waste.)

(3) It contains any of the toxic constituents listed in appendix VIII and, after considering the following factors, the Administrator concludes that the waste is capable of posing a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise managed:

[§261.11(a)(3) introductory text amended at 57 FR 14, Jan. 2, 1992]

(i) The nature of the toxicity presented by the constituent.

(ii) The concentration of the constituent in the waste.

(iii) The potential of the constituent or any toxic degradation product of the constituent to migrate from the waste into the environment under the types of improper management considered in paragraph (a)(3)(vii) of this section.

(iv) The persistence of the constituent or any toxic degradation product of the constituent.

(v) The potential for the constituent or any toxic degradation product of the constituent to degrade into non-harmful constituents and the rate of degradation.

(vi) The degree to which the constituent or any degradation product of the constituent bioaccumulates in ecosystems.

(vii) The plausible types of improper management to which the waste could be subjected.

(viii) The quantities of the waste generated at individual generation sites or on a regional or national basis.

(ix) The nature and severity of the human health and environmental damage that has occurred as a result of the improper management of wastes containing the constituent.

(x) Action taken by other governmental agencies or regulatory programs based on the health or environmental hazard posed by the waste or waste constituent.

(xi) Such other factors as may be appropriate.

Substances will be listed on appendix VIII only if they have been shown in scientific studies to have toxic, carcinogenic, mutagenic or teratogenic effects on humans or other life forms.

(Wastes listed in accordance with these criteria will be designated Toxic wastes.)

(b) The Administrator may list classes or types of solid waste as hazardous waste if he has reason to believe that individual wastes, within the class or type of waste, typically or frequently are hazardous under the definition of hazardous waste found in section 1004(5) of the Act.

(c) The Administrator will use the criteria for listing specified in this section to establish the exclusion limits referred to in §261.5(c).

Subpart C—Characteristics of Hazardous Waste

§261.20 General.

(a) A solid waste, as defined in §261.2, which is not excluded from regulation as a hazardous waste under §261.4(b), is a hazardous waste if it exhibits any of the characteristics identified in this subpart.

Comment: §262.11 of this chapter sets forth the generator's responsibility to determine whether his waste exhibits one or more of the characteristics identified in this subpart

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(b) A hazardous waste which is identified by a characteristic in this subpart is assigned every EPA Hazardous Waste Number that is applicable as set forth in this subpart. This number must be used in complying with the notification requirements of section 3010 of the Act and all applicable recordkeeping and reporting requirements under parts 262 through 265, 268, and 270 of this chapter.

(c) For purposes of this subpart, the Administrator will consider a sample obtained using any of the applicable sampling methods specified in appendix I to be a representative sample within the meaning of part 260 of this chapter.

Comment: Since the appendix I sampling methods are not being formally adopted by the Administrator, a person who desires to employ an alternative sampling method is not required to demonstrate the equivalency of his method under the procedures set forth in §§260.20 and 260.21.

§261.21 Characteristic of ignitability.

(a) A solid waste exhibits the characteristic of ignitability if a representative sample of the waste has any of the following properties:

(1) It is a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume and has flash point less than 60°C (140°F), as determined by a Pensky-Martens Closed Cup Tester, using the test method specified in ASTM Standard D-93-79 or D-93-80 (incorporated by reference, see §260.11), or a Setaflash Closed Cup Tester, using the test method specified in ASTM Standard D-3278-78 (incorporated by reference, see §260.11), or as determined by an equivalent test method approved by the Administrator under procedures set forth in §§260.20 and 260.21.

(2) It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.

(3) It is an ignitable compressed gas as defined in 49 CFR 173.300 and as determined by the test methods described in that regulation or equivalent test methods approved by the Administrator under §§260.20 and 260.21.

(4) It is an oxidizer as defined in 49 CFR 173.151.

(b) A solid waste that exhibits the characteristic of ignitability has the EPA Hazardous Waste Number of D001.

§261.22 Characteristic of corrosivity.

(a) A solid waste exhibits the characteristic of corrosivity if a representative sample of the waste has either of the following properties:

(1) It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5, as determined by a pH meter using Method 9040 in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, as incorporated by reference in §260.11 of this chapter.

[§261.22(a)(1) revised at 58 FR 46049, Aug. 31, 1993]

(2) It is a liquid and corrodes steel (SAE 1020) at a rate greater than 6.35 mm (0.250 inch) per year at a test temperature of 55°C (130°F) as determined by the test method specified in NACE (National Association of Corrosion Engineers) Standard TM-01-69 as standardized in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, as incorporated by reference in §260.11 of this chapter.

[§261.22(a)(2) revised at 58 FR 46049, Aug. 31, 1993]

(b) A solid waste that exhibits the characteristic of corrosivity has the EPA Hazardous Waste Number of D002.

§261.23 Characteristic of reactivity.

(a) A solid waste exhibits the characteristic of reactivity if a representative sample of the waste has *any* of the following properties:

(1) It is normally unstable and readily undergoes violent change without detonating.

(2) It reacts violently with water.

(3) It forms potentially explosive mixtures with water.

(4) When mixed with water, it generates toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.

(5) It is a cyanide or sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment.

(6) It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.

(7) It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.

(8) It is a forbidden explosive as defined in 49 CFR 173.51, or a Class A explosive as defined in 49 CFR 173.53 or a Class B explosive as defined in 49 CFR 173.88.

(b) A solid waste that exhibits the characteristic of reactivity has the EPA Hazardous Waste Number of D003.

§261.24 Toxicity characteristic.

(a) A solid waste exhibits the characteristic of toxicity if, using the Toxicity Characteristic Leaching Procedure, test Method 1311 in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, as incorporated by reference in §260.11 of this chapter, the extract from a representative sample of the waste contains any of the contaminants listed in table 1 at the concentration equal to or greater than the respective value given in that table. Where the waste contains less than 0.5 percent filterable solids, the waste itself, after filtering using the methodology outlined in Method 1311, is considered to be the extract for the purpose of this section.

statistical definition is not one but rather the set of grab or auto samples

[§261.24(a) revised at 58 FR 46049, Aug. 31, 1993]

(b) A solid waste that exhibits the characteristic of toxicity has the EPA Hazardous Waste Number specified in Table I which corresponds to the toxic contaminant causing it to be hazardous.

Table 1-Maximum Concentration of Contaminants for the Toxicity Characteristic

EPA HW No.[1]	Contaminant	CAS No.[2]	Regulatory Level (mg/L)
D004	Arsenic	7440-38-2	5.0
D005	Barium	7440-39-3	100.0
D018	Benzene	71-43-2	0.5
D006	Cadmium	7440-43-9	1.0
D019	Carbon tetrachloride	56-23-5	0.5
D020	Chlordane	57-74-9	0.03
D021	Chlorobenzene	108-90-7	100.0
D022	Chloroform	67-66-3	6.0
D007	Chromium	7440-47-3	5.0.
D023	o-Cresol	95-48-7	[4]200.0
D024	m-Cresol	108-39-4	[4]200.0
D025	p-Cresol	106-44-5	[4]200.0
D026	Cresol		[4]200.0
D016	2,4-D	94-75-7	10.0
D027	1,4-Dichlorobenzene	106-46-7	7.5
D028	1,2-Dichloroethane	107-06-2	0.5
D029	1,1-Dichloroethylene	75-35-4	0.7
D030	2,4-Dinitrotoluene	121-14-2	[3]0.13
D012	Endrin	72-20-8	0.02
D031	Heptachlor (and its epoxide)	76-44-8	0.008
D032	Hexachlorobenzene	118-74-1	[3]0.13
D033	Hexachlorobutadiene	87-68-3	0.5
D034	Hexachloroethane	67-72-1	3.0
D008	Lead	7439-92-1	5.0
D013	Lindane	58-89-9	0.4
D009	Mercury	7439-97-6	0.2
D014	Methoxychlor	72-43-5	10.0
D035	Methyl ethyl ketone	78-93-3	200.0
D036	Nitrobenzene	98-95-3	2.0
D037	Pentrachlorophenol	87-86-5	100.0
D038	Pyridine	110-86-1	[5]5.0
D010	Selenium	7782-49-2	1.0

Table 1-Maximum Concentration of Contaminants for the Toxicity Characteristic

EPA HW No.[1]	Contaminant	CAS No.[2]	Regulatory Level (mg/L)
D011	Silver	7440-22-4	5.0
D039	Tetrachloroethylene	127-18-4	0.7
D015	Toxaphene	8001-35-2	0.5
D040	Trichloroethylene	79-01-6	0.5
D041	2,4,5-Trichlorophenol	95-95-4	400.0
D042	2,4,6-Trichlorophenol	88-06-2	2.0
D017	2,4,5-TP (Silvex)	93-72-1	1.0
D043	Vinyl chloride	75-01-4	0.2

[1] Hazardous waste number.
[2] Chemical abstracts service number.
[3] Quantitation limit is greater than the calculated regulatory level. The quantitation limit therefore becomes the regulatory level.
[4] If o-, m-, and p-Cresol concentrations cannot be differentiated, the total cresol (D026) concentration is used. The regulatory level of total cresol is 200 mg/l.

Subpart D—Lists of Hazardous Wastes

§261.30 General.

(a) A solid waste is a hazardous waste if it is listed in this subpart, unless it has been excluded from this list under §§260.20 and 260.22.

(b) The Administrator will indicate his basis for listing the classes or types of wastes listed in this subpart by employing one or more of the following Hazard Codes:

Ignitable Waste	(I)
Corrosive Waste	(C)
Reactive Waste	(R)
Toxicity Characteristic Waste	(E)
Acute Hazardous Waste	(H)
Toxic Waste	(T)

Appendix VII identifies the constituent which caused the Administrator to list the waste as a Toxicity Characteristic Waste (E) or Toxic Waste (T) in §§261.31 and 261.32.

(c) Each hazardous waste listed in this subpart is assigned an EPA Hazardous Waste Number which precedes the name of the waste. This number must be used in complying with the notification requirements of Section 3010 of the Act and certain recordkeeping and reporting requirements under parts 262 through 265, 268, and part 270 of this chapter.

(d) The following hazardous wastes listed in §261.31 or §261.32 are subject to the exclusion limits for acutely hazardous wastes established in §261.5: EPA Hazardous Wastes Nos. FO20, FO21, FO22, FO23, FO26, and FO27.

§261.31 Hazardous wastes from non-specific sources.

(a) The following solid wastes are listed hazardous wastes from non-specific sources unless they are excluded under §§260.20 and 260.22 and listed in appendix IX.

Industry and EPA hazardous waste No.	Hazardous waste	Hazard code
Generic:		
F001	The following spent halogenated solvents used in degreasing: Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; all spent solvent mixtures/blends used in degreasing containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents or those solvents listed in F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures	(T)
F002	The following spent halogenated solvents: Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichlorobenzene, trichlorofluoromethane, and 1,1,2-trichloroethane; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents or those listed in F001, F004, or F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures	(T)
F003	The following spent non-halogenated solvents: Xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; all spent solvent mixtures/blends containing, before use, only the above spent non-halogenated solvents; and all spent solvent mixtures/blends containing, before use, one or more of the above non-halogenated solvents, and, a total of ten percent or more (by volume) of one or more of those solvents listed in F001, F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures	(I)*
F004	The following spent non-halogenated solvents: Cresols and cresylic acid, and nitrobenzene; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures	(T)
F005	The following spent non-halogenated solvents: Toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, benzene, 2-ethoxyethanol, and 2-nitropropane; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, or F004; and still bottoms from the recovery of these spent solvents and spent solvent mixtures	(I,T)

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(10) The name and model numbers of the instrument(s) used in performing the tests;

(11) QA/QC documentation; and

(12) The following statement signed by the generator or his authorized representative:

I certify under penalty of law that all process equipment required to be cleaned or replaced under 40 CFR 261.35 was cleaned or replaced as represented in the equipment cleaning and replacement plan and accompanying documentation. I am aware that there are significant penalties for providing false information, including the possibility of fine or imprisonment.

EFFECTIVE DATE NOTE: At 55 FR 50482, Dec. 6, 1990, §261.35 was added. Paragraph (c) contains information collection and recordkeeping requirements and will not become effective until approval has been given by the Office of Management and Budget. A notice will be published in the FEDERAL REGISTER once approval has been obtained.

APPENDICES TO PART 261

APPENDIX I— REPRESENTATIVE SAMPLING METHODS

The methods and equipment used for sampling waste materials will vary with the form and consistency of the waste materials to be sampled. Samples collected using the sampling protocols listed below, for sampling waste with properties similar to the indicated materials, will be considered by the Agency to be representative of the waste.

Extremely viscous liquid—ASTM Standard D140-70 Crushed or powdered material—ASTM Standard D346-75 Soil or rock-like material—ASTM Standard D420-69 Soil-like material—ASTM Standard D1452-65

Fly Ash-like material—ASTM Standard D2234-76 [ASTM Standards are available from ASTM, 1916 Race St., Philadelphia, PA 19103]

Containerized liquid wastes-"COLIWASA" described in "Test Methods for the Evaluation of Solid Waste, Physical/Chemical Methods,"[1a] U.S. Environmental Protection Agency, Office of Solid Waste, Washington, D.C. 20460. [Copies may be obtained from Solid Waste Information, U.S. Environmental Protection Agency, 26 W. St. Clair St., Cincinnati, Ohio 45268]

Liquid waste in pits, ponds, lagoons, and similar reservoirs.—"Pond Sampler" described in "Test Methods for the Evaluation of Solid Waste, Physical/Chemical Methods."[1a]

This manual also contains additional information on application of these protocols.

[1a]These methods are also described in "Samplers and Sampling Procedures for Hazardous Waste Streams," EPA 600/2-80-018, January 1980.

APPENDIX II—METHOD 1311 TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP)

Note: The TCLP (Method 1311) is published in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, as incorporated by reference in §260.11 of this chapter.

[Appendix II revised at 58 FR 46049, Aug. 31, 1993]

APPENDIX III—CHEMICAL ANALYSIS TEST METHODS

Note: Appropriate analytical procedures to determine whether a sample contains a given toxic constituent are specified in Chapter Two, "Choosing the Correct Procedure" found in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," EPA Publication SW-846, as incorporated by reference in §260.11 of this chapter. Prior to final sampling and analysis method selection, the individual should consult the specific section or method described in SW-846 for additional guidance on which of the approved methods should be employed for a specific sample analysis situation.

[Appendix III revised at 58 FR 46049, Aug. 31, 1993]

APPENDIX IV—[RESERVED FOR RADIOACTIVE WASTE TEST METHODS]

APPENDIX V—[RESERVED FOR INFECTIOUS WASTE TREATMENT SPECIFICATIONS]

APPENDIX VI—[RESERVED FOR ETIOLOGIC AGENTS]

APPENDIX VII— BASIS FOR LISTING HAZARDOUS WASTE

EPA hazardous waste No.	Hazardous constituents for which listed
F001	Tetrachloroethylene, methylene chloride trichloroethylene, 1,1,1-trichloroethane, carbon tetrachloride, chlorinated fluorocarbons.
F002	Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trichfluoroethane, ortho-dichlorobenzene, trichlorofluoromethane.
F003	N.A.
F004	Cresols and cresylic acid, nitrobenzene.
F005	Toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, 2-ethoxyethanol, benzene, 2-nitropropane.
F006	Cadmium, hexavalent chromium, nickel, cyanide (complexed).
F007	Cyanide (salts).
F008	Cyanide (salts).
F009	Cyanide (salts).
F010	Cyanide (salts).
F011	Cyanide (salts).
F012	Cyanide (complexed).
F019	Hexavalent chromium, cyanide (complexed).
F020	Tetra- and pentachlorodibenzo-p-dioxins; tetra and pentachlorodi-benzofurans; tri- and tetrachlorophenols and their chlorophenoxy derivative acids, esters, ethers, amine and other salts.
F021	Penta- and hexachlorodibenzo-p-dioxins; penta- and hexachlorodibenzofurans; pentachlorophenol and its derivatives.
F022	Tetra-, penta-, and hexachlorodibenzo-p-dioxins; tetra-, penta-, and hexachlorodibenzofurans.
F023	Tetra-, and pentachlorodibenzo-p-dioxins; tetra- and pentachlorodibenzofurans; tri- and tetrachlorophenols and their chlorophenoxy derivative acids, esters, ethers, amine and other salts.
F024	Chloromethane, dichloromethane, trichloromethane, carbon tetrachloride, chloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, trans-1-2-dichloroethylene, 1,1-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethylene, 1,1,1,2-tetra-chloroethane, 1,1,2,2-tetrachloroethane, tetrachloroethylene, pentachloroethane, hexachloroethane, allyl chloride (3-chloropropene), dichloropropane, dichloropropene, 2-chloro-1,3-butadiene, hexachloro-1,3-butadiene, hexachlorocyclopentadiene, hexachlorocyclohexane, benzene, chlorbenzene, dichlorobenzenes, 1,2,4-trichlorobenzene, tetrachlorobenzene, pentachlorobenzene, hexachlorobenzene, toluene, naphthalene.
F025	Chloromethane; Dichloromethane; Trichloromethane; Carbon tetrachloride; Chloroethylene; 1,1-Dichloroethane; 1,2-Dichloroethane; trans-1,2-Dichloroethylene; 1,1-Dichloroethylene; 1,1,1-Trichloroethane; 1,1,2-Trichloroethane; Trichloroethylene; 1,1,1,2-Tetrachloroethane; 1,1,2,2-Tetrachloroethane; Tetrachloroethylene; Pentachloroethane; Hexachloroethane; Allyl chloride (3-Chloropropene); Dichloropropane; Dichloropropene; 2-Chloro-1,3-butadiene; Hexachloro-1,3-butadiene; Hexachlorocyclopentadiene; Benzene; Chlorobenzene; Dichlorobenzene; 1,2,4-Trichlorobenzene; Tetrachlorobenzene; Pentachlorobenzene; Hexachlorobenzene; Toluene; Naphthalene.
F026	Tetra-, penta-, and hexachlorodibenzo-p-dioxins; tetra-, penta-, and hexachlorodibenzofurans.
F027	Tetra-, penta-, and hexachlorodibenzo-p-dioxins; tetra-, penta-, and hexachlorodibenzofurans; tri-, tetra-, and pentachlorophenols and their chlorophenoxy derivative acids, esters, ethers, amine and other salts.