TESTING PROGRAMS FOR INCIINERATORS WITH ELECTROSTATIC PRECIPITATOR CONTROL SYSTEM

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ABSTRACT

This paper discusses the approach that should be used in conducting Regulatory Compliance, Contract Compliance, and Design Data Studies for ESPs used for controlling particulate emission on incinerators.

Problems associated with testing this process including the numerous operating parameters affecting ESP performance, correction factors for excess air, and entrained water particles are discussed.

Recommendations for more intensive testing programs are presented.

INTRODUCTION

During the past several years there has been increased emphasis placed on the use of testing programs to evaluate air pollution control equipment. These testing programs have had a greater impact on electrostatic precipitators (ESP’s) than on any other type of control equipment.

The increased emphasis on test programs has been caused by the incinerator owner’s and designer’s concern for the environment, by public pressure for improved environment, by increased pressure by regulatory agencies and by stringent emission standards. Changes in testing programs can be illustrated by reviewing the testing and ESP industry prior to 1960. During this period of time, the vast majority of the source testing was provided as a “Free Service” by most of the control equipment manufacturers. Since then many testing/engineering/consultants such as our company have established their place in the industry. The growth of the consultants developed with the demand for “independent” evaluation and diversified technology. A secondary reason for the expansion of consultants was the publication of Federal EPA test methods. The consultants who were anxious to fill the void for qualified testing services purchased test equipment and started to apply the test method while several of the largest ESP manufacturers attempted to disprove the concepts of the EPA test methods.

In the 1950’s and 60’s, some utility industry units failed to meet contract specifications after ESP performance tests were conducted. In most of these cases the owners kept the 10 percent retainer fee and little effort was made to bring the units into compliance. Owners are now being denied operating permits by regulatory control agencies for installations that do not comply with emission standards. Recently, plants have been totally shut down or have been forced to operate at reduced production rates in order to comply with emission standards.

Plant owners have passed on to the ESP manufacturer strict and severe contract penalties. Several lawsuits are pending which may include judgments that far exceed the original selling price of the control equipment. Presently, most of these lawsuits are concerned with the utility industry but there are several in the incineration industry.

Some of the present lawsuits involve judgment for lost income, extra operating expenses, total re-
placement of control equipment, and installation of competitor equipment at the manufacturer's expense. With the Federal EPA intervention through the New Source Emission Standard and Section 114 of the Clean Air Act we predict that lawsuits involving equipment vendors in the incinerator industry will increase.

As a result of the new regulation, there will result increased cost of plant operation, higher costs for control equipment coupled with long increases in penalties, and longer delivery lead time on ESP's and fans. Consequently all this will lead to better requirements and more comprehensive test programs to accomplish the following three objectives:

1) Determine compliance with regulations
2) Determine contract performance
3) Trouble shooting programs to improve performance of ESP's or to document accurate design data.

This paper will discuss the various testing procedures to meet these three objectives. Also discussed will be the special problems associated with testing incinerators, ESP's and the various types of analyses needed to determine ESP performance.

It is important to remember that test programs discussed in this paper are not interpreted to mean test methods such as EPA 5 and ASME or PTC-27. Although the selection of the test method is important in each of the test programs, each method has an application in the three programs.

**TYPES OF TEST PROGRAMS**

As previously mentioned there are three types of performance tests:

1) Compliance with regulatory standards
2) Contract compliance
3) Problem analysis or design data.

The order of presentation represents an increase in the complexity and cost of the test programs. One of the basic reasons for failures and high costs of test programs, is in not bringing the test consultant into the project during the early planning stages. The consultant should be brought in after the concept and objectives have been established so that he can then review preliminary plans and specifications before they are offered for bid. Based upon the equipment location and layout, the consultant can advise owners and engineers on the types and numbers of tests, the limits of test accuracy, potential problems, and if the test objectives can be reached. Most of the architectural and engineering firms have personnel on staff for evaluating stack testing. But most of them lack the practical experience and diversified technology to adequately provide these services.

There are three distinct phases for any testing program of incinerator ESP's.

1) Presurvey and test protocol
2) On-site testing programs
3) Laboratory analysis, calculation, evaluation and the test report.

**PRELIMINARY WORK BEFORE TESTING**

(a) Presurvey

Although it has not been a consistent practice that a test site be presurveyed, our experience has indicated that it should be done in all cases, regardless of the tests to be conducted. Many clients do not appreciate the savings in time, expense, and assured accuracy when the site is adequately prepared for testing. Trying to save a few dollars by not conducting a presurvey can cost many dollars in the end; for instance, having a test crew sit for a day while scaffolding is modified.

The success of the program is largely based on a thorough presurvey and complete test protocol. This is partially due to the great difference in physical plant, test port locations, and ESP design and operation. Also, a good test program will depend on proper sampling locations and preparations for testing based on a presurvey.

A supervisory test engineer should visit the installation site at least four weeks before starting the test. He should be accompanied by his counterpart in the architectural engineering firm and a plant liaison person. A full discussion of the precise intent of the test or evaluation program must cover;

1) Emission tests for purposes of state and/or federal compliance
2) Efficiency tests for purposes of acceptance of control equipment
3) Evaluation and corrective tests for purposes of (a) improving the combustion processes, (b) correcting airflow problems to or through the control equipment and (c) evaluating new control methods.

The supervisory engineer must become completely familiar with the extent of recorded or available plant operational data. These data are essential for the correct calculation of test results. Most facilities have complete descriptive Manuals for each installed ESP from which pertinent design and operating data can be obtained. It is important to assure that these data accurately reflect the actual operational conditions of the unit since it is not unusual for the system to be modified after
installation. The supervisory engineer should prepare an accurate log book containing data on actual operating conditions. It should serve as a guide for the following test crew to obtain proper operating test data and also clearly indicate who should collect the data.

A thorough inspection of the test port locations must be accomplished. It is very rare, except when testing in the stack, that ideal sampling port locations are found. Serious consideration should be given to relocating ports to reduce the time of tests and to obtain more precise results if this found necessary.

If sampling ports are located in areas which will result in turbulent flow conditions caused by bends or disturbance in duct work, there will be a positive error in velocity measurements. Consequently, the gas volume will be higher than actual. This provides an advantage to ESP manufacturers in performance guarantee tests. If design information is based upon data obtained from a poor sampling location and a performance test run, then consideration must be given in the design of the ESP to compensate for the inaccurate gas volume.

In our experience, it is better from an accuracy viewpoint to relocate ports to reduce sampling time than to conduct a test when more than 60 points must be measured. However, it may be less expensive and of sufficient accuracy to use more sampling points than to erect 200 feet (61 m) of scaffolding and only be able to conduct one test per day.

The use of sampling sites on tall stacks usually offers the best sampling locations for velocity measurement. Safe access to these sampling stations should be a matter of high priority. Often, there are only open-rung ladders.

Even when elevators have been installed, test operators complain that they are often inoperable or inconveniently located. Admittedly, the cost of an elevator can rarely be justified only for use in testing. But elevators are often helpful for maintenance work and for routine checks.

The caps on the test ports must be opened since in almost all cases they are frozen in place because of infrequent use. Most test ports which should be a minimum of 4 inches are found clogged with residual flyash material, the entire area must be completely cleaned. This operation will save a considerable amount of time if done before the test team arrives. It also prevents possible flyash pickup during tests. Almost all tests with less than ideal sampling locations encompass a consecutive four hour test period. It is strongly recommended that good lighting be provided for night testing. Safety lines should be rigged around the outside of the breeching to prevent possible personnel injury. In many cases, due to the depth of the breeching, it is necessary to erect scaffolding of twelve (12) feet (3.7 m) from one level. A schematic of the required scaffolding should be prepared and arrangements made with plant management for its construction. The scaffolding must be wide enough to support the weight of up to three men and four hundred pounds of equipment. Since the elevation of the test area above ground level is 60 (18.3 m) to 120 (36.5 m) feet, the scaffolding should be cross-braced to withstand wind velocities in excess of thirty knots.

Arrangements must be made for the availability of 110-volt power for operation of the pumps, probe, heater cables and other electrical test equipment. A minimum of two separate double outlets rated at twenty amperes each should be available for each sampling train. It is also important that a weather protected enclosure be set aside near the test site for storage of test equipment.

A clean-up area should be set aside where probes, filters, impingers, and test equipment can be cleaned, repaired and re-calibrated. Even a small amount of dust pick up could invalidate test results.

A most important but often overlooked step in the presurvey is the logistics of getting the equipment to the test area. A large test program involves the utilization of over 2600 pounds (1.2 m tons) of equipment, glassware, apparatus, and chemicals. It is no easy task to move this equipment to the top of the breeching 120 feet (36.5 m) above ground. Even in the few cases where plant elevators rise to the same level as the test area, it is necessary to transport the equipment up, down, and over plant facilities and horizontal distances of 300 feet (91.3 m) or more. Where possible, arrangements should be made to erect a ground hoist at the test area so that all equipment can be lifted into place readily. At least one half day should be set aside for this assignment.

At the conclusion of the presurvey a final meeting should take place between plant personnel, plant liaison representatives of the ESP manufacturer, design engineer and the supervisory test engineer to make sure that there is complete understanding of what will occur, why it must be done and who will do it.

(b) Test Protocol
The next aspect of this phase is to prepare a
test protocol. The protocol must detail how, why, where and when the test will be run and who is responsible for each aspect. In reality the test protocol is a draft of the final report minus the actual data. It should include information obtained during the presurvey as to scaffolding, test port, electrical and equipment hoisting problems. Any deviation from a standard practice or method, contract conditions and/or regulations that is required to perform the test program should be highlighted and explained. Table I shows the Table of Contents of a test protocol to conduct an ESP contract performance test.

The test protocol should be approved by all parties concerned prior to starting the test program. Having approved protocols documented has saved millions of dollars in legal expenses. Test protocols are no less important for a state compliance test than for a contract performance test. It presents an excellent opportunity to clarify contract conditions and regulatory rules.

FIELD TEST PROGRAMS

COMPLIANCE TEST

The performance of a compliance test for a regulatory agency is critically important for obtaining operating permits. Emission standards are the least complicated of the test programs.

Many agencies have recently adopted the submittal requirement of a test protocol before conducting compliance tests. Before these tests are performed or even before an ESP installation contract is released for bid, the cognizant regulatory agency should be contacted for this information.

Other typical deficiencies of these programs are:
1) Little or no calibration data is requested.
2) Only token process data and ESP readings are taken. Only sufficient data is taken to prove that the process is operating at near design capacity and the ESP is on. If any test result is in question generally there is insufficient data to evaluate. The concern of most control agencies is compliance with emission standards.
3) Local agencies have different policies on emission tests meeting standards. This point should be clarified with each local agency since several have adopted a policy that if one of three tests exceeds the standard the unit does not meet the standard. Usually three emission tests are run and their average is used to determine compliance.
4) Generally no provisions are made for determining emission or plant performance under

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transient, partial load or with one or more fields out of service.

Most compliance tests can be performed in 1 to 2 days of field testing time. The cost range is $2,000 to $5,000.

It is general practice to provide the regulatory agency with 30 days notice before conducting the testing program.

CONTRACT PERFORMANCE TEST

Contract performance tests differ from the compliance test in that the plant's owners want to insure that they are obtaining the control equipment they ordered. Likewise, the ESP manufacturer wants to insure that the equipment, once installed, is being operated and tested within the specification for which it was designed. ESP have more variable parameters that affect performance than other types of control equipment. These parameters must be closely monitored during the test.

When performing contract compliance test programs it has been common practice in the industry to prepare a test protocol. With all of the system variables, it is of the utmost importance that the program coordination and responsibility be clarified with all parties. Some contracts for control equipment provide for bonuses if the equipment meets certain emission standards and conversely, penalties for not meeting standards.

In order to comply with the objectives of contract performance tests, the following is a summary of differences between regulatory compliance tests.

1) The calibration of field test equipment such as pitot tubes, dry gas meter, and pyrometer are required. Plant and ESP equipment such as recorders and monitors must be calibrated.

2) Sufficient plant and ESP operating data must be collected in order that they can be correlated to contract specifications. Representative garbage, ash and flyash samples might have to be collected and analyzed for chemical composition.

In some cases, especially where tests are being conducted at varying load conditions, we have found it necessary to have an additional engineer on the job site, one who is intimately familiar with the combustion process. He records all operational data, observes operation conditions, and assures that they are integrated into the test results. Also, we have found that under varying loads test conditions, the supervising test engineer is so completely immersed in the actual sampling program that he cannot properly collect the operating data. It is absolutely mandatory that accurate operational data be collected in order to have valid test results. Even a slight upset condition can have a serious effect on test results.

Sufficient data must be collected to permit analysis of the test results to prove that:

1) the plant was operating within contract specifications,
2) the ESP performed to contract specifications,
3) the noncontrollable variables such as composition of fuel are acceptable,
4) there were no testing errors.

Sometimes, for very large projects, we will find it worthwhile to send a small test crew to the site at least one week before the official test begins. This crew can acquire useful preliminary data and may save days in the field of 5 to 18 man crews. This preliminary crew can determine if the ESP is functioning properly and establish the operating conditions of the plant in order that it will have proper amounts of flue gas as specified in the contract.

Recent contracts have ranges in their specifications from no specified number of tests (range 3-30) and the conditions under which they must be performed. Some contracts even state that the ESP must be retested after a specified operating time.

During actual operations, it is very common for ESP to trip or lose a field due to electrical problems, swinging wires, hopper buildup, etc. Therefore, many specifications are being written to state that the ESP must meet contract guarantees with 1 or more fields out of service or under varied plant load conditions. This will protect the owner from having to shut their plants down in order to comply with emission standards and repair the ESP.

Recently there has been an increasing demand for statistical analysis of source testing data. There is very little data analysis that can be accurately accomplished when only three tests are performed. Our firm was retained several years ago to conduct a test program which included a contract specification provision that the emission test results from the control equipment must be within a 98 percent confidence level. A team of independent statisticians were retained. They reviewed the variations in plant and control equipment operations with the variations and errors in testing. They concluded, that with these conditions, to determine the plant's performance on three similar units, nearly a hundred tests would have to be run.
Since most ESP performance tests require the measurement of particulate efficiency and more data collection and analysis than compliance tests, they of necessity require more testing time and subsequently cost more money. These programs generally require from two days to a week for field testing. We have conducted contract performance tests that have employed between 3 to 18 field engineers and cost between $3,000 to $120,000.

**SPECIAL TEST PROGRAMS**

There are test programs to determine if an ESP's efficiency can be improved, and why an ESP is not performing to design or developing design data. These programs are the most complex and professionally interesting. There are no rules of thumb for these test programs as to what should be included, how long they should run or at what cost. An experimental plan must be developed for each problem in each plant as they have their own individual characteristics.

Designers must consider that an ESP performance is controlled by many variables. Some of these variables are:

1) Gas velocity through ESP
2) Gas distribution across the box
3) Particle re-entrainment
   a) from hopper
   b) from rapping
4) Gas temperature
5) Chemical composition of flyash
6) Chemical composition of flue gases such as NH₃, HCl, and H₂SO₄
7) Flue gas moisture
8) Power inputs
9) Particle size
10) Number of particles per cubic feet of gas
11) Dust layer thickness on plates.

Very small changes in any one of the parameters can have drastic effects on an ESP performance. Table II is a summary of some typical effects of small process changes.

In many cases, an installation design is based upon theoretical data or on actual data. However a plants operating conditions can change from time of design to installation. If this condition prevails or the ESP does not operate in accordance with specifications certain tests can be performed to determine if the performance can be improved.

The most common problem is caused by poor distribution across the face of an ESP. Velocity profiles must be determined with the incinerator running under various load conditions and with no fire in the incinerator. Only the fans should be operating. With these data, the design engineers can design new distribution plates or turning vanes. Another velocity problem is hopper re-entrainment. ESPs are designed to have the highest gas velocity on top in order to reduce the re-entrainment of the collected dust from the plates when rapping or from the hopper. The top of the hopper can be profiled to determine if there is excessive gas velocity in the area. This type of analysis is very dangerous, costly, and time consuming.

Even with these velocity profiles, the designer might have to go to modeling to experiment with new designs.

When conducting trouble shooting programs some auxiliary analyses that are required as part of the usual source emission tests are:

1) Resistivity
2) Chemical analyses of ash and fuel
3) Particle size.

Though ASME has standard methods for these analyses, they are not widely accepted for incinerators or by industry. The application of the most commonly known methods for resistivity and particle size measurements will depend upon the desired objectives of the program.

EPA Method 5 for particulate measurements has very little application in these programs. The most desirable method using instack filters provides the fastest and most accurate results. By using in-stack

**TABLE II**

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<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Effect</th>
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<td>H₂O</td>
<td>Increase flue gas moisture from 10% to 13%</td>
<td>Increase efficiency from 98% to 99%</td>
</tr>
<tr>
<td>Gas Volume</td>
<td>Increase gas volume 2.6% from optimum design condition</td>
<td>Decrease efficiency from 99.1% to 98.8%</td>
</tr>
<tr>
<td>Temperature</td>
<td>Increase temperature from 300°F to 310°F</td>
<td>Decrease efficiency from 99.1% to 99.0%</td>
</tr>
<tr>
<td>Chemical Composition</td>
<td>Increase Na content of garbage from 1% to 2%</td>
<td>Decrease resistivity of flyash from 10¹¹ to 10¹³</td>
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These results are based upon typical design data for 99% efficiency ESP and a typical garbage with less than 0.5% S content.
filters from the time a test is completed until preliminary data is obtained required only 2 hours (1 hour to dry filter and 1 hour to dessicate). The time required to verify test results should be kept as short as possible. Once the results are received the test engineer can determine if another test is needed at a specific operation condition before it changes or proceed to a new test condition.

If Method 5 is used, it requires a minimum of 24 hours to obtain test results. The method requires the filter to be air dried and the acetone washing to be evaporated at 70°F.

To assist in generating accurate data as soon as possible many testing firms have developed computer programs using portable terminals on site. These data also aid in the judgment process by evaluating the progress of these programs.

Our firm has conducted research programs which included particulate concentrations measurement inside operating ESPs. To accomplish this task, special probe guides were designed and installed to prevent the probes from touching any of the plates or wires.

The probes were also designed to minimize the disturbance of the gas flow utilizing special velocity measurement equipment. The object of these studies was to determine the efficiency of each field, re-entrainment from each field, and the optimum rapping intensity and cycle for each field.

Engineers should consider in their designs the constant requirement for conducting trouble shooting programs on ESPs.

When an ESP is being installed, plans should be made in the design to test, trouble shoot and evaluate the ESP. For an example, test ports should be located at the inlet and outlet of each half of the precipitator. Generally, it is our experience that these test ports have been poorly located for accurate gas volume measurements. However, they usually can be used to determine with “ball park accuracy” if each half of the ESP is receiving an equal volume of gas and if they each have the same efficiency.

Provision should also be made to determine the “in situ” particle size and resistivity of the flyash. These tests do require special test facilities such as 6” test ports.

SPECIAL PROBLEMS ASSOCIATED WITH EMISSION MEASUREMENT PROGRAMS FROM INCINERATOR ESPS

Besides the normal stack sampling problems, there are numerous special problems associated with ESP Incinerator testing programs. Some of these special problems are:

1) Charging rates
2) CO₂ and excess air correction
3) Fuel and residue analysis
4) Water carry over
5) Charging of particles
6) Rapping cycle.

These are discussed as follows.

1. Charging Rates
There are two basic types of charging methods:
   a. Batch feed
   b. Continuous

It is necessary to determine the charging rates for the following reasons:

1) To see if unit meets capacity.
2) To determine if the unit complies with emission standards written in terms of lbs. emission per lbs. charged (burned).
3) To calculate theoretical emissions needed for correction to 12 percent CO₂ or 50 percent excess air.

The most predominant problem in correcting concentrations to an excess air basis is the measurement of the total combusted carbon input when using the stoichiometric method. This entails measuring the fuel input and refuse discharge from the process and performing an ultimate analysis for both. The accuracy of this correction depends upon the accuracy of the measured weight of the fuel input, refuse discharge and the homogeneity of the fuel.

The advantage of the stoichiometric method is that the answer can be checked against CO₂ or O₂ readings, and gas volumes measured by pitot tube of H₂O content of gas. The two disadvantages are the difficulty in obtaining accurate fuel input weights and the cost and time to obtain and analyze the samples. If all of the inputs are accurate, the stoichiometric method is the most accurate of all the methods.

Incinerators are a particularly difficult problem in that most incinerators have no method of weighing the fuel (refuse) input except by counting crane bucket loads. We recently participated in an extensive incinerator-design study where crane bucket loads of garbage were accurately weighed. One of the results of the study was that during any one-hour period the actual weight was ± 25 percent from the calculated value. The method for calculating the weight input usually is to weigh 2 or 3 bucket loads in a dump truck and then use the average weight per bucket for the test period.
There recently has been a substantial improvement in this method of weighing which involves the installation of an ammeter on a crane motor. A calibration curve can be developed for amperes vs. weight. The accuracy of this system will depend on the operator recording the data and constant calibrations. At this time, we do not have any long term data on this system. During a recent study conducted in Sweden, this method proved out within 4-5 percent of the value calculated from a heat rate.

2. CO₂ and Excess Air Correction

Historically, emission standards corrected to various common bases were developed from the normal operating conditions or individual processes. The purpose of these corrections is to compare emissions from similar processes of different capacities, or from boilers operated under different combustion parameters.

As an example, one commonly used correction for dilution effects, adjusts measured volumes to 12 percent CO. This factor came from normal operating conditions in stoker-fired boilers around the turn of the century. 12 percent CO operation was employed to assure maintenance of safe conditions with the limited combustion controls then available.

A second reason for correcting to these common bases was to prevent the reduction of emission concentrations by the addition of dilution air. A number of the most commonly used bases for correcting concentrations to standardized flue gas volumes are:

1) 50% excess air  
2) 12% CO₂ *(F_c factor)  
3) 3% O₂  
4) 15% O₂  
5) 7% O₂  
6) 1000 lbs. of flue gas @ 50% excess air  
7) total air (F factor)

These corrections apply to measurements of gaseous and particulate emissions in the following common terms:

1) gr/SCF (wet or dry gas basis)  
2) gr/ACF (wet or dry gas basis)  
3) lb/1000 lb of flue gas (wet or dry basis)  
4) lb/MMBTU heat input  
5) PPM

*Contribution of CO₂ from auxiliary fuels for the incinerators or unburned carbon for combustion sources must be subtracted for accuracy.

It should be noted that all of the above examples are concentrations values which are independent of total mass emission rates.

Other possible errors may result in corrections for temperature, moisture and pressure.

The correction factor to 12 percent CO₂ involves errors introduced from the measurement technique which is generally an Orsat device. These errors are magnified when trying to measure low CO₂ values using the normal triplicate analysis. Figure 1 illustrates these errors both positive and negative as they affect correction to 12 percent CO₂. If, rather than using a CO₂ correction, the emission concentration is corrected to a total air or 50 percent excess air bases, errors are again introduced. Figures 2 and 3 illustrate these errors using two different equations for calculating total air. Theoretically, the excess air correction has a smaller error associated with it than the 12 percent CO₂ correction. The correction factor such as 50 percent excess air, F factor and adjusting to various O₂ levels are dependent upon accuracy of total or excess air measurements. The following is a summary of the inputs that will affect the accuracy of various techniques for the measurement of total or excess air:

1) weight of fuel input  
2) total combustion of fuel  
3) gas stratification  
4) flue gas analysis  
5) fuels analysis  
6) sampling errors  
7) total gas volume measurements such as pitot tube measurement

Any errors in determination of excess air will directly affect corrected emission rates.

Two of these problems which are particularly relevant for incinerators in correcting to 50 percent excess air involves the ability to collect a representative sample of the fuel input and the weight and representative sample of the residue. In actuality, the collection of the residue sample usually is most difficult and may be the more important aspect of the conversion factor. In applications of the carbon-mole method of stoichiometric calculation for gas volume in fossil-fired boiler, the carbon content of the bottom is considered to be the same as the flyash sample. Flyash samples are rather easy to collect and analyze in comparison to bottom ash samples.

Due to the relatively poor combustion efficiency of most municipal incinerators, this assumption is not valid. The grate ash will be significantly different in composition from the flyash. This problem
FIG. 1 ERROR RESULTING IN CONVERSION OF ORSAT READINGS TO 12% CO₂ OR $F_c$ FACTOR (/>.4% STD. DEVIATION)
FIG. 2 ERRORS IN DETERMINING TOTAL AIR FROM ORSAT READINGS FROM COAL FIRED BOILERS OR REFUSE INCINERATORS

Positive Error
Negative Error

Typical Gas Analysis from
Bituminous Coal or Garbage
(Ultimate CO₂ = 10.5%)

%CO₂
% O₂

Ta = [O₂/ .264 (N₂) · O₂] + 100
FIG. 3 ERRORS IN DETERMINING TOTAL AIR FROM ORSAT \( \text{O}_2 \) READINGS FROM COAL FIRED BOILERS OR REFUSE INCINERATORS

\[ Ta = \frac{2090}{(20.9 - 02)} \]
was illustrated in a study conducted by our firm during a testing program on several incinerators to determine contract compliance for scrubbers. Differences were noted in calculating gas volumes for stoichiometric excess air calculations, and pitot measurements. Large variations were visually noted in the residue. These varied from periods where significant amounts of unburned paper were observed in comparison to times when no combustibles were present.

A system was established to collect residue samples before it was quenched by the plant’s system. The collected samples were quenched with known amounts of clean water. Samples were collected every half hour, 24/hour day for two weeks. The combustible content varied from 0-100 percent with the average being close to 50 percent.

The flyash samples were measured and found to have consistent values of much lower combustible content. Based upon an analysis of the garbage, the ultimate CO₂ should have been 19.5 percent and 50 percent excess air corresponding to 13.0 percent CO₂. When the garbage analysis was corrected for the carbon content of the ash, the CO₂ values for ultimate and 50 percent excess air became 13.5 and 9.0 respectively. The change in the ultimate CO₂ was caused by the selective combustion of elements of the garbage (C, H, N, S and O₂). The fuel (garbage) being charged into the incinerator had the characteristics of coal while the fuel being combusted had those of natural gas.

3. Fuel and Residue Analysis

We have already discussed the problems encountered in trying to measure the quantity of refuse burned and obtaining a representative sample. Since garbage is composed of a wide variety of materials, to obtain a representative sample for analysis requires the mixing, quartering and drying of the material prior to analysis. The exact procedures are well documented in papers by Elmer Kaiser and York Research.

The EPA has recently published a technique for calculating total pollutant emission “E” based upon “F” factor which represents a ratio of the volume of dry flue gas generated to the colorific value of fuel combusted. These values are published and found to be relatively constant for a particular type of fuel. As an example, even if one considers the very wide range of materials encountered in typical municipal refuse, it is shown by Mr. Roger Shigehara of EPA in Table 3 that the standard deviation calculated for the “F” factor is only 2.93 percent. Emission rates are calculated using the “F” factor, the concentration of pollutant “C”, and the total air using the following equation:

\[ E = CF \times \frac{2090}{20.9} - \% O_2 \]

The “F” factor shown in Table 3 appears to solve some of the analysis problems involved in incinerator test programs. It will eliminate one of the needs for measurement of the feed rate and garbage analysis.

4. Water Carry Over

Wet conditioning towers or systems when used on refractory walled incinerators have caused serious sampling problems. Most systems, when tested, have had a significant amount of water carry over. The carry over will interfere with in situ of particle size and resistivity particulate mass measurements and analyses. When using EPA 5 and entrained water is present, the mass emission analyses will include solids that are present in the
spray water, particles that the droplets may pick from the gas stream and the by-products of the interreaction of the water with gaseous acids. The water droplets will absorb the HCl and H₂SO₄ from the gas stream and the droplets absorbed on the filter. The HCl and H₂SO₄ may react with the alkaline ash and leave Cl⁻ and SO₄²⁻ salts, and H₂SO₄, which will remain on the filter after drying. Even if you deviate from the analytical procedures in EPA-5 and heat the filter to 105°C, the H₂SO₄ will remain.

Many contracts for conditioning systems state that there shall be no entrained water carry over. Unfortunately there is no quantitative method for measuring this carry over.

There are two qualitative techniques employed. One is to observe if there is any impaction or collection on a stained media. The second method is a water balance technique using psychometric data. Both methods have vast open gaps in reliability, accuracy and repeatability.

Where significant entrainment has been observed, there has been widely scattered data. This condition might be caused by the buildup of "mud" on the wires and plates and re-entrainment when rapping.

5. Charging of Particles

It is known that the particulate at the ESP outlet has a residual static electrical charge. The contact between these charged particles and the sampling probe, results in a shock hazard for the test personnel. Although this hazard is not severe enough to cause death, it can cause serious discomfort to the person holding the probe. A reliable method of grounding the probe to the ductwork is an important consideration for all ESP outlet work. The charge on the particulate will not affect the results of a concentration or mass loading test but will seriously affect tests for the determination of particle size distribution. The charged particulate will be attracted to an ungrounded in-stack impactor and probably be collected in the first stage even though it should pass to other stages. If a probe is used with an out-of-stack impactor, most of the particulate would probably be collected in the ungrounded probe and not reach the impactor. Both of these occurrences would artificially bias the results. A reliable grounding strap would eliminate this problem.

6. Rapping Cycle

A wider scattering of test results has been observed from tests on ESPs than either scrubbers or baghouses on incinerators. One possible explanation of this scatter would be the rapping cycle and rapping intensity of the ESP. A poorly tuned ESP as regarding rapping cycle and intensity could allow peak (spike) emissions when there is rapping. Inadequate rapping intensity would allow buildup which could slough off at irregular intervals causing re-entrainment and peak emissions. Too intense rapping could also cause re-entrainment. A rapping cycle which leaves too much time between raps could allow a buildup similar to inadequate intensity and cause the same peak emissions.

DATA ANALYSIS

The most important aspect of any program is the analysis of the data. A careful program can be worthless if insufficient data was gathered and if inadequate time is spent on data analysis. The goals of the program must be first established in the planning stage. Individuals responsible for gathering these data must be made aware of exactly what is needed. These requirements vary with the purpose of the testing program.

Careful analysis of the operating data and log books can many times yield an explanation for the scatter of results. Quite often the scatter is attributed to test error. Thus, costly tests must be repeated. Many times a careful inspection of the process and operating data indicates changes which are the cause for this scatter. This careful inspection of process data is generally overlooked by the manufacturers or owners. It has been the unfortunate general rule that if any of the parties involved in the test program do not agree with the test result, they simply blame the testing engineers and find fault with the test. Table 2 illustrates the effect that a small parameter change can have on emission rates.

Analysis of the data from (regulatory) compliance testing programs is a fairly simple task. All that is required is verification of all calculations and analysis of the data by a competent person to verify that all results are realistic.

If a compliance test is performed on an incinerator ESP control system by a regulatory agency, testing consultant or manufacturer, the probable causes or reasons for not meeting desired performance levels may not be obtained. By definition a compliance test is designed only to determine compliance with regulatory standards.

Contract compliance testing calls for a more detailed analysis of results. Following verification of data, it is necessary to determine that all specifica-
tions of the equipment contract have been met. These specifications include ESP power input, inlet dust loading, gas temperature, fuel analysis, gas flow (ACFM) and others. This type of program calls for a more rigorous recording of plant operating and control equipment operating data than is necessary for a regulatory compliance testing program.

Trouble shooting a piece of equipment requires the most involved data analysis. These programs require that the best possible plant and control equipment operating data be gathered as well as observations of any unusual occurrences. The testing program should be structured so that all necessary data is available for complete analysis of the problem. The necessary data includes the following (some values are calculated):

1) Specific collection area of ESP
2) Migration velocity (effective)
3) Power input
4) Inlet dust loading
5) Outlet dust loading
6) Flue gas temperature
7) Flue gas analysis (O₂, CO₂, CO, H₂O)
8) Flue gas flow rate
9) Removal efficiency (particulate)
10) Fuel analysis (%S, %Ash)

From the above data a series of histograms and graphs can be made to facilitate analysis of the problem. These graphical analyses have advantages in that they show trends. And they can also show time lags between changes in various parameters and the effects on ESP performance.

A complete test report should include all of the items listed in Table 1, The Typical Table of Contents, plus all raw data collected in the field.

**RECOMMENDATIONS**

With the importance placed on current laws and regulations a need for more intensive and thorough testing programs have evolved. However, no guidelines for these programs developed.

It is still common practice to try to determine compliance, regulatory or contract based upon three test runs. Statistically three tests cannot be used with high confidence levels for data quality assurance programs. In addition, the combination of ESP incinerator in series are one of the most difficult processes to conduct test programs on.

If the number of parameters affecting the performance of ESPs and that changes in these may have time delay factors from several hours to several days. Another complicated problem has to be considered in the evaluation of this process.

Therefore it is our recommendation that testing programs include the following:

1) Intensive monitoring of all parameters.
2) Ten or more test runs conducted over 3 or more days.
3) Conductance of pre-test surveys.
4) Preparation of test protocol.
5) Eliminate the use of the Orsats for adjusting emission rates to excess air standards.
6) That ASME conduct a research program to confirm the accuracy and application of the F factor for garbage.
7) Develop standard methods for auxiliary analyses such as particle size, resistivity, and chemical analysis of fuels and flyash.
8) Before contracts are prepared be sure that the conditions specified can be tested.

**REFERENCES**