2 Jul
Atlanta, Ga

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

File 16/7

REGION IV
**345 COURTLAND STREET
ATLANTA, GEORGIA 30365**

DER

JUL 2 1987

4APT/APB-ljf

JUL 6 1987

BAQM

Mr. Thomas M. Henderson, Project Director
Broward County Resource Recovery Office
115 South Andrews Avenue, Room 521
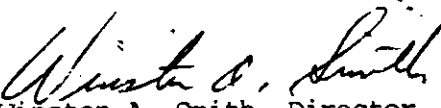Fort Lauderdale, Florida 33301

Re: South Broward Resource Recovery Facility Permit
   (PSD-FL-105)

Dear Mr. Henderson:

This is to notify you that no petitions have been filed with the Administrator regarding the above-issued Prevention of Significant Deterioration (PSD) permit which you received on May 20, 1987, for the above-referenced municipal solid waste incineration facility located in Broward County, Florida. Therefore, in accordance with the provisions of the above permit, the effective date is June 20, 1987. If construction does not commence within eighteen (18) months after this effective date, or if construction is discontinued for a period of eighteen (18) months or more, or if construction is not completed within a reasonable time, this permit shall expire and authorization to construct shall become invalid.

Please direct any questions you may have to Mr. Wayne Aronson, Chief, Program Support Section, of my staff at (404) 347-2864.

Sincerely,

Winston A. Smith, Director
Air, Pesticides, & Toxics
   Management Divison

cc: Mr. Clair Fancy

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV
345 COURTLAND STREET
ATLANTA, GEORGIA 30365

MAY 1 5 1987

APT-APB/eaw

DER
MAY 18 1987
BAQM

<u>CERTIFIED MAIL</u>
<u>RETURN RECEIPT REQUESTED</u>

Mr. Thomas M. Henderson
Project Director
Broward County Resource Recovery Office
115 South Andrews Avenue, Room 521
Ft. Lauderdale, Florida 33301

Re: South Broward Resource Recovery Facility (PSD-FL-105)

Dear Mr. Henderson:

Review of your May 30, 1986, application to construct a three unit,
323.6 mmBTU/hr (each) heat input, mass burn, municipal solid waste
fired, energy recovery facility in Broward County, Florida, has
been completed. The construction is subject to rules for the
Prevention of Significant Deterioration (PSD) of air quality con-
tained in 40 CFR §52.21. The Florida Department of Environmental
Regulation (FDER) performed the preliminary determination concern-
ing the proposed construction and published a request for public
comment on February 12, 1987. No public comments were received
during the public comment period. On May 1, 1987, the Environmental
Protection Agency (EPA) prepared a final determination recommending
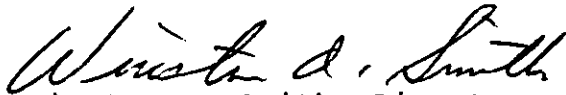issuance of the PSD permit by EPA.

EPA has determined that the construction as described in the appli-
cation meets all the applicable requirements of 40 CFR §52.21.
Accordingly, pursuant to 40 CFR §124.15, the Regional Administrator
has made a final decision to issue the enclosed <u>Permit to Construct:
Part I. - Specific Conditions and Part II. - General Conditions.</u>
This authority to construct, granted as of the effective date of
the permit, is based solely on the requirements of 40 CFR §52.21,
air quality. It does not apply to other permits issued by this
Agency or by other agencies. Please be advised that a violation of
any permit condition, as well as any construction which proceeds in
material variance with information contained in the final determi-
nation, will be subject to enforcement action.

This final permit decision is subject to appeal under 40 CFR
§124.19 by petitioning the Administrator of the EPA within thirty
(30) days after receipt thereof. The petitioner must submit a
statement of reasons for the appeal and the Administrator must
decide on the petition within a reasonable time period. If the
petition is denied, the permit shall become effective upon notice
of such action to the parties to the appeal. If no appeal is

filed with the Administrator, the permit shall become effective thirty (30) days after receipt of this letter. Upon the expiration of the thirty (30) day period, EPA will notify you of the status of the permit's effective date.

Receipt of this letter does not constitute authority to construct. Approval to construct this three unit, mass burn, municipal solid waste fired, energy recovery facility shall be granted as of the effective date of the permit. The complete analysis which justifies this approval has been fully documented for future reference, if necessary. Any questions concerning this approval may be directed to Mr. Bruce Miller, Chief, Air Programs Branch at (404) 347-2864.

Sincerely yours,

Winston A. Smith, Director
Air, Pesticides, and Toxics
    Management Division

Enclosure

cc: Mr. Steve Smallwood, P.E., Chief
     Bureau of Air Quality Management
     Florida Department of Environmental
      Regulation

PERMIT TO CONSTRUCT UNDER THE RULES FOR THE
PREVENTION OF SIGNIFICANT DETERIORATION OF AIR QUALITY

Pursuant to and in accordance with the provisions of Part C, Subpart 1 of the Clean Air Act, as amended, 42 U.S.C. §7470 et. seq., and the regulations promulgated thereunder at 40 CFR §52.21, as amended at 45 Fed. Reg. 52676, 52735-41 (August 7, 1980),

South Broward County Resource Recovery Facility

is, as of the effective date of this permit (PSD-FL-105) authorized to construct a resource recovery facility consisting of three 863 ton per day (maximum capacity) mass burn, municipal solid waste incinerators and appurtenances at the following location:

> On a 248 acre tract at the southeast intersection of State Road 84 and U.S. Route 441 in Broward County, Florida.

Upon completion of authorized construction and commencement of operation/production, this stationary source shall be operated in accordance with the emission limitations, sampling requirements, monitoring requirements and other conditions set forth in the attached Part I.-Specific Conditions and Part II.-General Conditions.

> This permit is hereby issued on MAY 15 1987 and shall become effective thirty (30) days after receipt hereof unless a petition for administrative review is filed with the Administrator during that time. If a petition is filed any applicable effective date shall be determined in accordance with 40 CFR §124.19(f)(1).

If construction does not commence within 18 months after the effective date of this permit, or if construction is discontinued for a period of 18 months or more, or if construction is not completed within a reasonable time, this permit shall expire and authorization to construct shall become invalid.

This authorization to construct shall not relieve the owner or operator of the responsibility to comply fully with all applicable provisions of Federal, State, and local law.

May 15, 1987
Date Signed

Jack E. Ravan
Regional Administrator

PART I. – Specific Conditions

1. Emission Limitations

    a. Stack emissions from each unit shall not exceed the following:

    Particulate: 0.0150 gr/dscf dry volume corrected to 12% CO_2.

    Sulfur Dioxide: (1) 0.140 lb/mmBtu heat input and 60 ppm (3-hr rolling average, dry volume, corrected to 12% CO_2); or

    (2) 65% reduction of uncontrolled SO_2 emissions.* In no case shall the SO_2 emissions exceed 0.310 lb/mmBtu heat input and 124 ppm (3-hr rolling average, dry volume, corrected to 12% CO_2).

    The 124 ppm limit above shall be modified to reflect a new emission limit (in ppm) from the control device at 65% control efficiency. Within 18 months of start-up of operation, the County shall submit compliance tests that will be used to determine the new SO_2 emission limit (in ppm). The limit will be determined by observed average emission rate ($\bar{x}$) from the submitted compliance tests and will be statistically analyzed using the one tailed student T test ($t_{.05} = (\bar{x} - u) \sqrt{n}/s$) at the 95% confidence level to derive a mean emission rate (u), where s is the standard deviation of observed values n. The final operating SO_2 emission limit (in ppm) shall be this mean emission rate (u). This value shall be restricted to no more than 124 ppm or less than 60 ppm (3-hr rolling average, dry volume, corrected to 12% CO_2).

    Nitrogen Oxides: .560 lb/mmBtu heat input and 350 ppm (3-hr rolling average, dry volume, corrected to 12% CO_2).

    Carbon Monoxide: .090 lb/mmBtu heat input; 400 ppm (1-hr rolling average, dry volume, corrected to 12% CO_2); and 88 ppm (4-day rolling average, dry volume, corrected to 12% CO_2).

    Lead: .00150 lb/mmBtu

    Fluorides: .0040 lb/mmBtu

    Beryllium: 9.30 x 10^{-7} lb/mmBtu

    Mercury: 7.50 x 10^{-4} lb/mmBtu

---

* Uncontrolled SO_2 emissions will be measured at the inlet to the acid gas control device.

Visible Emissions: Opacity of stack emissions shall not be greater than 15% opacity. Excess opacity resulting from startup or shut-down shall be permitted providing (1) best operational practices to minimize emissions are adhered to and (2) the duration of excess opacity shall be minimized but in no case exceed two hours in any 24-hour period unless specifically authorized by EPA for longer duration.

Excess emissions which are caused entirely or in part by poor main-tenance, poor operation, or any other equipment or process failure which may reasonably be prevented during start-up or shutdown shall be prohibited.

The units are subject to 40 CFR Part 60, Subpart E and Subpart Db, New Source Performance Standards (NSPS), except that where requirements in this permit are more restrictive, the requirements in this permit shall apply.

There shall be no greater than 10% opacity for emissions from the refuse bunker and the ash handling and loadout. The potential for dust genera-tion by ash handling activities will be mitigated by quenching the ash prior to loading in ash transport trucks. Additionally, all portions of the proposed facility, including the ash handling facility, which have the potential for fugitive emissions will be enclosed. Also, those areas which have to be open for operational purposes, (e.g., tipping floor of the refuse bunker while trucks are entering and leaving) will be under negative air pressure.

b. Only distillate fuel oil or natural gas shall be used in startup burners. The annual capacity factor for use of natural gas and oil, as determined by 40 CFR 60.43b(d), shall be less than 10%. If the annual capacity factor of natural gas is greater than 10%, then the facility shall be subject to §60.44b.

c. None of the three individual municipal solid waste incinerators shall be charged in excess of 323.6 mmBtu/hr and 863 tons per day MSW (115% rated capacity) nor produce in excess of 192,000 lbs/hr of steam (3-hr rolling average).

d. Compliance Tests

(1) a. Annual compliance tests for particulate matter, lead, SO_2, nitrogen oxides, CO, fluorides, mercury, and beryllium shall be conducted in accordance with 40 CFR 60.8 (a), (b), (d), (e), and (f).

b. Compliance with the opacity standard for the incinerator stack emissions in condition 1.a. of this part shall be determined in accordance with 40 CFR 60.11 (b) and (e).

c. Compliance with the emission limitation for 65% control of total sulfur dioxide emissions shall be determined by using the test methods in condition 1.d.(2) and sampling for SO_2 emissions before and after the acid gas control device. Continuous emissions data shall also be used to demonstrate compliance with the SO_2 concentration limits in condition 1.a. above.

(2) The following test methods and procedures for 40 CFR Parts 60 and 61 shall be used for compliance testing:

a. Method 1 for selection of sample site and sample traverses.

b. Method 2 for determining stack gas flow rate when converting concentrations to or from mass emission limits.

c. Method 3 for gas analysis for calculation of percent O_2 and CO_2.

d. Method 4 for determining stack gas moisture content to convert the flow rate from actual standard cubic feet to dry standard cubic feet for use in converting concentrations in dry gases to or from mass emission limits.

e. Method 5 for concentration of particulate matter and associated moisture content. One sample shall constitute one test run.

f. Method 9 for visible determination of the opacity of emissions.

g. Method 6 for concentration of SO_2. Two samples, taken at approximately 30 minute intervals, shall contitute one test run.

h. Method 7 for concentration of nitrogen oxides. Four samples, taken at approximately 15 minute intervals, shall constitute one test run.

i. Method 10 for determination of CO concentrations. One sample constitutes one test run.

j. Method 12 for determination of lead concentration and associated moisture content. One sample constitutes one test run.

k. Method 13B for determination of fluoride concentrations and associated moisture content. One sample shall constitute one test run.

l. Method 101A for determination of mercury emission rate and associated moisture content. One sample shall constitute one test run.

m. Method 104 for determination of beryllium emission rate and associated moisture content. One sample shall constitute one test run.

2. Compliance with emission limitations specified in lb/mmBtu in conditions 1.a. and 1.c. of this part shall be determined by calculating an "F" factor in dscf/mmBtu corrected to 12% CO_2 using the boilers' efficiency (as determined by the calorimeter method contained in Attachment A during acceptance testing) and the measured steam production. Data obtained from test methods required in condition 1.d. of this part for compliance testing shall be used for the calculation of the "F" factor required by this condition.

3. Devices shall be installed to continuously monitor and record steam production. These devices shall be adequately maintained and operating during all periods of steam production.

4. The height of each boiler exhaust stack shall not be less than 59.4 meters above ground level at the base of the stack.

5. Each incinerator boiler shall have a metal name plate affixed in a conspicuous place on the shell showing manufacturer, model number, type waste, rated capacity, and certification number.

6. The permittee must submit to EPA and DER, within fifteen (15) days after it becomes available to the County, copies of technical data pertaining to the incinerator boiler design, acid gas control equipment design, particulate control equipment design, and the fuel mix that will be used to evaluate compliance of the facility with the preceeding emission limitations.

7. Fuel

   The Resource Recovery Facility shall utilize refuse such as garbage and trash (as defined in Chapter 17-7, FAC) but not grease, scum, grit screenings or sewage sludge.

8. Air Pollution Control Equipment

   The permittee shall install, continuously operate, and maintain the following air pollution controls to minimize emissions. Controls listed shall be fully operational upon startup of the proposed equipment.

   a. Each boiler shall be equipped with a particulate emission control device for the control of particulates.

   b. Each boiler shall be equipped with an acid gas control device designed to remove at least 90% of the acid gases.

9. Continuous Emission Monitoring

   a. Prior to the date of startup and thereafter, the County shall install, maintain, and operate the following continuous monitoring systems for each boiler exhaust stack:

      (1) Continuous emission monitoring (CEM) systems to measure stack gas opacity and SO_2, NO_x, CO, CO_2, and O_2 concentrations for each unit.

Continuous monitors for SO_2 shall be installed after the acid gas control device for each unit. The systems shall meet the EPA monitoring performance specifications of 40 CFR 60.13 and 40 CFR 60, Appendix B, during initial compliance testing and annually thereafter. Additionally, CEM's shall meet the quality control requirements of 40 CFR 60, Appendix F (Attachment B).

(2) CEM data recorded during periods of startup, shutdown, and malfunction shall be reported but excluded from compliance averaging periods for CO, NO_x, and opacity.

(3) a. CEM data recorded during periods of startup and shutdown shall be excluded from compliance averaging periods for SO_2.

   b. CEM data recorded during periods of acid gas control device malfunctions shall be excluded from compliance averaging periods for SO_2 provided that the preceeding thirty day period which ends on the last day of the malfunction period meets an average SO_2 emission limit equal to the SO_2 limit specified in condition 1.a. CEM data must be available for 90% of the operating time for this exemption to apply. A malfunction as used in this permit means any sudden and unavoidable failure of air pollution control equipment or process equipment or of a process to operate in a normal or usual manner. Failures that are caused entirely or in part by poor maintenance, careless operation, or any other preventable upset condition or preventable equipment breakdown shall not be considered malfunctions.

b. An excess emissions report shall be submitted to EPA for every calendar quarter. The report shall include the following:

(1) The magnitude of excess emissions computed in accordance with 40 CFR 60.13(h), any conversion factors used, and the date and time of commencement and completion of each period of excess emissions (60.7(c)(1)).

(2) Specific identification of each period of excess emissions that occurs during startups, shutdowns, and malfunctions of the furnace/boiler system. The nature and cause of any malfunction (if known) and the corrective action taken or preventive measures adopted shall also be reported (60.7(c)(2)).

(3) The date and time identifying each period during which the continuous monitoring system was inoperative except for zero and span checks, and the nature of the system repairs or adjustments (60.7(c)(3)).

(4) When no excess emissions have occurred or the continuous monitoring system has not been inoperative, repaired, or adjusted, such information shall be stated in the report (60.7(c)(4)).

(5) County shall maintain a file of all measurements, including continuous monitoring systems performance evaluations; all continuous monitoring systems or monitoring device calibrartion checks; adjustments and maintenance performed on these systems or devices; and all other information required by this permit recorded in a permanent form suitable for inspection (60.7(d)).

(6) Excess emissions shall be defined as any applicable period during which the average emissions of CO, NO_x, and/or SO_2, as measured by the continuous monitoring system, exceeds the CO, NO_x, and/or SO_2 maximum emission limit (in ppm) set for each pollutant in condition 1.a. above.

c. Excess emissions indicated by the CEM systems shall be considered violations of the applicable opacity limit or operating emission limits (in ppm) for the purposes of this permit provided the data represents accurate emission levels and the CEM's do not exceed the calibration drift (as specified in the respective performance specification tests) on the day when initial and subsequent compliance is determined. The burden of proof to demonstrate that the data does not reflect accurate emission readings shall be the responsibility of the permittee.

10. Reporting

a. A copy of the results of the compliance tests shall be submitted within forty-five days of testing to the DER Bureau of Air Quality Management, the DER Southeast Florida District Office, Broward County, and EPA Region IV.

b. Continuous emissions monitoring data shall be reported to the DER Southeast District Office and EPA Region IV on a quarterly basis in accordance with Section 17-2.710, FAC, and 40 CFR 60.7.

c. Addresses for submitting reports are:

EPA Region IV

   Chief, Air Compliance Branch
   U.S. Environmental Protection Agency
   345 Courtland Street, N.E.
   Atlanta, Georgia   30365

Florida Department of Environmental Regulation (DER)

Deputy Chief, Compliance and Ambient Monitoring
Bureau of Air Quality Management
Florida Department of Environmental
  Regulation (DER)
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32301

Southeast District Office of DER

District Manager
Department of Environmental Regulation
3301 Gun Club Road
P.O. Box 3858
West Palm Beach, Florida 33402

Broward County

Broward County Environmental Quality
  Control Board
500 Southwest 14th Court
Ft. Lauderdale, Florida 33315

PART II. - General Conditions

1. The permittee shall comply with the notification and record-keeping require-
   ments codified at 40 CFR Part 60.7. In addition, the permittee shall pro-
   vide EPA with 30 days notice prior to conducting any compliance testing
   required under condition 1.a.

2. The permittee shall retain records of all information resulting from
   monitoring activities and information indicating operation parameters
   as specified in the specific conditions of this permit for a minimum
   of two (2) years from the date of recording.

3. If, for any reason, the permittee does not comply with or will not be
   able to comply with the emission limitations specified in this permit,
   the permittee shall provide EPA with the following information in writing
   within five (5) days of such condition:

   (a) description of noncomplying emission(s),
   (b) cause of noncompliance,
   (c) anticipated time the noncompliance is expected to continue or, if
        corrected, the duration of the period of noncompliance,
   (d) steps taken by the permittee to reduce and eliminate the noncomplying
        emission.

   Failure to provide the above information when appropriate shall constitute
   a violation of the terms and conditions of this permit. Submittal of the
   aforementioned information does not constitute a waiver of the emission
   limitations contained within this permit.

4. Any proposed change in the information contained in the final determina-
   tion regarding facility emissions or changes in the quantity or quality of
   materials processed that would result in new or increased emissions or ambient
   air quality impact must be reported to EPA. If appropriate, modifications to
   the permit may then be made by EPA to reflect any necessary changes in the
   permit conditions. In no case are any new or increased emissions allowed
   that will cause violation of the emission limitations specified herein. Any
   contruction or operation of the source in material variance with the final
   determination shall be considered a violation of this permit.

5. In the event of any change in control of ownership of the source described in
   the permit, the permittee shall notify the succeeding owner of the existence
   of this permit and EPA of the change in control of ownership within 30 days.

6. The permittee shall allow representatives of the state and local environ-
   mental control agency or representatives of the EPA, upon presentation of
   credentials:

(a) to enter upon the permittee's premises, or other premises under the control of the permittee, where an air pollutant source is located or in which any records are required to be kept under the terms and conditions of this permit;

(b) to have access to and copy at reasonable times any records required to be kept under the terms and conditions of this permit, or the Clean Air Act;

(c) to inspect at reasonable times any monitoring equipment or monitoring method required in this permit;

(d) to sample at reasonable times any emissions of pollutants; and

(e) to perform at reasonable times an operation and maintenance inspection of the permitted source.

7. The conditions of this permit are severable, and if any provision of this permit or the application of any provisions of this permit to any circumstances is held invalid, the application of such provision to other circumstances and the remainder of this permit shall not be affected.

ATTACHMENT A

AN EXAMINATION OF PROPOSED ACCEPTANCE TESTING METHODS

K. E. GRIGGS
Department of the Army
U.S. Army Construction Engineering Research Laboratory
Champaign, Illinois

ABSTRACT

This paper describes test procedures proposed to be used to determine the acceptance or operational performance of solid waste incinerators with heat recovery. The throughput capacity of the heat recovery incinerator, volume and mass reduction, environmental emissions, and overall thermal efficiency are used as performance indicators.

To develop the performance test, the manufacturers of heat recovery incinerators (HRI's) were contacted to obtain literature describing their products. The literature was reviewed to determine the characteristics that manufacturers use to describe their HRI's, and to learn general operating procedures and conditions. The Power Test Codes of the American Society of Mechanical Engineers (ASME) were reviewed to see whether they could be used for testing HRI's. In addition, the proposals presented at the last three National Waste Processing Conferences were also reviewed. Four efficiency test procedures—the input-output, heat-loss, modified heat-loss, and calorimeter methods—were identified from this information, along with an alternate concept of separate combustion efficiency and thermal energy recovery testing. Recommendations are made as to what should be considered as the "standard" for acceptance testing, based upon a user's perspective.

INTRODUCTION

The Resource Conservation and Recovery Act of 1976 recommended the use of recovered-material derived fuels to the maximum extent practical in Federally owned fossil fuel fired energy systems. To fulfill the intent of this Act and to take advantage of possible energy cost savings, the Army has undertaken the task of installing heat recovery incinerators (HRI's) at various installations throughout the continental United States. To provide planning guidance for such HRI installations, the U.S. Army Construction Engineering Research Laboratory (USA–CERL) has developed several publications [1–3]. Currently, HRI's are operational at Fort Eustis, Virginia, Fort Leonard Wood, Missouri, Fort Rucker, Alabama, and Redstone Arsenal, Alabama. By 1990, it is expected that waste may be burned at over 15 Army installations.

Unlike other large-scale equipment, such as coal- or oil-fired boilers, no standard performance test is currently available to assess field performance or to use as an acceptance test specifically for HRI plants. Within the Army, Directorates of Engineering and Housing (DEH's) and District Engineers need standard performance test procedures to trouble-shoot HRI systems and to ensure that new HRI's meet waste throughput and efficiency specifications before the systems are accepted and turned over to the DEH for operation.

233

Manufacturers of HRI's were contacted to obtain literature describing their incinerators. The literature was reviewed to determine the characteristics that manufacturers use to describe their products, and to learn general operating procedures and conditions. The American Society of Mechanical Engineers (ASME) Power Test Codes (PTC 4.1 and PTC 33) were reviewed to see whether they could be used for testing HRI's. The Naval Civil Engineering Laboratory procedures in HRI testing were reviewed for applicable testing information. It was determined that the basis, or core, of the acceptance test should be the repeated ability to demonstrate that the unit will operate at the specified thermal efficiency while simultaneously achieving the rated throughput capacity, weight and volume reduction, steam (or other thermal) output, and environmental emissions. While thermal efficiency (the ability to release the theoretical heat energy available in a useful form) can not be the sole criteria for acceptance, it is the best single indicator of the correctness of design and quality of manufacture.

The Army's requirement is for an acceptance test developed for HRI's in the range of 20–100 TPD (18–91 tpd) of solid waste. Tests for compliance with clean air requirements are defined by local, State, and Federal agencies. It is intended that new HRI's meet stipulated capacity, volume and weight reduction and efficiency guarantees while operating in compliance with clean air requirements. Therefore, the test procedures must be conducted concurrently with environmental testing, assuring compliance with air emission standards during normal operation.

Unfortunately, no matter how rigorous an acceptance test is, the performance standards that the HRI is required to meet must be clearly and completely defined in the project specifications. The test itself will not prevent or correct problems that previous HRI projects have encountered. However, the test procedures described in this paper will reveal the existence of these problems.

ELEMENTS OF A GOOD ACCEPTANCE TEST

The question of an appropriate and accurate HRI acceptance test is a matter that has been discussed in technical papers at the three ASME National Waste Processing Conferences in 1980, 1982, and 1984 [4–7]. The acceptance testing of an HRI is a very complex issue due to both the variability of the quality (heat content versus moisture and noncombustibles) of the

refuse and the variety of technologies used to burn it, some of which are still developing. The simplest acceptance test would be to see if the HRI could produce the rated amount of steam when firing the rated amount of refuse and supplementary fuel (if required). Unfortunately, this does not take into consideration possible variations in the heat content (Btu/lb) of the waste which may allow a poorly operating unit to still make its rated steam output (high Btu waste) or may prohibit a well operating unit from making its rated steam output (low Btu waste) at the rated mass firing rate. There seems to be a general consensus by most investigators, in this area, that thermal efficiency is the best indicator of quality of performance, since it takes into consideration the heat content of the waste stream.

However, none of the investigators that have reported at the conferences referenced above, has directly addressed the problem of how much the thermal efficiency of the various HRI technologies may change due to "off design" operation as a result of burning waste of a quality other than that specified. The main controversy seems to be the method (and the degree of effort) that should be the standard in determining that thermal efficiency. Much of this controversy is prompted by the difficulty in determining the Higher Heating Value (HHV) of the waste. The various proposals that were made, have had the implied aim of minimizing the effect of this uncertainty. Very little effort has been made to develop automated equipment for more economic and accurate determination of the waste HHV. The National Bureau of Standards (NBS) has developed a calorimeter for "large", kilogram size RDF pellets. However, the methods for making this determination are still very labor intensive and involve the collection and processing of large amounts of waste in order to achieve a reasonable accuracy.

In addition to the above, it must not be forgotten that thermal efficiency can not be the sole criterion for acceptance, although it may be the central part or core of testing. The plant must also have the capability of processing the design amount of waste, produce acceptable environmental emissions, discharge ash that exhibits the desired volume and mass reductions, and do all of this reliably. The plant must be able to do all of these things, including demonstrating an acceptable thermal efficiency, at the same time. USA–CERL is currently recommending that acceptance testing consist of three 24 hr runs conducted within 5 days in order to demonstrate reliability. With the exception of thermal efficiency testing, all of the above criteria have very specific and well defined methods of being measured.

THERMAL EFFICIENCY TESTING PROCEDURES

The efficiency testing procedures described in this paper can serve two purposes. First, they may be used as the basis of an acceptance test to establish whether a specific system has complied with the capacity, volume and mass reduction, and efficiency criteria in the specification under which it was purchased. Second, these tests can be used as a periodic performance evaluation indicating when abnormally high inefficiencies are occurring. In this instance, the test is conducted regularly and the information is compared with that from previous tests. Reduced thermal efficiency may also indirectly indicate the possibility of environmental emission problems. This comparison may be made because of the common procedure and data base.

To accomplish these tasks, four thermal efficiency testing procedures have been identified, along with an alternate concept of separate combustion efficiency and thermal energy recovery testing. The primary procedures are the input–output, the heat-loss, the modified heat-loss, and the calorimeter methods. Figure 1 provides a very simplified illustration of most of the factors that must be considered in utilizing these methods. They are discussed in detail in the previously referenced papers [4–7] and are described by the following equations:

Input–output method:

Thermal efficiency (%)

$$= \frac{\text{Useful Heat Output}}{\text{Heat Input}} \times 100 \quad (1)$$

Heat-loss method:

Thermal efficiency (%)

$$= \left(1 - \frac{\text{Losses}}{\text{Heat Input}}\right) \times 100 \quad (2)$$

Modified heat-loss method:

Thermal efficiency (%)

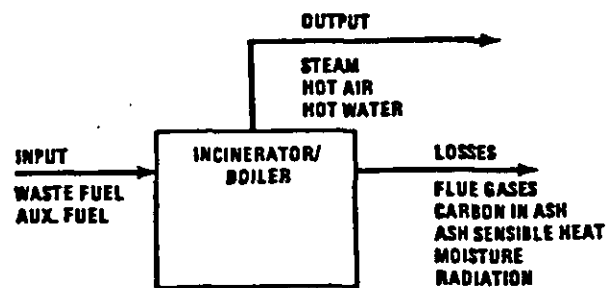$$= \left(1 - \frac{\text{Major Losses}}{\text{Heat Input}}\right) \times 100 \quad (3)$$

FIG. 1 ENERGY FLOW

Calorimeter method:

Thermal efficiency (%)

$$= \left(\frac{\text{Useful Heat Output}}{\text{Useful Heat Output + Losses}}\right) \times 100 \quad (4)$$

INPUT-OUTPUT

As the name input–output implies, only the energy inputs and the useful energy outputs are measured. The main disadvantage with this method is the accurate determination of the heat content of the waste. This normally involves the collection of large amounts of waste and making the determination based upon many laboratory analyses, sorting the waste into its components, or making a visual estimation. This method of efficiency determination is essentially based upon the very definition of thermal efficiency. However, it will only indicate that a problem exists and does nothing to define the problem.

The main advantage of the input–output method is that it is the simplest of the four. Much of the required instrumentation should already exist as a part of the system's normal operating controls. Moreover, there is a requirement for less data and laboratory analysis than with the other methods; except for the modified heat loss method, which is also the least accurate. The only method that has the potential for more accuracy than the input–output method is the calorimeter method, which is also very complex.

HEAT LOSS

The heat-loss method, which is also sometimes (erroneously) referred to as the heat-balance method, is less accurate than the input–output method. This

method involves the measurement of heat losses from the system, such as sensible and latent heat in the flue gas, sensible heat in the ash, combustible material in the ash, radiation and convection from the incinerator and boiler surfaces, latent heat from evaporation of ash quench water, and heat contained in boiler blow-down. This method varies from the calorimeter and input–output methods in that the useful energy output is not measured, but the total heat input is measured and some smaller heat losses may be partially estimated. The accuracy of this method is variable, based upon the number of the losses estimated and the accuracy of that estimation. In addition, this method is also affected by the accuracy of the determination of the heat content of the waste, as noted above; and the accuracy of the determination of the moisture in the flue gas, which will have a large impact upon the gas latent heat losses. The results of a heat-loss determination will never agree (in practice) with the results of the input–output method (based upon coal fired boiler experience), although the difference may be as little as 2%.

While the heat-loss method is more difficult and potentially less accurate than the input–output method, its advantage is that it does provide more useful information. For example, if an incinerator system is not operating efficiently, this method should show where the excessive losses are (e.g., unburned carbon in the residue, high exit gas temperature, etc.). Hence, this method is most valuable in identifying operating and maintenance problems, and preferred by many engineers for all types of fossil fuel fired facilities.

SHORT FORM (MODIFIED) HEAT LOSS

The least accurate method is the modified or "short form" of the heat-loss determination. This method was proposed by Hecklinger and Grillo in 1982 [5] and based upon earlier recommendations by Stabenow in 1980 [4]. Although it is the least accurate, it is also extremely simple and quick. It is based upon the assumption that the major heat loss in the system is up the stack and normally involves taking only O_2 and temperature measurements on the stack gases in addition to measuring the fuel firing rate. This is a good assumption for oil/gas fired boilers and is reasonable for most of the larger coal fired boilers where efficient combustion of the fuel is very certain and the amount of moisture in these gases is low and well defined. With the thermal efficiency calculation depending so heavily on so few measurements, the highly variable and generally larger amounts of moisture in the stack gases

from an HRI can have a large impact on the results, as noted above in the discussion of the heat loss method. Additionally, incomplete combustion of the waste can result in losses as significant as the stack losses as demonstrated by some of the operating instances at Fort Knox and Fort Eustis where labels and other paper goods were readable after going through the incinerator. This can be compensated for by measuring the ash production rate and the carbon content of the ash. Unfortunately, that would make this method almost as complex, but still less accurate than the input–output method. However, this method could be used for day-to-day comparative indications of changes in thermal efficiency that may require more detailed investigation. It could also be used to monitor the results of changes associated with the operating crew and/or maintenance procedures.

CALORIMETER

The most rigorous method (which is used in Europe) is to use the HRI as a continuous calorimeter. The calorimeter method is much more complex than any of the other methods. It involves doing a complete mass and energy balance around the HRI, with the only unknown being the heat content of the waste stream. This involves a very large number of measurements (some of which can be quite tedious, such as heat loss to ash quench water including evaporation) and much more instrumentation than normally found on all but the largest HRI's. Essentially, all of the losses associated with the heat-loss method, and the energy output measurements associated with the input–output method, must be actually made, and not estimated. If these measurements are made carefully with accurate instrumentation, this method would produce the most accurate results, and avoid the problem of determining the heat content of the waste. However, the measurement of the total moisture of the flue gas is still a major problem at this time, since the traditional EPA Method 5 only involves grab samples. The amount of this moisture can be quite significant if internal sprays are used to cool the combustion zone, the waste is very wet, and/or a quench, ash cooling system is used that is not isolated from the combustion zone. In addition, the potential improvement in accuracy over the input–output method is not significant (0.73% [7]) based upon the size range and lack of sophistication of typical Army HRI plants.

Due to the complexity involved, the not yet totally resolved question of measuring the moisture in the flue gas, and a relatively small increase in accuracy, this

method is not considered appropriate for the size and type of HRI plants the Army would typically build. Starved air technology (the most common type of plant), specifically, is not sufficiently developed to warrant this level of accuracy, and additional instrumentation would have to be supplied (at a significant additional cost), especially for the testing. However, this method would be appropriate to very large (greater than 75 TPD/unit) excess air/water wall plants that also might include electrical cogeneration, and would most likely already have all of the instrumentation necessary, and represent both a state of the art and a magnitude of investment that *would* warrant this level of accuracy and effort. This type of plant would be typical of what the Army would be involved with on a joint basis with a local municipality.

AN ALTERNATE CONCEPT

The basis of this alternate concept is to consider that an HRI facility has two basic purposes: thermal reduction of the waste and energy recovery. These two functions could be examined separately and tested independently of each other. This would involve testing the boiler (separate or integral) by delivering to it the rated amount of hot gases at the temperature specified, and measuring its thermal efficiency by conventional methods. These hot gases would be produced by conventional firing of gas or oil. The efficiency of the incinerator itself would be measured only by determining the amount of carbon in the ash as an indicator of completeness of combustion at the design firing rate. The functioning of the incinerator and the heat content of the waste would not be directly involved in the determination of the efficiency of producing useful thermal output. Unfortunately, incinerators are not normally supplied with start-up and auxiliary (secondary zone) burners of sufficient size to produce the boiler's rated steam output with out burning any waste. However, some manufacturers of modular starved air systems do offer an option of a burner installed in the heat recovery boiler, capable of full steam production, as a back-up, in the event the incinerator ceases to function and steam output must be maintained. In those cases, this separate testing concept could be applicable.

CONCLUSIONS AND RECOMMENDATIONS

This paper has documented the investigation of a standard performance test for Army HRI's. The pro-

posed test methods are based on existing ASME boiler and incinerator test procedures. A summary comparison of them may be found in Table 1. Unfortunately, there has not yet been any field comparison of these methods, and they have only been examined on a theoretical basis. It is recommended that the input–output method be used by the Army as the basis for the thermal efficiency portion of acceptance testing. The heat-loss method should be used to isolate the areas of inefficiencies should losses be excessive. The modified heat-loss method could be used for routine monitoring of the system. It is also recommended that the Army encourage the use of the calorimeter method for commercial HRI installations of unit sizes larger than 75 TPD (generally beyond starved air size), since that method seems most appropriate for plants of that size and expected sophistication. The alternate concept of separate combustion efficiency and thermal recovery testing should be allowed as an alternative where appropriate.

The procedure recommended above has been field tested for applicability at the Redstone Arsenal, Alabama, HRI. Revisions were made to the test procedure details to maximize the use of field available equipment. In addition, contractor-supplied data from performance and emissions tests at the Fort Leonard Wood, Missouri, HRI have been reviewed to evaluate the results of the procedure.

This paper is a condensation of a technical report currently being prepared by the US Army Construction Engineering Research Laboratory. The final report will discuss in much greater detail, the above testing methods, data requirements, and the procedure for conducting an acceptance test with consideration of field experience. When published, this report will be available through NTIS.

REFERENCES

[1] Hathaway, S. A., and Dealy R. J. "Technical Evaluation of Army-Scale Waste-to-Energy Systems." Interim Report E-110/ADA042578. USA–CERL, July 1977.

[2] Hathaway, S. A. "Recovery of Energy from Solid Waste at Army Installations." Technical Manuscript E-118/ADA044514. USA–CERL, August 1977."

[3] Hathaway, S. A. "Application of the Package Controlled-Air, Heat Recovery Solid Waste Incinerator on Army Fixed Facilities and Installations." Technical Report E-151/ADA071539. USA–CERL, June 1979.

[4] Stabenow, G. "Predicting and Testing Incinerator-Boiler Efficiency...." In *Proceedings of the 9th National Waste Processing Conference.* New York: The American Society of Mechanical Engineers, 1980, 301-313.

[5] Hecklinger, R., and Grillo, L. "Thermal Performance Eval-

TABLE 1 COMPARISON OF METHODS

Method	Heat Input	Heat Output	Heat Losses	Complexity	Advantages	Disadvantages	Recommendation
Input-Output	Yes	Yes	No	Simple	Direct Indication	No Indication of Problem Area Waste Quality	Use for Small Units (<75 TPD)
Heat-Loss	Yes	No	Most	Moderate	Indicates Problems	Some Losses Estimated Waste Quality	Use as Diagnostic
Modified Heat-Loss (Short Form)	Yes	No	Some	Very Simple	Simplicity	Most Losses Estimated Waste Quality	Use only to Monitor Operation
Calorimeter Method	Aux. Fuel Waste Feed	Yes	All	Very Complex	Most Accurate Avoids Waste Quality	Complexity	Use for Large Units (>75 TPD)
Alternate Concept	Fossil Fuel Only	Optional	Optional	Moderate	Avoids Waste Quality	Special Provision for Aux. Burners	Allow for Special Cases

238

uation of MSW Fired Steam Generators...." In *Proceedings of the 10th National Waste Processing Conference*. New York: The American Society of Mechanical Engineers, 1982, 65–69.

[6] Beckman, Dragovich, and DeGeyter. "Calculating Efficiency of Muncipal Waste Mass Burning Energy Recovery Systems." In *Proceedings of the 11th National Waste Processing Conference*. New York: The American Society of Mechanical Engineers, 1984, 217–229.

[7] Fernandes, J. "Uncertainties and Probable Errors Involved in Various Methods of Testing Incinerator/Boiler." In *Proceedings of the 11th National Waste Processing Conference*. New York: The American Society of Mechanical Engineers, 1984, 230–240.

CALCULATING EFFICIENCY OF MUNICIPAL WASTE MASS BURNING ENERGY RECOVERY SYSTEMS

ARTHUR H. BECKMAN and MARK G. DRAGOVICH

Katy-Seghers, Incorporated

St. Louis, Missouri

FERDNAND DeGEYTER

Seghers Engineering, SA

ABSTRACT

One of the questions on mass burning of municipal waste has been how much heat can be recovered from the waste. The answer must always be conditioned on the heating value of the waste. The problem is to determine that value. Every sample of waste will have different moisture, ash and chemical composition, which will calculate to different heating values. The practice in the U.S. is to use the high heat value in calculating energy production, which further complicates the question. Our suggestion is to use the furnace as the calorimeter to determine the heating value of the waste.

This is accomplished by measuring all the known inputs: waste quantity; combustion air; feedwater and cooling water; and all the known outputs: steam; blowdown; ash; radiation and flue gas. Flue gas O_2, CO_2, H_2O and S are measured and used to calculate a waste Btu content. Efficiency is calculated by dividing the net heat in steam by the calculated heat input.

INTRODUCTION

One system of incineration has been proven by over 30 years of successful operation in Europe and, to a limited extent, in the U.S.: mass burning of unsorted waste on specially designed grate systems.

Specially designed waterwall boilers recover heat energy from the hot flue gases in the form of steam for district heating, process or electrical production. One of the questions on mass burning has been determining exactly how much heat can be recovered from the waste. The main problem is calculating the heating value of municipal waste. If 20 samples are taken, it is likely that 20 different heating values will result. Every sample of waste will have different moisture, ash and chemical composition, which will calculate to different heating values.

The practice in the U.S. is to use the high heat value in calculating energy production, which further complicates the question. Two samples of waste may have similar high heat values (Table 1) but different moisture content and the resultant energy production (steaming rate) will vary significantly.

The steaming rate varies with the Btu content of the waste in a linear relationship over a range of about 3800 to 5200 Btu/lb kcal/kg (2100-29,000) assuming all other factors are equal. Below 4300 and above 5200, the ratio changes as indicated below:

HHV	3000	4300	4500	5200	6000 Btu/lb
	(1667)	(2400)	(2500)	(2900)	(3333 kcal/kg)
LHV	2400		4270		5740
	(1333)			(1318)	(3200 kcal/kg)
Steam Rate	1.25	2.20	2.31	2.67	3.20

Approximately the same amount of heat is lost through radiation of the boiler so lower Btu fuel would have a lower net steaming rate. Steaming rate would likewise vary inversely with the flue gas temperature, all other factors being equal.

Flue Gas Exhaust Temperature:	400°F (205°C)	374°F (190°C)
Steaming Rate (Net lb/lbs):	2.22	2.31

Finally, steaming rate varies with the percent furnace loading. Normally, mass burning furnaces will be run at

90 to 105 percent of rated capacity. Below 66 percent furnace loading, the boiler efficiency falls off rapidly to the point where it is not economically feasible to operate a furnace for energy recovery below 60 percent capacity.

The question is always asked: "What will the manufacturer guarantee as a steaming rate?" The answer must always be conditioned on the composition and heating value of the waste. The problem then is to determine those values. Our suggestion is to use the furnace as the calorimeter to determine the heating value of the waste.

Most furnace/boiler systems are designed for a total heat throughput or a maximum furnace capacity for waste at some specific heating value (Btu/lb or kcal/kg). The throughput may increase to some design overload if the heating value decreases and vice versa, so the maximum total heat throughput is not exceeded (Fig. 1).

PERFORMANCE GUARANTEES

Mass burning waste incinerator plants must meet specific performance guarantees, which are only partly within the dictates of the furnace/boiler and mostly a function of the waste processed.

Common guarantees are:

(a) waste throughput, hourly, daily or yearly (should be based on some assumed heating value of the waste);

(b) energy production (usually expressed as a factor of waste input (lb steam/lb waste) and contingent on an assumed composition and heat value of the waste);

(c) maximum putrescibles and combustible material in residue (a better indication of furnace performance than total amount of residue, which is more a function of the waste);

(d) maximum particulate emissions and other environmental factors.

We are concerned here with (a) and (b) and suggest a method for helping the supplier and customer to agree on how to determine if a system meets its guarantees.

ADJUSTMENTS TO OBSERVED THROUGHPUT CAPACITY AND ENERGY RECOVERY RATES

It is recognized that the refuse delivered to a mass burning facility for acceptance test purposes may not have the same composition as the reference processible waste and that throughput capacity and energy recovery are dependent upon the refuse composition, particularly its moisture content and heating value.

For example, the processing of lower Btu content than that of the reference waste will allow higher throughput rates but result in lower energy yield and may, therefore, appear to demonstrate higher throughput but lower per ton energy yields than that which would have been obtained had the plant been tested with reference processi-

ble waste. Similarly, if the waste furnished for acceptance testing purposes has a higher Btu content than that of the reference waste, the demonstrated throughput capacity may be less than that which would have been obtained with reference processible waste but the per ton energy yield would be higher.

It is further recognized that it is difficult and economically unfeasible to obtain an accurate measurement of the heating value of the waste through sampling of the waste being processed during the acceptance test and impossible after it has been incinerated. It is therefore proposed that the combustion system be used as a calorimeter, following in general the principles for determining efficiency and capacity described in the ASME Power Test Code 4.1 for steam generating units (1964, reaffirmed 1979) and the ASME Performance Test Code 33 for large incinerators (1978). The abbreviated effciency test (PTC 33a-1980, Appendix to ASME PTC 33) may be used to determine efficiency by the heat balance method.

The concept is to measure all the known inputs: fuel (waste) in pounds, combustion air flow and temperature, feedwater temperature and flow, and cooling water (to ash extractor) flow and temperature; and to measure all the outputs: steam flow, temperature and pressure, blow-down flow and temperature, ash quantity, temperature and carbon contents, and skin temperature (to calculate radiation).

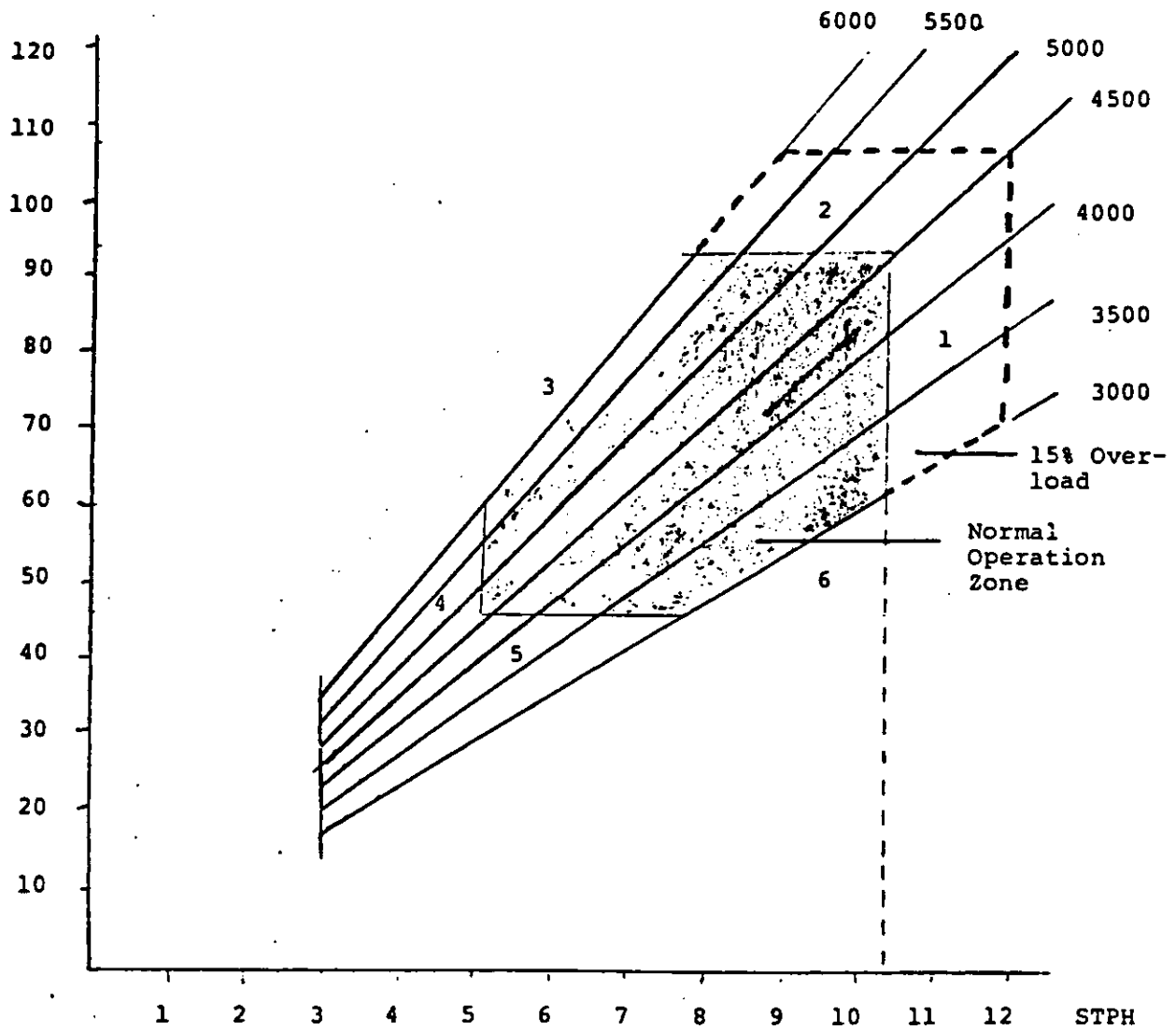We also measure flue gas temperature and flow so we know everything going in and coming out.

The flue gas is further analyzed to measure oxygen, carbon dioxide, water and sulphur and these figures are used to back into a waste analysis. Btu content is calculated from this analysis and compared with output to figure furnace/boiler efficiency. Given this calculated efficiency and, assuming that the efficiency obtained during the test, after appropriate corrections, would be the same as that which would have been obtained using reference processible waste, the throughput capacity and energy outputs observed in the test will be adjusted to reflect the difference between the calculated heating value of the test fuel and the assumed heating value of the reference processible waste.

SPECIFIC TEST PROCEDURES

INCINERATOR CAPACITY TEST

- The purpose of this test is to demonstrate the ability of the boiler plant to handle and burn the guaranteed throughput of specified solid waste while staying within the limits of the specified normal operating grate temperatures and while meeting the guaranteed degree of burnout. This test should also give an indication regarding the reliability of

BTU/HR X 10^6

120
110
100
90
80
70
60
50
40
30
20
10

6000 5500
5000
4500
4000
3500
3000

2
3
1
4
5
6

15% Over-load

Normal Operation Zone

1   2   3   4   5   6   7   8   9   10   11   12   STPH

1 Maximum MSW throughput (10.41 STPH)
2 Maximum heat release rate (94 X 10^6 BTU/HR)
3 Maximum expected caloric value (6000 BTU/LB)
4 Minimum MSW through (50% Max)
5 Minimum heat release rate (50% Max)
6 Minimum expected caloric value (3000 BTU/LB)

FIG. 1 TYPICAL FURNACE OPERATION DIAGRAM

the equipment and, therefore, each line should be run at full load for at least 7 days, after stabilization, without interruption. In the event of a breakdown, the test should be repeated. All equipment should operate during the test at its normal mode and capacity, and the maintenance force and supplies should be those proposed to be available during normal operation of the plant — all to demonstrate the availability of the plant under normal operating conditions.

The facility should be operated for a 7 day period, at the maximum rated capacity and process at least six times (85 percent) the rated daily tons of processible waste.

During the 7 day test period, the total residue from the combustion process should be measured and sampled. The composition of the residue should be determined by hourly samples taken during the 72 hr period when the Facility is processing a total of three times the daily rated tons of processible waste.

The residue sampling should be submitted to the independent engineer for analysis by an independent laboratory prior to the conclusion of the acceptance tests. As a minimum, the residue should be analyzed for moisture content, combustible matter and putrescible matter in accordance with PTC 33.

The facility shall not have been deemed to have passed the throughput capacity test, even though the tonnage processed meets the capacity requirements stated above, if the percentage of combustible and putrescible matter in the total residue exceeds the guaranteed percentages of combustible and putrescible matter.

If the results are not as guaranteed, the Contractor and Customer will likely not be able to agree that the waste processed was identical to the "standard" waste used for contract purposes. Twenty samples will likely result in twenty different results. And, of course, there is no way to sample the waste after it has been incinerated, which would normally be when a controversy would arise. A reasonable alternative is what we are proposing.

The heat balance method of determining efficiency as described herein may be used to calculate the heat value of the waste fired during the test period. If the facility does not meet the throughput capacity test, the demonstrated throughput capacity will be adjusted by the inverse ratio of the heat value of the waste actually processed to the heat value of the reference waste usually assumed to be 4500 Btu/lb HHV.

If this adjustment results in a throughput capacity meeting the guarantee, the facility will have been deemed to have passed the throughput capacity test. If the heat value of the waste fired is determined to have been below 3800 Btu/lb HHV, the waste supplied shall be considered as not representative of processible waste and the test will then be repeated at the customer's expense.

ENERGY RECOVERY TEST

The energy recovery test will consist of a test of the steam raising rate and a test of the electric generation rate, if applicable. The test of the steam raising rate will establish whether the combustion process produces the guaranteed quantity of steam. The test of the electric generation rate will then determine whether the overall performance of the facility meets the guarantees as to energy recovery.
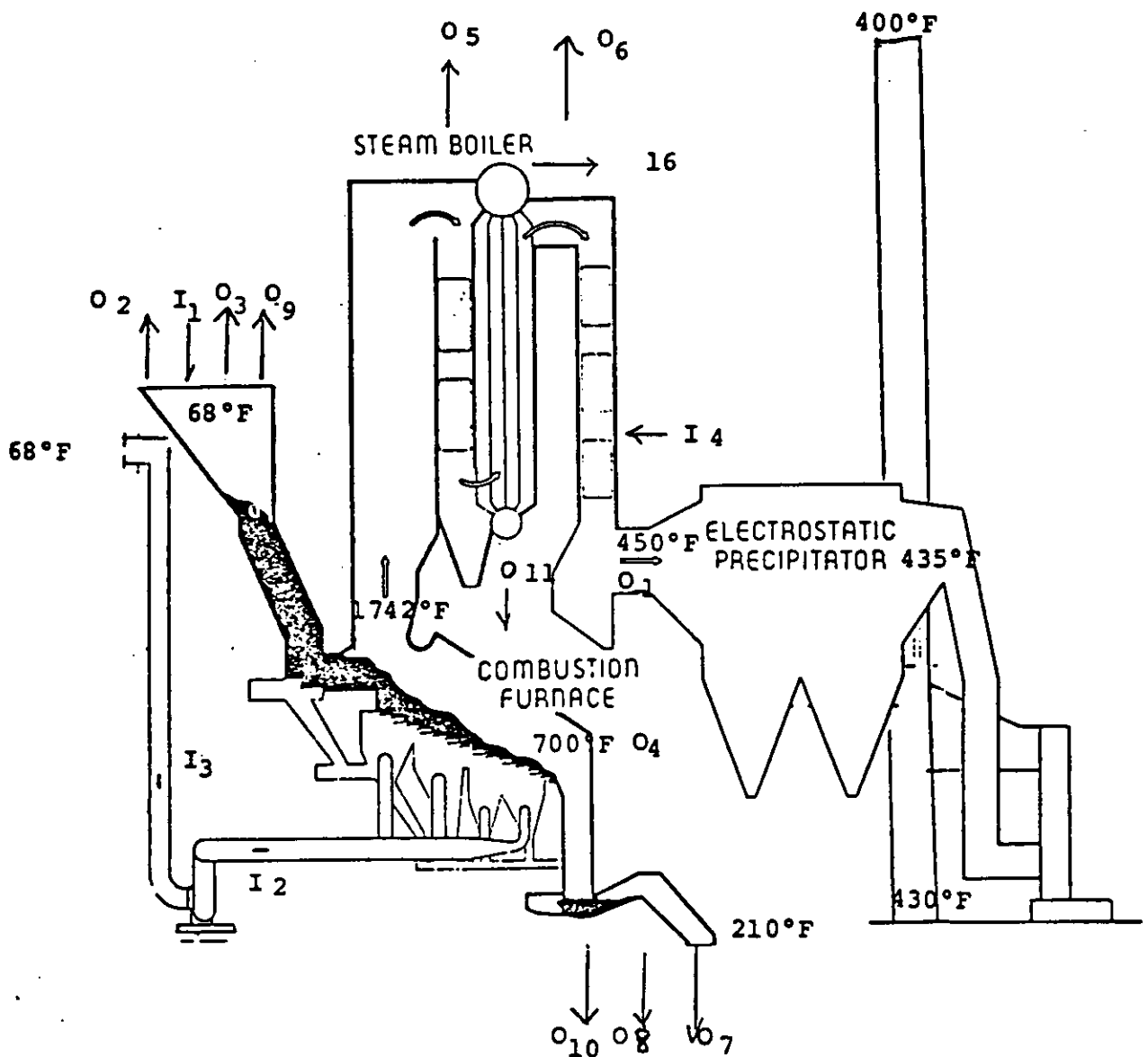
Steam Raising Rate

The purpose of this portion of the energy recovery test is to determine whether the facility meets the guaranteed steam raising rate, when processing solid waste, having the heating value of the reference solid waste, at a rate equal to the guaranteed daily throughput capacity under normal operating conditions as to boiler blowdown, exit gas temperatures and excess air ratio.

The test shall be conducted in accordance with the test codes referenced above, as modified herein, for the determination of heat outputs, credits and losses and the calculation of efficiency and fuel heating value by the heat balance method. For the purpose of determining the efficiency, steam output shall be measured at the superheater outlet and hot flue gases shall be measured at the inlet to the stack.

The test shall extend over an 8 hr test period. Pertinent test data shall be recorded at appropriate intervals, in accordance with the test code and shall include the following — all of which are relatively easy to measure with a high degree of accuracy:
- Processible waste feed rate (weight) and moisture
- Boiler outlet steam rate, temperature and pressure
- Feedwater rate and temperatures
- Desuperheater water rate, temperature and pressure (as applicable)
- Boiler drum pressure
- Flue gas rate and temperature at the stack inlet
- CO_2, O_2, SO_2 and H_2O in the flue gas at the stack inlet by various EPA methods
- Residue and fly ash quantities, temperature and unburned carbon and sulfur content
- Barometric pressure
- Combustion air flow and temperatures
- Ambient wet/dry bulb temperatures
- Residue quench water quantity and temperature
- Moisture in residue (after quench)
- In-house steam consumption
- Steam quality — percent moisture or PPM
- Boiler blowdown rate and temperature
- Furnace boiler skin temperature and area

Test measurements should be taken from installed plant instruments which have been previously calibrated

O_5 O_6 400°F

STEAM BOILER 16

O_2 I_1 O_3 O_9

68°F

68°F

I_4

$\leftarrow I_4$

ELECTROSTATIC
PRECIPITATOR 435°F

450°F

O_1

1742°F O_{11}

COMBUSTION
FURNACE

I_3

700°F O_4

I_2

210°F

430°F

O_{10} O_8 O_7

Efficiency = $\dfrac{\text{Net Heat in Steam}}{\text{Net Avail. Heat Input}}$ X 100

FIG. 2 ENERGY BALANCE FURNACE BOILER SYSTEM

221

TABLE 1 STEAMING RATE

Assumed Waste Composition		% Moisture
	20%	25%
Carbon	26.6	22.7
Hydrogen	3.4	4.3
Sulphur	0.2	0.2
Oxygen	25.4	22.6
Nitrogen	0.2	0.2
Moisture	20.0	25.0
Ash	24.2	25.0
High Heat Value	4502	4494 BTU/lb. (2500 KCAL/
Gas Temperature	1742	1742° F. $(950^{\circ}$ C.) KG
Excess Air	1.3882	1.2503
O_2-Stoichiometric	0.6925	0.6870 lb./lb.
Total Air	7.1445	6.6775 lb./lb.
O_2	0.9614	0.8589 lb./lb.
CO_2	0.9320	0.7875 lb./lb.
H_2O	0.5273	0.6585 lb./lb.
N_2	5.4925	5.1337 lb./lb.
Flue Gas	7.9132	7.4386 lb./lb.
Exhaust Temperature	374° F.	374° F. $(190^{\circ}$ C.)
Steam Temperature	750° F.	750° F. $(400^{\circ}$ C.)
Steam Pressure	600 psi	600 psi (41 ATA)
Make-Up Water Temperature	250° F.	250° F. $(121^{\circ}$ C.)
Steaming Rate, lb.steam/ lb.waste	2.31	2.22

and agreed accurate by the independent engineer. Special portable instrumentation may also be used where required and agreed upon.

Utilizing the test data and measurements from the test, calculations will be made in accordance with the ASME test codes as modified herein, for the determination of boiler heat losses, heat outputs and heat credits (Fig. 2 and Table 2).

METHOD OF DETERMINING SOLID WASTE HIGH HEATING VALUE

With the information accurately obtained during the performance test, the high heating value of the solid waste can be calculated. In order to simplify the method of calculation and the test procedure, the ultimate analysis of the waste will be assumed to consist of only the major components:

- Carbon — Carbon content of the waste is calculated from the percentage of carbon dioxide in the flue gas and the percentage of carbon in the residue.
- Sulfur — Sulfur content of the waste is calculated from the percentage of sulfur dioxide in the flue gas and the percentage of sulfur in the ash.
- Hydrogen — Hydrogen is determined from the amount of moisture in the flue gas taking into account the moisture in the waste, combustion air and ash quench vapor.
- Nitrogen — Nitrogen is an assumed value agreed upon before the test. The nitrogen content of the refuse is very small and will have very little effect on the high heating value of the waste.
- Moisture — Moisture content is determined from samples taken during the performance tests.
- Ash — Ash content is determined from the total residue produced during the test less the moisture, sulfur and carbon contained in the ash.

TABLE 2 REFUSE-FIRED BOILER ENERGY BALANCE

Item	Heat Loss	BTU/LB_R	$BTUX10^6/DAY$
01.	Heat loss due to dry gas. Dry flue gas LB/LB_R x specific heat x (exit gas temp. - ambient air temp.) 6.791 LB/LB_R x .254 $Btu/Lb.^{\circ}F.$ $(400^{\circ}F-70^{\circ}F.)$.	569.2	170.8
02.	Heat loss due to moisture in fuel = (Enthalpy of vapor at 1.0 PSIA @ exit gas temp. - enthalpy of liquid @ ambient air temp.) x moisture in the fuel LB/LB_R (.2119 LB/LB_R x (1240 Btu/LB-48 Btu/LB).	252.6	75.8
03.	Heat loss due to H_2O from comb. of H_2 = 9 x hydrogen in fuel LB/LBL (Enthalpy of vapor - enthalpy of liquid) 9 x .0338 x (1240-48).	362.6	108.8
04.	Heat loss due to combustibles in residue Carbon in residue x 14.500 Btu/LB .0136 x 14.500 Btu/LB.	197.2	59.2
05.	Heat loss due to radiation (ABMA Chart).	45.0	13.5
06.	Unaccounted for losses.	55.0	16.5
07.	Heat loss in residue. Dry residue including unburned carbon x (specific heat of residue) x (residue temp. leaving furnace - residue temp. after quench) .2730 LB/LB_R x .25 $Btu/LB^{\circ}F.$ x $(700^{\circ}F-210^{\circ}F.)$.	33.4	10.0
08.	Heat loss due to moisture in residue. Moisture content of residue x (temp. @ residue leaving quench - temp. of water entering quench) 15/100 (.2730 LB/LB_R) $(210^{\circ}F.-70^{\circ}F.)$ x 1 $Btu/LB^{\circ}F.$	5.7	1.7
09.	Heat loss due to moisture in air. Total dry air required based on fuel rate x moisture in air x specific heat of air x exit gas temp.-inlet air temp.)(0.5583 LB/LB_R x .013 LB_{water}/LB_{air} x 0.429 $BTU/LB^{\circ}F.$ $(400^{\circ}F-70^{\circ}F)$.	12.1	3.6
010.	Heat loss due to quench vapor. (Heat loss in dry residue $\div$ latent heat of vapor @ atmospheric pressure) x (enthalpy of vapor entering boiler-enthalpy of vapor entering furnace. (33.44 Btu/LB $\div$ 970.4 Btu/LB) x (1240 Btu/LB-970.4 Btu/LB).	9.3	2.8

223

TABLE 2 REFUSE-FIRED BOILER ENERGY BALANCE (CONT'D.)

Item	Heat Loss	BTU/LB_R	$BTUX10^6/DAY$
011.	Heat loss due to blowdown. Estimated steam production x specific heat of steam @ 150 PSIG sat. x blowdown rate. 2.8 LB/LB_R x ~~1196~~ Btu/LBS x 3%	106.5	32
		1648.6	494.6

Heat Input

Item	Heat Loss	BTU/LB_R	$BTUX10^6/DAY$
I1.	Fuel heat input. HHV of refuse.	4500	1350
I2.	Dry air heat input. Total dry air required based on fuel rate x specific heat of air x (ambient air temp. - $32^{\circ}F.$) 6.5583 LB/LB_R x .24 $Btu/LB^{\circ}F.$ x ($70^{\circ}F.-32^{\circ}F.$).	59.81	17.9
I3	Heat input due to moisture in air. Moisture in air x specific heat of water vapor (ambient air temp. - $32^{\circ}F.$). 6.5583 LB/LB_R x .013 LB_w/LB_{air} x .489 $Btu/LB^{\circ}F.$ ($70^{\circ}F. - 32^{\circ}F.$).	1.6	.5
I4.	Enthalpy of feedwater entering boiler (Feedwater temp.-$32^{\circ}F.$) x specific heat of water x lbs. of water/lb. of refuse. ($250^{\circ}F.-32^{\circ}F.$) x 1 $Btu/LB^{\circ}F$ x 2.884 LB_w/LB_R	628.7	188.6
		5190.1	1557.0

Steam Production

Item	Heat Loss	BTU/LB_R	$BTUX10^6/DAY$
S1.	Heat absorbed in steam. (Items I1 + I2 + I3 +I4)-(Items 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 + 11) (4500 + 59.81 + 1.6 + 628.7) - (569.2 + 252.6 + 362.6 + 197.2 + 45.0 + 55.0 + 33.4 + 5.7 + 12.1 + 9.3 + 106.5). 5190.11 - 1648.6.	3541.5	1062.4

		LB_S/LB_R
Steaming Rate. Item S1. ÷ enthalpy of lbs. Steam @ 150 PSIG 465° F. 3529.4÷1254.		2.82

TABLE 3 SAMPLE FUEL HEATING VALUE DETERMINATION

DATA FROM PERFORMANCE TEST

Flue Gas

CO_2	– 11.19%	by wt.
H_2O	– 8.90%	" "
O_2	– 11.55%	" "
SO_2	– 0.20%	" "
Flow	– 155,675 lbs./hr.	
Temp.	– 400° F.	

Ash

Weight	– 5,515 lbs./hr.
C	– 5.0% by wt.
S	– .1% " "
Temp.	– 210° F.
Mois.	– 15% by wt.

Combustion Air

Flow	– 140,067 lbs.
Temp.	– 70° F.

Refuse

Weight	– 20,200 lbs.
Moisture	– 27,74% by wt.

Ash Cooling Water

Temp.	– 70° F.
Flow	– 957 lbs./hr.

TABLE 3 SAMPLE FUEL HEATING VALUE DETERMINATION (CONTINUED)

DETERMINATION OF ULTIMATE ANALYSIS OF REFUSE

Item		Lbs./Lb. Refuse
1	**Carbon Content**	

$$\frac{\% \; CO_2 \; \text{Flue Gas} \; X \; Lb./Hr. \; \text{Flue Gas} \; X \; Lb._c/CO_2}{Lbs. \; \text{Refuse}}$$

$$+ \frac{\% \; C_{Ash} \; X \; Lb._{Ash \; Dry}}{Lbs. \; \text{Refuse}}$$

$$\frac{.1179 \; X \; 155,675 \; X \; .2732}{20,200} + \frac{.08 \; X \; 4687}{20,200} \qquad\qquad .2472$$

2   **Hydrogen Content**

H_2O from H_2 Comb. $= H_2O_{Flue \; Gas} -$

$H_2O_{Refuse} - H_2O_{Ash \; Vapor} - H_2O_{Comb.Air}$

$$H_2O_{Flue \; Gas} = \frac{\% \; H_2O_{FG} \; X \; Lb._{FG}}{Lbs._{Refuse}}$$

$$= \frac{.0890 \; X \; 155.675}{20,200} = .6859$$

$$H_2O_{Comb.Air.} = \frac{Lb._{Comb.Air} \; X \; Lb._{H_2O}/Lb._{Ash}}{Lb._{Refuse}}$$

$$= \frac{140,067 \; X \; .013}{20,200} = .090$$

$$H_2O_{Ash \; Vap.} = \frac{Cooling \; Water \; Flow}{Lb._{Refuse}} - \frac{\% \; Mois.in \; Ash \; X \; Lb._{Ash}}{Lb._{Refuse}}$$

$$= \frac{957}{20,200} - \frac{.15 \; X \; 5155}{20,200} = .007$$

$$H_2O_{Refuse} = Lb._{H_2O}/Lb._{Refuse}$$
$$= .2774$$

TABLE 3 SAMPLE FUEL HEATING VALUE DETERMINATION (CONTINUED)

DETERMINATION OF ULTIMATE ANALYSIS OF REFUSE CONT'D.

Item		Lbs./Lb. Refuse

2 H_2O from H_2 Comb. = .6859 - .090 - .007 - .2774
$\qquad\qquad\qquad$ = .3115

Convert to Lb. H per Lb.$_{Refuse}$

$H = Lb._{H_2O} \times Lb._H/Lb._{H_2O}$

$\quad = .3115 \times .1188$ $\qquad\qquad\qquad\qquad$ .03484

3 Sulfur Content

$$\frac{\% SO_2 \times Lb._{FG} \times Lb._S/Lb._{SO_2}}{Lb._{Refuse}} + \frac{\% S_{Ash} \times Lb._{Ash}}{Lb._{Refuse}}$$

$$\frac{.002 \times 155,675 \times .5 + .0024 \times 4682}{20,200 \qquad\qquad 20,200} \qquad .0011$$

4 Moisture Content $\qquad\qquad\qquad\qquad\qquad$ .2774

5 Nitrogen Content (Est. Value) $\qquad\qquad\qquad$ .0060

6 Ash Content

$= Residue - H_2O_{Refuse} - C_{Ash} - S_{Ash}$

$= \dfrac{55.5}{20,200} - \dfrac{.15 \times 5515}{20,200} - \dfrac{.05 \times 5515}{20,200} -$

$\dfrac{.001 \times 5515}{20,200}$ $\qquad\qquad\qquad\qquad\qquad$ .21817

7 Oxygen Content

1.00 - (Items) + 2 + 3 + 4 + 5 + 6) =

1.00 - (.2472 + .03483 + .0011 + .2774 +
$\qquad$ .0060 + .2183) $\qquad\qquad\qquad$ = $\qquad$ .21529

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ 1.000

TABLE 3 SAMPLE FUEL HEATING VALUE DETERMINATION (CONTINUED)

DETERMINATION OF HIGH HEATING VALUE

OF SOLID WASTE BY BOJE FORMULA

		Weight Fraction	Btu/Lb.	HHV
1	C	.2472	14,976	3702
2	H	.03484	49,374	1720
3	S	.0011	4,500	5
4	Moisture	.2774	–	
5	N	.0060	2,700	16
6	Ash	.21817	–	–
7	O	.21529	– 4,644	– 1000

<div align="right">4443 Btu/Lb.</div>

• Oxygen — Oxygen content is taken as the remaining component of the refuse after all values have been calculated.

Neglecting the other minor components in the waste will result in a relatively small error in the high heating value calculation.

After the calculated analysis of the solid waste is determined, the heating value can be calculated using the BOJE formula.

This method of determination of heating values makes a number of assumptions and the results are contingent upon good testing methods.

The results reflect an accurate representation of the solid waste during the test period without the elaborate sampling and testing methods needed to do an accurate and representative chemical analysis of this waste.

SUMMARY

Calculating efficiency of municipal waste mass burning energy recovery systems by measuring the output of the system and basically using the furnace as a calorimeter seems to be reasonable and more accurate than trying to determine the precise composition of refuse by sorting and analysis.

All measurements are practical, timely and appropriate to the fuel actually used. Calculations are mathematically accurate and scientifically correct. This method actually answers more questions and leaves less to chance than any previously suggested procedure. More improvements will likely be found, but this seems to be a good place to start.

REFERENCES

[1] *Steam/It's Generation and Use*, The Babcock & Wilcox Company, 1978.
[2] *Handbook of Solid Waste Management*, David Gordon Wilson, 1977.
[3] *Steam Generating Units — Power Test Codes*, ASME PTC 4.1, 1964.
[4] *Industrial Guide for Air Pollution Control*, EPA Handbook.
[5] *Predicting & Testing Incinerator-Boiler Efficiency. A Proposed Short Form Method in Line with the ASME Test Code PTC-33*, Georg Stabenow, 1980.
[6] *Large Incinerators*, ASME, PTC 33-1978.

Key Words: Calorific value • Efficiency • Energy • Furnace • Performance • Steam • Testing

Appendix F. Quality Assurance Procedures

Procedure 1. Quality Assurance Requirements for Gas Continuous Emission Monitoring Systems Used for Compliance Determination

1. Applicability and Principle

1.1 Applicability. Procedure 1 is used to evaluate the effectiveness of quality control (QC) and quality assurance QA) procedures and the quality of data produced by any continuous emission monitoring system (CEMS) that is used for determining compliance with the emission standards on a continuous basis as specified in tne applicable regulation. The CEMS may include pollutant (e.g., SO_2 and NO_x) and diluent (e.g., O_2 or CO_2) monitors.

This procedure specifies the minimum QA requirements necessary for the control and assessment of the quality of CEMS data submitted to the Environmental Protection Agency (EPA). Source owners and operators responsible for one or more CEMS's used for compliance monitoring must meet these minimum requirements and are encouraged to develop and implement a more extensive QA program or to continue such programs where they already exist.

Data collected as a result of QA and QC measures required in this procedure are to be submitted to the Agency. These data are to be used by both the Agency and the CEMS operator in assessing the effectiveness of the CEMS QC and QA procedures in the maintenance of acceptable CEMS operation and valid emission data.

Appendix F, Procedure 1 is applicable _____(6 months after the promulgation date). The first CEMS accuracy assessment shall be

a relative accuracy test audit (RATA) (see Section 5) and shall be
completed by_____(9 months after the promulgation date) or the
date of the initial performance test required by the applicable regulation,
whichever is later.

1.2 Principle. The QA procedures consist of two distinct and equally
important functions. One function is the assessment of the quality of the
CEMS data by estimating precision and accuracy. The other function is the
control and improvement of the quality of the CEMS data by implementing QC
policies and corrective actions. These two functions form a control loop:
When the assessment function indicates that the data quality is inadequate,
the control effort must be increased until the data quality is acceptable.
In order to provide uniformity in the assessment and reporting of data
quality, this procedure explicitly specifies the assessment methods for
response drift and accuracy. The methods are based on procedures included
in the applicable performance specifications (PS's) in Appendix B of 4U CFR
Part 60. Procedure 1 also requires the analysis of the EPA audit samples
concurrent with certain reference method (RM) analyses as specified in the
applicable RM's.

Because the control and corrective action function encompasses a
variety of policies, specifications, standards, and corrective measures,
this procedure treats QC requirements in general terms to allow each source
owner or operator to develop a QC system that is most effective and
efficient for the circumstances.

2. Definitions.

2.1 Continuous Emission Monitoring System. The total equipment
required for the determination of a gas concentration or emission rate.

2.2 Diluent Gas. A major gaseous constituent in a gaseous pollutant mixture. For combustion sources, CO_2 and O_2 are the major gaseous constituents of interest.

2.3 Span Value. The upper limit of a gas concentration measurement range that is specified for affected source categories in the applicable subpart of the regulation.

2.4 Zero, Low-Level, and High-Level Values. The CEMS response values related to the source specific span value. Determination of zero, low-level, and high-level values is defined in the appropriate PS in Appendix B of this part.

2.5 Calibration Drift (CD). The difference in the CEMS output reading from a reference value after a period of operation during which no unscheduled maintenance, repair or adjustment took place. The reference value may be supplied by a cylinder gas, gas cell, or optical filter and need not be certified.

2.6 Relative Accuracy (RA). The absolute mean difference between the gas concentration or emission rate determined by the CEMS and the value determined by the RM's plus the 2.5 percent error confidence coefficient of a series of tests divided by the mean of the RM tests or the applicable emission limit.

3. QC Requirements.

Each source owner or operator must develop and implement a QC program. As a minimum, each QC program must include written procedures which should describe in detail, complete, step-by-step procedures and operations for each of the following activities:

1. Calibration of CEMS.

2. CD determination and adjustment of CEMS.

3. Preventive maintenance of CEMS (including spare parts inventory).

4. Data recording, calculations, and reporting.

5. Accuracy audit procedures including sampling and analysis methods.

6. Program of corrective action for malfunctioning CEMS.

As described in Section 5.2, whenever excessive inaccuracies occur for two consecutive quarters, the source owner or operator must revise the current written procedures or modify or replace the CEMS to correct the deficiency causing the excessive inaccuracies.

These written procedures must be kept on record and available for inspection by the enforcement agency.

4. <u>CD Assessment.</u>

4.1 CD Requirement. As described in 4U CFR Part 60.13(d), source owners and operators of CEMS must check, record, and quantify the CD at two concentration values at least once daily in accordance with the method prescribed by the manufacturer. The CEMS calibration must, as a minimum, be adjusted whenever the daily zero (or low-level) CD or the daily high-level CD exceeds two times the limits of the applicable PS's in Appendix B of this regulation.

4.2 Recording Requirement for Automatic CD Adjusting Monitors. Monitors that automatically adjust the data to the corrected calibration values, e.g., microprocessor control, must be programmed to record the unadjusted concentration measured in the CD prior to resetting the calibration or record the amount of adjustment.

23

4.3 Criteria for Excessive CD. If either the zero (or low-level) or high-level CD result exceeds twice the applicable drift specification in Appendix B for five, consecutive, 24-hour periods, the CEMS is out-of-control. If either the zero (or low-level) or high-level CD result exceeds four times the applicable drift specification in Appendix B during any CD check, the CEMS is out-of-control. If the CEMS is out-of-control, take necessary corrective action. Following corrective action, repeat the CD checks.

4.3.1 Out-Of-Control Period Definition. The beginning of the out-of-control period is the time corresponding to the completion of the daily CD check immediately preceding the completion of the daily CD check that results in the excessive CD (e.g.; the end of the fifth consecutive, 24-hour period with a CD in excess of two times the allowable limit when the sixth, consecutive daily CD is also in excess of two times the allowable limit; or the time corresponding to the daily CD check preceding the daily CD check with a CD in excess of four times the allowable limit). The end of the out-of-control period is the time corresponding to the completion of the daily CD check immediately preceding the daily CD check that results in the CD's at both the zero (or low-level) and high-level measurement points are within the corresponding allowable CD limit (i.e., either two times or four times the allowable limit in Appendix B).

4.3.2 CEMS Data Status During Out-Of-Control Period. During the period the CEMS is out-of-control, the CEMS data may not be used in calculating emission compliance nor be counted towards meeting minimum data availability as required and described in the applicable subpart [e.g., §60.47a(f)].

4.4 Data Recording and Reporting. As required in Section 6U.7(d) of this regulation, all measurements from the CEMS must be retained on file by the source owner for at least 2 years. However, emission data obtained on each successive day while the CEMS is out-of-control may not be included as part of the minimum daily data requirement of the applicable subpart [e.g., §60.47a(f)] nor be used in the calculation of reported emissions for that period.

5. Data Accuracy Assessment.

5.1 Auditing Requirements. Each CEMS must be audited at least once each calendar quarter. Successive quarterly audits shall occur no closer than 2 months. The audits shall be conducted as follows:

5.1.1 Relative Accuracy Test Audit. The RATA must be conducted at least once every four calendar quarters. Conduct the RATA as described for the RA test procedure in the applicable PS in Appendix B (e.g., PS 2 for SO_2 and NO_x). In addition, analyze the appropriate performance audit samples received from EPA as described in the applicable sampling methods (e.g., Methods 6 and 7).

5.1.2 Cylinder Gas Audit (CGA). If applicable, a CGA may be conducted in three of four calendar quarters, but in no more than three quarters in succession.

To conduct a CGA: (1) Challenge the CEMS (both pollutant and diluent portions of the CEMS, if applicable) with an audit gas of known concentration at two points within the following ranges:

25

Audit point	Audit range		
	Pollutant monitors	Diluent monitors for --	
		CO₂	O₂
1	20 to 30% of span value	5 to 8% by volume.	4 to 6% by volume.
2	50 to 60% of span value	10 to 14% by volume.	8 to 12% by volume.

Challenge the CEMS three times at each audit point, and use the average of the three responses in determining accuracy.

Use a separate audit gas cylinder for audit points 1 and 2. Do not dilute gas from the audit cylinder when challenging the CEMS.

The monitor should be challenged at each audit point for a sufficient period of time to assure adsorption-desorption of the CEMS sample transport surfaces has stabilized.

(2) Operate each monitor in its normal sampling mode, i.e., pass the audit gas through all filters, scrubbers, conditioners, and other monitor components used during normal sampling, and as much of the sampling probe as is practical. At a minimum, the audit gas should be introduced at the connection between the probe and the sample line.

(3) Use audit gases that have been certified by comparison to National Bureau of Standards (NBS) gaseous Standard Reference Materials (SRM's) or NBS/EPA approved gas manufacturer's Certified Reference Materials (CRM's) (See Citation 1) following EPA Traceability Protocol No. 1 (See Citation 2). As an alternative to Protocol No. 1 audit gases, CRM's may be used directly as audit gases. A list of gas manufacturers that have prepared approved CRM's is available from EPA at the address shown

in Citation 1. Procedures for preparation of CRM's are described in Citation 1. Procedures for preparation of EPA Traceability Protocol 1 materials are described in Citation 2.

The difference between the actual concentration of the audit gas and the concentration indicated by the monitor is used to assess the accuracy of the CEMS.

5.1.3 Relative Accuracy Audit. The RAA may be conducted three of four calendar quarters, but in no more than three quarters in succession. To conduct a RAA, follow the procedure described in the applicable PS in Appendix B for the relative accuracy test, except that only three sets of measurement data are required. Analyses of EPA performance audit samples are also required.

The relative difference between the mean of the RM values and the mean of the CEMS responses will be used to assess the accuracy of the CEMS data.

5.1.4 Other Alternative Audits. Other alternative audit procedures may be used as approved by the Administrator for three of four calendar quarters. One RATA is required at least once every four calendar quarters.

5.2 Criteria for Excessive Inaccuracy. If the RA, using the RATA, exceeds 20 percent or 10 percent of the applicable standard, whichever is greater, the CEMS is out-of-control. For SO_2 emission standards between 130 and 86 ng/J (0.30 and 0.20 lb/million Btu), use 15 percent of the applicable standard; below 86 ng/J (0.20 lb/million Btu), use 20 percent of emission standard. If the inaccuracy exceeds ±15 percent using the CGA or the RAA, or, for the RAA, 7.5 percent of the applicable standard, whichever is greater, the CEMS is out-of-control. If the CEMS is out-of-control, take necessary corrective action to eliminate the problem. Following

corrective action, the source owner or operator must audit the CEMS accuracy with a RATA, CGA, or RAA to determine whether the CEMS is operating properly. A RATA must always be used following an out-of-control period resulting from a RATA. The audit following corrective action does not require analysis of EPA performance audit samples. If accuracy audit results show the CEMS to be out-of-control, the CEMS operator shall report both the audit results showing the CEMS to be out-of-control and the results of the audit following corrective action showing the CEMS to be operating within specifications.

5.2.1 Out-Of-Control Period Definition. The beginning of the out-of-control period is the time corresponding to the completion of the sampling for the RATA, RAA, or CGA. The end of the out-of-control period is the time corresponding to the completion of the sampling of the subsequent successful audit.

5.2.2 CEMS Data Status During Out-Of-Control Period. During the period the monitor is out-of-control, the CEMS data may not be used in calculating emission compliance nor be counted towards meeting minimum data availability as required and described in the applicable subpart [e.g., §60.47a(f)].

5.3 Criteria for Acceptable QC Procedure. Repeated excessive inaccuracies indicates the QC procedures are inadequate or that the CEMS is incapable of providing quality data. Therefore, whenever excessive inaccuracies occur for two consecutive quarters, the source owner or operator must revise the QC procedures (see Section 3) or modify or replace the CEMS.

28

6. Calculations for CEMS Data Accuracy

6.1 RATA RA Calculation. Follow the equations described in Section 8 of Appendix B, PS 2 to calculate the RA for the RATA. The RATA must be calculated in units of the applicable emission standard; e.g., ng/J.

6.2 RAA Accuracy Calculation. Use Equation 1-1 to calculate the accuracy for the RAA. The RAA is calculated in units of the applicable standard.

6.3 CGA Accuracy Calculation. Use Equation 1-1 to calculate the accuracy for the CGA. Each component of the CEMS must meet the acceptable accuracy requirement.

$$A = \frac{C_m - C_a}{C_a} \times 100 \qquad \text{Eq. } 1\text{-}1$$

where:

A = Accuracy of the CEMS percent.

C_m = Average CEMS response during audit in units of applicable standard or appropriate concentration.

C_a = Average audit value (CGA certified value or three-run average for RAA) in units of applicable standard or appropriate concentration.

6.4 Example Accuracy Calculations. Example calculations for the RATA, RAA, and CGA are available in Citation Number 3.

7. Reporting Requirements.

At the reporting interval specified in the applicable regulation, report for each CEMS the accuracy results from Section 6 and the CD assessment results from Section 4. Report the drift and accuracy

29

information as a Data Assessment Report (DAR), and include one copy of this DAR for each quarterly audit with the report of emissions required under the applicable subparts of this part.

As a minimum, the DAR must contain the following information:

1. Source owner or operator name and adoress.

2. Identification and location of monitors in the CEMS.

3. Manufacturer and model number of each monitor in the CEMS.

4. Assessment of CEMS data accuracy and date of assessment as determined by a RATA, RAA, or CGA described in Section 5 including the RA for the RATA, the A for the RAA or CGA, the RM results, the cylinder gases certified values, the CEMS responses, and the calculations results as defined in Section 6. If the accuracy audit results show the CEMS to be out-of-control, the CEMS operator shall report both the audit results showing the CEMS to be out-of-control and the results of the audit following corrective action showing the CEMS to be operating within specifications.

5. Results from EPA performance audit samples described in Section 5 and the applicable RM's.

6. Summary of all corrective actions taken when CEMS was determined out-of-control, as described in Sections 4 and 5.

An example of a DAR format is shown in Figure 1.

8. Bibliography

1. "A Procedure for Establishing Traceability of Gas Mixtures to Certain National Bureau of Standards Standard Reference Materials." Joint publication by NBS and EPA, EPA-600/7-81-010. Available from the U.S.

Environmental Protection Agency. Quality Assurance Division (MD-77). Research Triangle Park, North Carolina 27711.

2. "Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors (Protocol Number 1)." June 1978. Section 3.0.4 of the Quality Assurance Handbook for Air Pollution Measurement Systems. Volume III. Stationary Source Specific Methods. EPA-600/4-77-027b. August 1977. U.S. Environmental Protection Agency. Office of Research and Development Publications, 26 West St. Clair Street, Cincinnati, Ohio 45268.

3. Calculation and Interpretation of Accuracy for Continuous Emission Monitoring Systems (CEMS). Section 3.0.7 of the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume III, Stationary Source Specific Methods. EPA-600/4-77-027b. August 1977. U.S. Environmental Protection Agency. Office of Research and Development Publications, 26 West St. Clair Street, Cincinnati, Ohio 45268.

Figure 1. EXAMPLE FORMAT FOR DATA ASSESSMENT REPORT

Period ending date _____   Year _____

Company name _____

Plant name _____   Source unit no. _____

CEMS manufacturer _____   Model no. _____

CEMS serial no. _____   CEMS type (e.g., in situ) _____

CEMS sampling location (e.g., control device outlet) _____

CEMS span values as per the applicable regulation, SO_2 _____ ppm,

O_2 _____ percent, NO_x _____ ppm, CO_2 _____ percent

I. Accuracy assessment results (Complete A, B, or C below for each CEMS or for
    each pollutant and diluent analyzer, as applicable.) If the quarterly audit
    results show the CEMS to be out-of-control, report the results of both the
    quarterly audit and the audit following corrective action showing the CEMS
    to be operating properly.

A. Relative accuracy test audit (RATA) for _____(e.g., SO_2 in ng/J).

   1. Date of audit _____.

   2. Reference methods (RM's) used _____(e.g., Methods 3 and 6).

   3. Average RM value _____ (e.g., ng/J, mg/dsm^3, or percent volume).

   4. Average CEMS value _____.

   5. Absolute value of mean difference $|\overline{d}|$ _____.

   6. Confidence coefficient $|CC|$ _____.

   7. Percent relative accuracy (RA) _____ percent.

Figure 1.   EXAMPLE FORMAT FOR DATA ASSESSMENT REPORT
(Continued)

8.   EPA performance audit results:

a.   Audit lot number   (1) _____   (2) _____

b.   Audit sample number   (1) _____   (2) _____

c.   Results (mg/dsm^3)   (1) _____   (2) _____

d.   Actual value (mg/dsm^3)* (1) _____   (2) _____

e.   Percentage difference*   (1) _____   (2) _____

B.   Cylinder gas audit (CGA) for _____ (e.g., SO_2 in ppm).

1.   Date of audit _____.

	Audit point 1	Audit point 2
2. Cylinder DOT/ID number	_____	_____
3. Date of certification	_____	_____
4. Type of certification	_____	_____ (e.g., EPA protocol 1 or CRM).
5. Certified audit value	_____	_____ (e.g., ppm).
6. CEMS response value	_____	_____ (e.g., ppm).
7. Percentage difference	_____	_____ percent.

C.   Relative accuracy audit (RAA) for _____ (e.g., SO_2 in ng/J).

1.   Date of audit _____.

2.   Reference methods (RM's) used _____ (e.g., Methods 3 and 6).

3.   Average RM value _____ (e.g., ng/J).

4.   Average CEMS value _____.

5.   Percentage difference _____ percent.

_____

* To be completed by the Agency.

Figure 1. EXAMPLE FORMAT FOR DATA ASSESSMENT REPORT
(Continued)

6. EPA performance audit results:

    a. Audit lot number   (1)_____   (2)_____

    b. Audit sample number   (1)_____   (2)_____

    c. Results (mg/dsm^3)*   (1)_____   (2)_____

    d. Actual value (mg/dsm^3)*   (1)_____   (2)_____

    e. Percentage difference*   (1)_____   (2)_____

D. Corrective action for excessive inaccuracy.

    1. Out-of-control periods.

        a. Date(s) _____.

        b. Number of days _____.

    2. Corrective action taken _____

        _____

        _____

        _____.

    3. Results of audit following corrective action. (Use format of A, B, or C above, as applicable.)

II. Calibration drift assessment.

A. Out-of-control periods.

    1. Date(s) _____.

    2. Number of days _____.

B. Corrective action taken _____

    _____

    _____

    _____