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Technical Assistance Document:

Performance Audit Procedures for Opacity Monitors

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Abstract

This manual contains monitor-specific performance audit procedures and data forms for use in conducting audits of installed opacity continuous emission monitoring systems (CEMS's). General auditing procedures and acceptance limits for various audit criteria are discussed. Practical considerations and common problems encountered in conducting audits are delineated, and recommendations are included to optimize the successful completion of performance audits.

Performance audit procedures and field data forms were developed for six common opacity CEMS's: (1) Lear Siegler, Inc. Model RM-41; (2) Lear Siegler, Inc. Model RM-4; (3) Dynatron Model 1100; (4) Thermo Electron, Inc. Model 400; (5) Thermo Electron, Inc. Model 1000A; and (6) Enviroplan Model D-R280 AV. These procedures were designed to be performed by a single auditor. The concise, step-by-step format of the audit procedures promotes a thorough evaluation of the quality of the monitoring data and the reliability of the opacity monitoring program.

Generic audit procedures have been included for use in evaluating opacity CEMS's with multiple transmissometers and combiner devices. In addition, several approaches for evaluating the zero alignment or "clear-path" zero response have been described. The zero alignment procedures have been included since this factor is fundamental to the accuracy of opacity monitoring data, even though the zero alignment checks cannot usually be conducted during a performance audit.

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SECTION 1

INTRODUCTION

1.1 BACKGROUND

In 1975, the U. S. Environmental Protection Agency (EPA) first promulgated specific requirements for several source categories subject to the Standards of Performance for New Stationary Sources to install, operate, and maintain systems for continuous monitoring of effluent opacity. At the same time, EPA also promulgated similar provisions necessitating revisions to State Implementation Plans to include opacity monitoring requirements for selected source categories. Since these actions, Federal, state, and local air pollution control agencies have expanded the applications of opacity continuous emission monitoring systems (CEMS's) by adopting monitoring requirements for additional source categories, requiring monitoring in operating permits, and through the use of other source-specific mechanisms. In most cases, the source owner or operator must periodically report data related to excess emissions and monitor performance to the appropriate control agency. Data on excess emissions are most often used as an indication of whether proper operation and maintenance practices for process and control equipment are being used. However, the opacity monitoring data may also be evaluated by the control agency as an indication of: (1) the degree of compliance with applicable opacity standards, (2) particulate emission levels, and (3) the need for an inspection of the source.

Regardless of the particular monitoring requirements or the control agency's use of the data, issues affecting the quality of the CEM data are of concern to both control agency and source representatives. In almost all cases, the source/owner or operator is required to demonstrate that the opacity CEMS complies with Performance Specification 1 of Appendix B, 40 CFR 60. This demonstration (referred to as a performance specification test) is usually completed shortly after the opacity CEMS becomes operational, and serves to ensure that the monitoring system is properly installed and is capable of providing reliable data.

EPA regulations and most state and local regulations include minimum operating procedures that the source owner or operator must follow after completing the initial performance specification test. Typically, source operators are required to check the response of the opacity CEMS at two points at least once each day. These checks are usually performed at zero opacity and an upscale point referred to as the span check through the use of an internal device that simulates a zero opacity condition and an internal filter that obscures a known quantity of the light beam. (Some opacity CEMS's substitute a low range opacity check for the zero check.) For sources subject to EPA requirements in 40 CFR 60, cleaning of the optical surfaces exposed to the effluent stream and adjustment of the monitor are required if the zero or span check responses exceed two times the drift limits in Performance Specification 1. Most state and local regulations are similar. Except for the zero and span check requirements, EPA and most state and local monitoring regulations do not require the source operator to conduct tests or otherwise periodically assess the quality of the opacity monitoring data. However, most monitoring regulations require the source owner or operator to properly operate and maintain the opacity CEMS, to keep records of all adjustments and repairs to the monitoring system, and to submit periodic reports to the control agency (i.e., quarterly excess emissions reports).

Audits of CEMS's may be conducted in order to assess the quality of data provided by CEMS's and/or to identify operation and maintenance problems that may impact the reliability of opacity monitoring results. A performance audit provides a quantitative evaluation of monitor performance in terms of the accuracy and precision of the data acquired by the opacity monitoring system. Since it is not feasible to obtain independent effluent measurements for comparison with the measurements provided by an installed opacity monitor, a series of checks of the individual monitoring system components is conducted. Based on the results of these checks, an assessment of the performance of the entire monitoring system can be made.

Audits of opacity CEMS's may be conducted by either the control agency or source personnel. Performance audits may be conducted by the control agency to assess the quality of opacity monitoring data, at sources selected randomly, or at sources where opacity monitoring problems or high levels of excess emissions are indicated in quarterly excess emission reports. Performance audits may also be conducted by source personnel (or other company representatives) on a routine basis, as part of a quality assurance program, or when specific concerns arise regarding the validity of the opacity monitoring data. A performance audit provides a relatively simple and quick method of obtaining an objective evalution of opacity monitor performance, regardless of who conducts the audit.

1.2 USE OF THIS MANUAL

This manual provides detailed procedures for conducting performance audits of opacity CEMS's. This manual updates and replaces the information and procedures contained in an earlier document "Performance Audit Procedures for Opacity Monitors," (EPA 340/1-83-010, January 1983). The audit procedures were revised based on experience gained in conducting several hundred opacity CEMS audits and during other EPA studies that involved the evaluation of opacity CEM reliability at particular sources.[1,2] The revised audit procedures more adequately address practical considerations and problems that are encountered in conducting audits. The revised procedures address changes in contemporary monitoring instrumentation, additional types of monitors, and new audit devices and methods for certain monitors. In many cases, revisions to the audit procedures have been made to eliminate the collection of unnecessary or irrevalent data and to simplify the audit procedures. These changes also significantly reduce the amount of time necessary to conduct a performance audit. This manual also provides updated guidance for the interpretation of audit results. Revisions of acceptance limits for some audit critera are included that reflect changes in applicable EPA regulations and/or additional experience with opacity CEMS's.

The procedures in this manual have been developed with the goal of simplifying the technical aspects of opacity CEMS's so that performance audits can be conducted by a single person who has a basic understanding of monitor

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[1]Peeler, J. W. CEMS Pilot Project: Evaluation of Opacity CEMS Reliability and QA Procedures, Volume I. EPA-340/1-86-009a, U. S. Environmental Protection Agency. May 1986.

[2]Peeler, J. W., and Quarles, P. Summary Report: A Pilot Project to Demonstrate to Feasibility of a State Continuous Emission Monitoring System (CEMS) Regulatory Program. EPA-340/1-86/007. U. S. Environmental Proetection Agency. June 1986.

operation. Section 2 of this manual discusses practical problems and considerations in conducting audits and the gathering of preliminary information prior to the audit. Section 2 also presents a discussion of general opacity monitor audit procedures and the evaluation of audit results. Sections 3 through 7 each provide monitor-specific information and annotated, step-by-step audit procedures for various monitors. Much information is provided in those sections so that relatively inexperienced personnel can conduct audits by carefully following the instructions; however, some amount of field training is recommended. Also provided in the appendices to this document are monitor-specific data forms (coded to correspond with the step-by-step instructions). Use of these data forms will assist the auditor in recording all of the necessary information and in calculating the audit results.

Section 8 of this manual describes performance audit procedures for use in evaluating opacity CEMS's that include multiple duct mounted transmissometers and a combiner device for computing the equivalent combined stack-exit opacity. A generic approach is presented for conducting audits of opacity CEMS's with combiners. These procedures require that the auditor understand the monitor-specific audit procedures for opacity CEMS's with a single transmissometer. Section 9 of this manual discusses several approaches for checking the zero alignment of the opacity monitoring system. Although the zero alignment checks cannot usually be conducted during a performance audit, these procedures are included because of the importance of the zero alignment to the accuracy of the opacity monitoring data.

The uninitiated auditor may find some of the discussions in Sections 1 and 2 of this manual somewhat overwhelming at first. However, review of these materials after working through the monitor-specific information for at least one monitor should eliminate confusion regarding the basic approach and terminology.

1.3 APPROACH AND LIMITATIONS

Opacity CEMS performance audits involve a series of checks of individual monitoring system components and/or factors affecting the operational status or accuracy of the opacity measurements. The first of these checks are performed from the monitor control unit/data recording location, which is usually installed in the boiler or process control room. Subsequent checks must be performed at the transmissometer installation location on the stack or duct. In general, performance audit procedures involve the following consecutive checks:

(1) Monitor Component Analysis

- An attempt is made to verify the accuracy of the pathlength correction factor used to convert measurements obtained at the monitoring location to the equivalent opacity that would be observed at the stack exit. Ideally, two issues are considered: (a) whether the proper dimensions were used in establishing the pathlength correction factor, and (b) whether the value of the pathlength correction factor used by the monitor is consistent with the calculated value. However, it is not always possible to address these issues during a performance audit because of practical constraints.

- Fault lamp indicators on the monitor control unit are checked to determine whether the monitor is operating within preset limits. Usually, these limits are established by the monitor manufacturer; however, for some monitors, the user may select activiation limits for the fault circuits.

- Various internal electronic checks are performed in accordance with the recommendation of the monitor manufacturer to determine the operational status of the monitor. These checks are performed using the controls and meters of the monitoring system; use of external electronic test equipment is generally beyond the scope of the performance audit.

- The responses of the opacity CEMS permanent data recorder and (if applicable) the control unit panel meter to the zero (or low range) and span check values are determined.

(2) Transmissometer Maintenance Analysis

- The optical alignment of the transmissometer (transceiver and reflector) components is checked using the alignment sight of the monitor. The results of this check are considered to be indicative of the mechanical stability of the monitor mounting.

- The dust accumulation on optical surfaces is checked to determine the status of the purge air system and the adequacy of the frequency of lens cleaning. This determination is based on the difference in the apparent opacity before and after cleaning of the optical surfaces exposed to the effluent stream. The results of this check may be adversely affected by fluctuations in the effluent opacity at some sources.

(3) Calibration Error Analysis

- The calibration linearity and the accuracy of the monitor's opacity measurements relative to a series of neutral density filters and to the monitor's own zero value are determined. For most monitors, this test is performed using an audit device that simulates clear-path conditions and allows insertion of the filters into the light path. For other monitors, the calibration error determination is accomplished by evaluating the monitor response to the superposition of audit filters and the effluent opacity. In either case, neutral density filters must be inserted into the light path of the transmissometer, and the corresponding response of the monitoring system is determined from the permanent data recorder.

Although the purpose of the performance audit is to provide a basis for evaluating the accuracy and precision of the monitoring data, the audit procedures do not provide a single result which is representative of the overall performance of the monitor. Instead, the series of steps described above serves to identify problems which detract from the accuracy of the opacity measurements. In the absence of such problems, the opacity measurements are assumed to be accurate.

It is emphasized that the results of the calibration error check of an installed opacity CEMS do not provide a measure of the absolute accuracy of the monitoring data prior to the audit for two reasons. First, the presence of the effluent opacity during the audit prohibits detection of any offset or error in the zero opacity response of the monitor. A determination of the absolute accuracy of an opacity CEMS can only be accomplished by combining the results of a performance audit (e.g., accuracy of monitoring data relative to the simulated zero value) with the results of an independent zero alignment check (e.g., determination of the degree of agreement between the simulated zero response and true zero response of the monitor under clear-path conditions). Normally, the zero alignment check cannot be conducted during a perforamnce audit (see Section 9).

Second, the results of the calibration error check do not include the measurement bias that is due to the accumulation of particulate material on the optical windows of the transmissometer, since the windows are cleaned prior to conducting the calibration error test. To estimate the accuracy of the opacity measurements prior to the audit, superposition of the results of the calibration error check and the dust accumulation checks would be necessary. Consideration of zero and span errors would not be necessary, provided that no adjustments to the monitor are made during the audit.

SECTION 2

GENERAL AUDIT PROCEDURES

This section provides an overview of opacity CEMS performance audit procedures as a supplement to the monitor-specific procedures detailed in Sections 3 through 7. Practical considerations affecting opacity CEMS performance evaluation programs are addressed. Information that should be acquired before the audit is conducted is identified in Section 2.2. A discussion of general audit procedures, acceptance limits for various audit criteria, and the evaluation of audit results is provided in Section 2.3.

2.1 PRACTICAL CONSIDERATIONS

Several practical considerations are addressed below since questions regarding these matters occur very frequently.

Manpower - Performance audits may be conducted by one person or by a team consisting of at least two people. If one person performs the audit, a sufficient period of time must be allowed to elapse after each action taken at the actual monitoring location (e.g., cleaning of windows, insertion of filters, etc.) to allow the monitoring system to obtain and record the proper response. This period would be approximately two minutes for monitors recording instantaneous opacity data on strip chart recorders. For an opacity CEMS that records only 6-minute averages, a period of 13 minutes must elapse between each action that the auditor performs, since it is not possible for an auditor at the monitoring location to determine when the 6-minute period begins. Conducting an audit under these circumstances would require the lone auditor to remain at the monitoring location for at least 5 hours. Since this is obviously impractical, the audit should be performed by two people in those very unusual cases where the CEMS cannot display instantaneous or short term averages. A second drawback of having one person conduct opacity CEMS audits is that the auditor has no real-time feedback to indicate when specific steps in the audit should be repeated because of the uncertainty of particular results. Thus, only after the audit is complete can the auditor ascertain if any or all of the checks at the monitoring location need to be repeated.

Using a team of at least two people (one at the monitoring location and one at the control unit/data recording location) greatly reduces the time required to complete the necessary steps at the monitoring location and eliminates the feedback problems, assuming that effective communication between the two locations is established. (The person recording the measurements at the control unit does not have to be trained in auditing monitors, since recording of the monitor responses and advising the auditor to continue with the next step is all that is required.) In many cases, a single control agency representative can perform the audit in an effective manner, provided that a source representative is willing to act as the second person. Personnel at most sources are usually willing to provide this assistance. However, control agency representatives who plan to conduct audits in this manner should request the assistance of plant personnel in advance of the audit to make sure that personnel are available and willing to perform specific activities. Also, the auditor should check to ensure that the plant representative determines the monitor responses from the appropriate data recording device and that he interprets and records the values correctly.

Communication - Communication between the monitoring location and the control unit/data recorder location is essential when audits are conducted using the team approach. Some power plants have hard-wired communication lines between the two locations that can be used by the auditor. In some cases, plant personnel will loan radios to the audit team or will operate radios for the auditors. However, the availability of such equipment at power plants and other stationary sources is generally very limited. Control agency auditors should not assume the availability or use of such equipment; they should discuss the need for such equipment with plant personnel in advance or provide their own equipment.

Communication between various locations at stationary sources using short wave radios is often severely restricted or impossible because of electrical interference and shielding problems. The use of FM radios is preferred. However, it is imperative that non-plant personnel obtain clearance to use such equipment prior to its use at any stationary source. In some cases, use or even possession of radios in the plant control room is prohibited, since these radios may interfere with instrumentation or control signals necessary to operate the plant safely. The consequence of unauthorized use of radios can be very significant.

Computer System Operations - Some plants are equipped with computerized data acquisition systems. The operation and control of such systems may be complex, and the output format may be confusing when first encountered. Control agency personnel who are conducting performance audits should not expect to fully understand how such systems operate. Plant personnel should be requested to enter necessary control commands to facilitate acquisition of the appropriate output. An explanation sufficient to allow the auditor to obtain the necessary monitor responses from the computer output should be obtained, or the auditor should request that source personnel determine the monitor responses from the computer output for each step of the audit.

Equipment Damage Liability - Auditing of opacity CEMS's presents a situation where there is a very remote chance that the monitoring equipment could be damaged. Control agency personnel should determine, in advance, their agency's policy with respect to assuming such liability. In the event that relevant policy prevents the assumption of such liability, control agency personnel should adopt a "hands off" posture and have qualified plant personnel perform the audit under their direct supervision. Plant personnel should be notified in advance of this situation so that appropriate personnel will be available at the time the audit is conducted.

Organizational and Labor Constraints - The auditor should be mindful of protocol with respect to plant organizational interaction. Because the operation and maintenance of the opacity CEMS's and reporting of opacity data may involve personnel from the corporate environmental department, as well as plant environmental operations, instrumentation, and maintenance departments, the auditor should plan to conduct a brief initial meeting with representatives of concerned organizations in order to describe the audit procedures, discuss possible actions resulting from the audit, and to answer questions. Also, the auditor must be aware in advance of restrictions of his actions resulting from union limitations. For example, the auditor may not be allowed to press buttons or even touch the monitor controls. Also, break, meal, and quitting times may be rigidly enforced, thereby restricting the auditor's access to plant equipment and personnel.

Preserving Objectivity - Regardless of whether control agency personnel or source representatives conduct the audit, it is advantageous to all parties to take several simple steps to preserve the objectivity of the auditors. Therefore, the correct values for the zero (or low range) and span checks of the monitor should be determined prior to initiating the zero or span checks. Also, the calculated values of the neutral density filters, as corrected to stack exit conditions, should not be divulged to the person recording the monitor responses for the calibration error test until after the test is completed.

2.2 PRE-AUDIT INFORMATION

The successful completion of an opacity audit requires certain information about the source, the monitor, and the data recording system. In the case of a control agency, this information is available typically in source files. Prior to an audit, it is necessary only to extract the information from the agency records. During the audit, the information should be verified and updated as necessary. If the auditor cannot acquire information on the source from existing files, then he should utilize the opacity audit data form (Figure 2-1) to compile the necessary information prior to or during the audit. This form should become part of the maintained and updated data base for the particular source. The information categories on this form are described as follows:

Critical Information: Tells the auditor at-a-glance the when, what, where, and who of the audit without having to search through the data form.

Source Identification: This information identifies the particular facility to be audited, both by the corporate name and the plant or station name. The plant mailing address and telephone number are included, and the person at the plant indentified as the principal contact is identified and his telephone number is included. This information facilitates communications with plant personnel responsible for the opacity monitors.

Corporate Contact: Many source organizations have corporate personnel charged with overseeing environmental activities in the satellite facilities. Typically, these persons should be notified as to audit plans and should receive copies of audit results. Therefore, their names, addresses, and telephone numbers should be included.

Additional Contacts: Source personnel concerned with monitor operation, maintenance, calibration, servicing, or data reduction should be identified as encountered. This information will aid the auditor in acquainting himself with the source's monitoring program. Also, it may be necessary to contact some of these individuals to answer specific questions as they arise.

Source Data: Information about the unit, its output capacity, and fuel and pollution control equipment is included to provide a basis for a description of the plant. The output capacity should be that from the most recent permit, in the same units as specified in the permit. Because communications between the opacity data recorder and transmissometer locations are vital in facilitating the completion of an audit by a lone auditor, the auditor should determine in advance if the source can supply communications equipment (radios, telephone, etc.) and an employee to take preliminary reading from the opacity data recorder during the transmissometer portion of the audit.

CRITICAL INFORMATION:

PERSON TO CONTACT UPON ARRIVAL: ______________ FINAL AUDIT DATE: ______________

AT (GATE, OFFICE, ETC.): ______________ TIME: ______________

UNIT #: ______________

MONITOR TYPE: ______________ SOURCE NAME: ______________

OPACITY AUDIT DATA FORM

DATE: ______________

INDIVIDUAL SUPPLYING INFORMATION AND HIS AFFILIATION: ______________

SOURCE IDENTIFICATION:

CORPORATION: ______________

PLANT OR STATION NAME: ______________

PRINCIPAL CONTACT: ______________ TELEPHONE #: ______________

PLANT MAILING ADDRESS: ______________ PLANT TELEPHONE #: ______________

____

____

CORPORATE CONTACT:

NAME: ______________

TITLE: ______________

MAILING ADDRESS: ______________

____

____

TELEPHONE #: ______________

ADDITIONAL CONTACTS:

1. NAME: ______________

AFFILIATION: ______________

TELEPHONE #: ______________

2. NAME: ______________

AFFILIATION: ______________

TELEPHONE #: ______________

3. NAME: ______________

AFFILIATION: ______________

TELEPHONE #: ______________

Figure 2-1. Opacity Audit Data Form

OPACITY AUDIT DATA FORM (CONTINUED)

SOURCE DATA:

UNIT #: ____________________ OUTPUT (MW): __________ (FROM PERMIT)

FUEL: ____________________ AIR POLLUTION CONTROL EQUIPMENT: ____________________

TYPICAL EFFLUENT OPACITY : ____________________

AVAILABILITY OF COMMUNICATIONS (RADIO, TELEPHONE, ETC.) BETWEEN MONITOR LOCATION AND CONTROL ROOM:

____

AVAILABILITY OF PERSONNEL TO TAKE READINGS FROM OPACITY DATA RECORDER DURING AUDIT:

____

MONITOR LOCATION:

MONITOR LOCATION (STACK/DUCT): ____________________

DISTANCE FROM NEAREST FLOW OBSTRUCTION: __________ (UPSTREAM) __________ (DOWNSTREAM)

HEIGHT (IN FEET): __________ (TO MONITOR) __________ (TOTAL STACK)

ACCESS TO SAMPLING LOCATION (LADDER, STAIRS, HOIST, ELEVATOR): ____________________

STACK/DUCT INSIDE DIAMETER: __________ (AT MONITOR LOCATION) __________ (STACK EXIT)

MONITOR DATA:

MANUFACTURER/MODEL #: ____________________

MONITOR PRESET STACK EXIT CORRECTION FACTOR (BY MONITOR MANUFACTURER): ____________________

MONITOR ZERO AND SPAN VALUES (BASED ON MOST RECENT CALIBRATION): __________ (ZERO) __________ (SPAN)

COMBINER SYSTEM IN USE ? ____________________

DATA RECORDING/LOGGING SYSTEM: ____________________

DATA FORMAT USED IN REPORTING TO A.Q. AGENCY (6-MIN/DAILY AVGS.): ____________________

AVAILABILITY OF INSTANTANEOUS MONITOR OUTPUT RECORD (METER, STRIPCHART, OR COMPUTER): __________

____

RECENT REPAIRS/MODIFICATIONS/CALIBRATIONS: ____________________

____

SOURCE EMPLOYEE MOST FAMILIAR WITH THE MONITORING SYSTEM: ____________________

____

Figure 2-1. (continued)

OPACITY AUDIT DATA FORM (CONTINUED)

COMMENTS: ____

MONITOR LOCATION SCHEMATIC	OPACITY DATA SYSTEM SCHEMATIC

Figure 2-1. (continued)

Monitor Location: The monitor location should be specified with respect to height and distances from upstream and downstream flow disturbances, in order to produce a schematic drawing of the monitor within the effluent system. The most critical dimensions to be acquired are the stack exit inside diameter and the stack inside diameter (or duct width) at the transmissometer location. These values form the basis of the stack exit correlation factor, and should be known with an accuracy of ± 1.0 inch. The form of access to the monitor location (ladder, stairs, elevator, etc.) should be known so that the auditor can budget his time if a lengthy climb is anticipated.

Monitor Data: The monitor should be identified by manufacturer and model number. If possible, the stack exit correlation factor and zero and span values should be identified either prior to or at the outset of the audit. Because the zero and span values may change due to clear path calibration results, these values should be verified prior to each audit.

The presence of a combiner system should be identified prior to the audit because specialized audit procedures are required for such systems. The data recording/logging system should be identified and categorized as to stripchart, circular chart, and/or computer. Frequently, sources employ a combination of chart and computer data systems, with both instantaneous and six-minute averaged opacity data being recorded. If the source records only six-minute averaged data, the auditor should request source personnel be available to reset the control unit integrator to produce instantaneous opacity data for the duration of the calibration error analysis. Also, the auditor should note the averaging format of data reported to the control agency. The auditor should inquire about any recent repairs, modifications, or calibrations of the monitor. This information will allow him to identify possible problems that may be encountered. Also, he should obtain the name of the source person most knowledgable about the operation and maintenance of the monitor so that this person could be consulted for additional information.

Comments: The auditor should include general comments about the source or monitor that will facilitate the audit.

Monitor Location Schematic: The auditor should sketch the effluent system, including the heights and distances associated with the monitor location and upstream and downstream flow disturbances. The schematic should include stack exit and monitor location dimensions.

Opacity Data System Schematic: The auditor should sketch the flow of opacity data from the transmissometer to the control unit and to the opacity data recorder. The sketch should show the content and format of the data (e.g., double-pass transmittance, instantaneous path opacity, six minute averaged stack exit opacity), as well as the system components (e.g., transmissometer, control unit, stripchart recorder, computer, printer, etc.).

2.3 PERFORMANCE AUDIT PROCEDURES

The following discussions identify and define the specific parameters that are evaluated during a performance audit, describe how these parameters are measured, and indicate acceptable limits for the various criteria. Additional suggestions and methods for evaluating various parameters are provided for those areas where problems are frequently encountered.

Opacity monitor performance audits provide an accurate, reliable indication of monitor performance through a simple, quick field test procedure which can be performed by a single technician who has a basic understanding of monitor operation. Specialized equipment necessary for a typcial audit includes a monitor-specific reflector ("audit jig") which is used to simulate clear stack conditions, materials for cleaning the optical surfaces exposed to the effluent, and a set of three calibrated neutral density filters to evaluate the calibration error of the monitor. All of the equipment required for an opacity monitor performance audit can be transported in a small suitcase. The auditor should also have safety equipment, including a hard hat, safety glasses, hearing protection, and any specialized equipment necessitated by the particular plant environment.

The audit procedures are organized sequentially according to the location of the monitoring system components (moving from the control unit location to the installed transmissometer and then back to the control unit), so that a single individual can conduct the audit. As previously described, in many cases it is advantageous for multiple personnel to be involved in conducting the audit. The general audit procedures and acceptable limits for the various criteria are described below.

2.3.1 Stack Exit Correlation Error

Typically, the cross-stack optical pathlength of the installed opacity monitor is not equal to the diameter of the stack exit. To obtain a true stack exit opacity value, the measured opacity at the monitor location is corrected to stack exit conditions through the use of a pathlength correction factor. Ideally, the stack exit correlation error is the percent error of the pathlength correction factor used by the CEMS, relative to the correct pathlength correction factor calculated from actual dimensions. The stack exit correlation error should not exceed ± 2 percent.

Determining both the actual and the correct pathlength correction factors is often difficult in practice. Measurement of the monitoring pathlength and the stack exit diameter is usually not possible; blueprints showing construction details are often not readily available at the source. The problem associated with determining the monitor pathlength and stack exit dimensions can be minimized by requesting the information in advance so that source personnel have time to locate the information. In addition, the flange-to-flange separation distance of the transceiver and reflector components should be requested. This information helps to identify the majority of problems that are likely to be encountered in the calculation of the pathlength correction factors, since by far the most common mistake is the use of the flange-to-flange separation distance in place of the depth of effluent (stack or duct internal diameter). (The flange-to-flange separation distance is always greater than the internal diameter of the stack or duct at the monitoring location and is used in establishing the proper pathlength for conducting off-stack, clear-path calibrations of the opacity monitor.) Unless there is an obvious error or question, the dimension provided by the source personnel should be used, and the auditor should calculate the correct value of the pathlength correction factor using the equations provided in the monitor-specific sections.

The auditor must attempt to determine the value of the pathlength correction factor that is used by the opacity CEMS. Two approaches may be used: (1) the auditor may be able to determine the value of the correction factor preset by the manufacturer, or (2) the auditor may be able to measure the pathlength correction factor in some cases.

The value of the pathlength correction factor preset by the manufacturer is sometimes indicated on the control unit, or is sometimes included in the documentation provided with the monitor. However, this information is sometimes unavailable or is undecipherable because several different values are found with no clue as to which one was finally used by the manufacturer. In such cases, it is not possible to determine whether the correct value was used by the monitor manufacturer. If the correction factor cannot be determined directly as described below, the audit report should indicate that the stack exit correlation error was not determined, and the correct value of the pathlength correction factor should be used in all subsequent audit calculations.

Any error associated with the value of the pathlength correction factor will result in a systematic, non-linear bias in the mean differences obtained for the low, mid, and high range calibration error checks. (In the absence of other problems, errors in the pathlength correction factor will result in increasing errors with increasing opacity.) When the audit results indicate such a bias, the auditor can, as a troubleshooting technique, calculate the value of the pathlength correction factor that would provide a zero value mean difference for the mid range filter, and then use this pathlength correction factor for recalculating the low and high range calibration error check results. If the systematic bias in the calibration error results is removed, it is likely that the problem with the monitor is due to an error in the pathlength correction factor. It is emphasized that when other problems with the monitor are found (e.g., zero offset, excessive span error, misalignment, etc.), use of the above calculation procedure to evaluate errors in the pathlength correction factor becomes significantly more complicated, if not impossible. Therefore, it is strongly recommended that the other problems be resolved prior to attempting to determine if the pathlength correction factor is wrong.

In some cases it is possible to measure the pathlength correction factor using the same procedures that are used by the monitor manufacturer for the initial set-up of the instrument. As an example, for the Lear Siegler RM41 opacity monitor, the pathlength correction factor can be determined by removing the opacity circuit board from the control unit and measuring the resistance of the R_6 potentiometer using a digital voltmeter or equivalent device. The value of the OPLR is then calculated as the resistance across R_6 divided by 400. Removal of circuit boards and/or performance of internal electronic checks should only be performed by qualified personnel. It is recommended that these types of procedures not be attempted by control agency representatives, since such diagnostic procedures are beyond the scope of the audit and involve the use of equipment that may be unfamiliar to the control agency auditor. Where applicable, procedures for measurement of the pathlength correction factor are included in the monitor-specific sections that follow.

2.3.2 Fault Lamp Indicators

The control unit of a typical opacity monitor has several fault lamps that warn of monitor system malfunctions. These fault lamps are indicative of a variety of conditions, depending on the manufacturer, but most units use fault lamps to monitor the intensity of the optical beam, the quantity of dust on monitor optical surfaces, and the status of internal circuitry that maintains monitor calibration. In general, the monitor parameter indicated by a fault lamp is "out of specification" if the fault lamp is illuminated. However, this simple rule does not always account for malfunctions in the fault indicator circuitry or for a burned-out or missing lamp bulb.

Many contemporary, computerized data handling systems are capable of performing a variety of self-diagnostic tests and of displaying "error messages," "flags," or CEMS malfunctions/faults in the permanent record. The availability of such outputs is dependent on both the type of monitor and the particular software that are used. In almost all cases, the explanation of error messages is either self-evident or can be adequately explained by the personnel responsible for CEMS operation.

2.3.3 Auxiliary Electronic Checks

Some opacity CEMS's provide access to various electronic signals or circuits which are indicative of the monitor operational status through the monitor control unit or data handling system. Such signals are inherently monitor-specific and tend to reflect parameters which the manufacturer identifies as critical to the accuracy of monitor calibration or operation. Examples of such signals are the Lear Siegler RM-41 reference signal and the Dynatron Model 1100 M lamp voltage, both of which are critical parameters in the operation of the respective monitors. Monitor-specific procedures are provided for the evaluation of these parameters in Sections 3 through 7 of this manual. For other monitors, the auditor should refer to the operator's manual for the identification of important parameters and corresponding test procedures.

2.3.4 Panel Meter Checks

Most opacity CEMS's are equipped with an analog or digital panel meter on the control unit. Some CEMS's are also equipped with an analog meter at the transceiver location which may be useful as a reference for making adjustments to the monitor. Checks of the accuracy of the panel meter may be performed for each type of measurement which can be displayed on the panel meter (i.e., opacity and optical density for most monitors and input current signals for some monitors). The panel meter correction factors are the ratio of the panel meter responses to the specified values for the opacity filter, input signal, or optical density filter. Results within ± 2 percent (ratios within the range of 0.98 to 1.02) are considered acceptable.

The determination of panel meter factors should be deleted (1) for all parameters that are not normally monitored or used to assess monitor performance by source personnel (e.g., optical density for most sources), and (2) when source personnel refer to other measurement output devices (e.g., strip chart recorders, computer outputs, and digital voltmeters) when they perform calibration adjustments for the monitoring system. However, when source personnel use the panel meter to determine when adjustments are necessary or to perform the actual adjustments, the appropriate panel meter scale factors should be determined. Specific recommendations regarding the determination of panel meter accuracy are provided in each monitor-specific section of this manual.

2.3.5 Zero and Span Errors

The zero and span errors are the percent opacity differences between the rated opacity values of the simulated zero device (or low range check) and interal span filter and the corresponding opacity CEMS responses, respectively. The opacity CEMS responses must be determined from the permanent data recorder that provides the basis for emissions data reported to the applicable control agency. (The zero and span errors are the same as the results of the required daily zero and span checks, except that they are performed during the audit rather than on the normal schedule.)

The previous performance audit procedures manual specified a zero (or low range) and span error acceptance limit of ± 2% opacity. At the time the manual was written, these limits were consistent with the applicable EPA regulations (40 CFR 60.13), which required adjustment of the opacity CEMS when the day-to-day zero drift exceeded the limits of Performance Specification 1. When EPA promulgated revisions to Performance Specification 1 (Federal Register, Vol. 48, No. 62, March 30, 1983, pp. 13322-13339), the drift limits of Performance Specification 1 for the 24-hour zero and calibration drift test did not change. However, when EPA promulgated revisions to Performance Specifications 2 and 3 (for SO_2, NO_x, CO_2, and O_2 monitors) and revisions to 40 CFR 60.13 (Federal Register, Vol. 48, No. 102, May 25, 1983, pp. 23608-23616), the requirement to adjust CEMS calibration was relaxed; adjustment is now required when the zero or calibration drift exceeds twice the applicable performance specification limit. Thus, for sources subject to EPA regulation, adjustment of opacity CEMS calibration is now required only when the drift exceeds ± 4% opacity. For sources subject to state or local requirements, the acceptance limits for zero and span errors should be consistent with the applicable regulations.

2.3.6 Zero Compensation Limit

Some opacity CEMS's are equipped with a circuit or other means of automatically adjusting the monitor calibration to compensate for drift in the monitor's response to the simulated zero opacity condition. This automatic adjustment (zero compensation) accounts for dust accumulation on the optical surfaces of the transceiver. The acceptable limit for zero compensation is ± 0.018 OD, which is equivalent to ± 4% opacity, both before and after cleaning of the optical surfaces of the transmissometer. This value is consistent with the limitation imposed by EPA regulations contained in 40 CFR 60.13 (d)(1):

> "For continuous monitoring systems measuring opacity of emissions, the optical surfaces exposed to the effluent gases shall be cleaned prior to performing the zero and span drift adjustments except that for systems using automatic zero adjustments. The optical surfaces shall be cleaned when the cumulative automatic zero compensation exeeds 4 percent opacity."

A reduced compensation limit should not be applied to the "post cleaning" value due to the sensitivity of this parameter.

2.3.7 Monitor Alignment Error

The optical alignment of the transceiver and reflector components is critical in maintaining accurate opacity measurements. Misalignment of the beam can cause erroneously high opacity readings, because a significant portion of the measurement beam is not returned to the transceiver. Most opacity monitor manufacturers include provisions for an optical alignment check, either as a standard feature or as an option. Monitor alignment errors are indicated by an off-center light beam.

2.3.8 Optical Surface Dust Accumulation

The amount of dust found on the optical surfaces of the transmissometer is quantified (in units of percent opacity) by recording the effluent opacity before and after each window is cleaned. The optical surface dust accumulation is excessive if the total reduction in apparent opacity (i.e., the sum of transceiver and reflector dust accumulation) after cleaning of the optical surfaces exceeds 4 percent opacity.

The results of this check may be adversely affected by fluctuations in the effluent opacity over the time period required to clean the windows and obtain the opacity measurements. The auditor should be careful in obtaining instantaneous opacity measurements that represent the effluent opacity; in some cases, average values may provide more representative results. In addition, when the windows are very clean at the time the audit is conducted, the auditor may actually increase the particulate matter on the optical surfaces rather than decrease it. The auditor should use the following procedures:

(a) For monitors with zero reflectors (e.g., Lear Siegler RM-4, RM-41, RM-4200, etc.), the auditor should clean the reflective side of the zero mirror when cleaning the transceiver window. Also, if the monitor is equipped with automatic zero compensation, the zero compensation should be reset after cleaning of the transceiver window (before cleaning of the zero reflector) and reset again after cleaning of the zero reflector, if possible. If this is not practical, the zero compensation should be reset after the cleaning of both the transceiver and zero reflector windows. Resetting of the zero compensation between cleaning of the optical surfaces provides an indication of whether dust has accumulated on each of the surfaces, independently. Since the biases introduced into the effluent opacity measurements from dust accumulation on the two optical surfaces are in opposite directions, the auditor must be careful in comparing changes in the zero compensation level with apparent changes in the effluent opacity.

(b) For all monitors, the auditor should check that the apparent effluent opacity decreases after the cleaning of each optical surface. (This is usually not practical if only one person performs the audit.) An increase in the apparent effluent opacity indicates that either (1) effluent opacity fluctuations have affected the results, or (2) the auditor has done an inadequate job in cleaning the optical surfaces. When an increase in the apparent effluent opacity occurs, the auditor should reclean the optical surfaces and recheck the effluent opacity.

(c) For all monitors, an apparent increase in the effluent opacity after cleaning of an optical surface provides a negative result for the quantity of dust accumulated on that optical surface. Presuming that the auditor has recleaned the optics and rechecked the effluent opacity, this nonsensical result can be attributed to variations in the effluent opacity. The negative result should be ignored; "negligible" dust accumulation should be stated in the report; and "zero" rather than the actual negative value should be used in calculating the total quantity of dust deposited on optical surfaces.

2.3.9 Calibration Error Checks

The calibration error check involves the comparison of the monitor responses to the known opacity values for three reference neutral density filters. (The values of the neutral density filters are corrected to stack exit conditions using the same pathlength correction factor that is used by the opacity CEMS.) For most monitors, this check is performed using an audit device that simulates clear-path conditions and allows insertion of the filters into the light path. The audit device is adjusted to provide the same zero response as the monitor's internal zero device. For other monitors, the calibration error check is performed by conducting an incremental calibration (i.e., superimposing the audit filters and the effluent opacity). For both types of calibration error checks, three filters are each placed in the light path five times. The low, mid, and high range calibration error results are computed as the mean difference and 95 percent confidence interval for the differences between the expected and actual responses of the monitor. The calibration error check results are acceptable if the calculated results for all three filters are less than or equal to 3 percent opacity.

The following additional procedures are applicable to calibration error checks:

(a) For all checks performed using a "clear path" audit device, the audit device is installed and adjusted to provide the zero response, and then each of three filters is placed in the light path five times. The calibration error results will be affected if the zero value provided by the audit device changes during the course of the 15 filter measurements. (Vibration at the monitoring location or the auditor accidentally bumping the iris adjustment lever of the audit device can cause such a change; these situtions occur quite frequently.) Therefore, at a minimum, the zero value produced by the audit device should be checked at the end of the calibration error test. If the difference between the "post test" and "before test" zero values is greater than 1 percent opacity, then the entire test should be repeated. For practical purposes, it is recommended that the auditor recheck the audit device zero value after each set of three filter measurements to make sure the zero value is stable. This practice allows the auditor to discover a problem sooner, and therefore requires that fewer measurements be repeated after the problem is corrected.

(b) For calibration error checks using "incremental calibration," the audit procedure involves superimposing a series of audit filters on the effluent opacity. The calculation procedure requires that the average of "before" and "after" effluent opacity readings be mathematically combined with the filter value in order to determine the expected or "correct" response. Thus, variations in the effluent opacity during each filter measurement will affect the accuracy and precision of the calibration error check results. Short term effluent opacity spikes present the greatest problem. Therefore, each instantaneous effluent opacity measurement and each filter measurement must be obtained from the digital panel meter as quickly as possible. Two-way communications between the monitoring location and the control unit location are required in this situation. When using this procedure, it is advantageous for the auditor to watch the panel meter for about 15 minutes before starting the test in order to recognize repeating patterns of opacity fluctuations such as those caused by activation of the rappers in the last stage of an electrostatic precipitator.

When particular monitor responses to the audit filters deviate by more than 1 to 2 percent opacity from the mean response to the filter, the audit procedures should be repeated. When the "before" and "after" effluent opacity measurements vary by more than 2 to 3 percent opacity, the audit procedures should also be repeated. It is usually possible to get 5 reasonable measurements of each filter in 7 or less attempts. The decision to accept or reject particular filter measurements is subject to the auditor's discretion. Where great difficulty is encountered in conducting the test, it is appropriate to relax the calibration error specification. It is suggested that where such difficulty is encountered, the confidence interval be ignored and the ± 3 percent opacity limit be applied only to the mean difference between the expected and actual monitor responses.

(c) For all monitors, the acquisition of a minimum of 15 filter responses using 6-minute averages (as are recorded at many stationary sources) is far too time consuming to be practical. Therefore, it is recommended that the calibration error check responses be determined from the permanent data recorder based on instantaneous measurements or short term averages (e.g., 1-minute) where possible. If the permanent data recorder cannot display such measurements, the calibration error measuremetnts can be obtained from the control unit panel meter or by use of a temporary output device such as a DVM, provided that two or more people perform the audit, and that communications between the control unit/data recorder location and transmissometer location are possible. This procedure is adequate for determining the accuracy and precision of the opacity monitor. An auxiliary check involving only one 6-minute average response for each of the three audit filters is adequate to determine whether the 6-minute averaging equipment is operating properly.

(d) Care must be exercised when handling the neutral density filters utilized in the calibration error check. Any contamination, such as fingerprints, dust, or moisture can cause positive biases in the audit results. If any visible foreign matter is present on the audit filters, the filters should be cleaned using lens paper and lens cleaner. The filters should be rechecked before each use to ensure that no foreign matter has accumulated in the interim. The filters should be recalibrated at least every six months and checked more frequently if they appear damaged.

SECTION 3

PERFORMANCE AUDIT PROCEDURES FOR LEAR SIEGLER, INC. OPACITY MONITORS

3.1 LEAR SIEGLER, INC. MODEL RM-41 TRANSMISSOMETER AND MODEL 611 CONTROL UNIT

3.1.1 CEMS Description

The RM-41 opacity CEMS consists of three major components: the transmissometer, the air-purging and shutter system, and the Model 611 control unit. The transmissometer component consists of a transceiver unit mounted on one side of a stack or duct and a retroreflector unit mounted on the opposite side. The transceiver unit contains a light source, a photodiode detector, and the optical, mechanical, and electronic components used in monitor operation and calibration. The output signal from the transceiver (double-pass, uncorrected transmittance) is transmitted to the control unit.

Figure 3-1 illustrates the general arrangement of the transceiver and retroreflector units on the stack, and provides further details of the chopped, dual-beam measurement technique. The light from the measurement lamp passes through a perforated rotating wheel which "chops" it into discrete pulses to minimize interference from ambient light. Next, the lamp beam is split into measurement and reference beams, with the reference beam being reflected to the photodetector and the measurement beam passing out of the transceiver and across the stack or duct. After being reflected back through the effluent, the measurement beam strikes the photodetector which also receives the reference beam. The reference beam signal is monitored continuously by the automatic gain control (AGC) circuit, which compensates for changes in lamp intensity so that the reference signal remains constant. Since the AGC circuit affects both the reference signal and the measurement signal amplitude equally, lamp intensity changes are theoretically elimiated from the measurement signal.

The air purging system serves a threefold purpose: (1) it provides an air window to keep exposed optical surfaces clean; (2) it protects the optical surfaces from condensation of stack gas moisture; and (3) it minimizes thermal conduction from the stack to the instrument. A standard installation has one air-purging system for the transceiver unit and one for the retroreflector unit; each system has a blower providing filtered air.

The shutters (optional) automatically provide protection for the transceiver and retroreflector exposed optical surfaces from smoke, dust, and stack gas. Whenever the purge airflow decreases below a predetermined rate (due to blower motor failure, clogged filter, broken hose, or stack power failure), the servo mechanism holding the shutter open is deactivated by an airflow sensor installed in the connecting hose between the air-purge blower and the instrument mounting flange. Under stack power failure conditions, the shutters are reset automatically upon restoration of power to the blowers; however, each solenoid may have to be reset manually under high negative or high positive stack pressure conditions.

The control unit (Figure 3-2) converts the double-pass transmittance output from the transceiver, in conjunction with the reference amplitude output, to linear optical density which is corrected to stack exit conditions. The resultant stack exit optical density is converted to instantaneous, single-pass

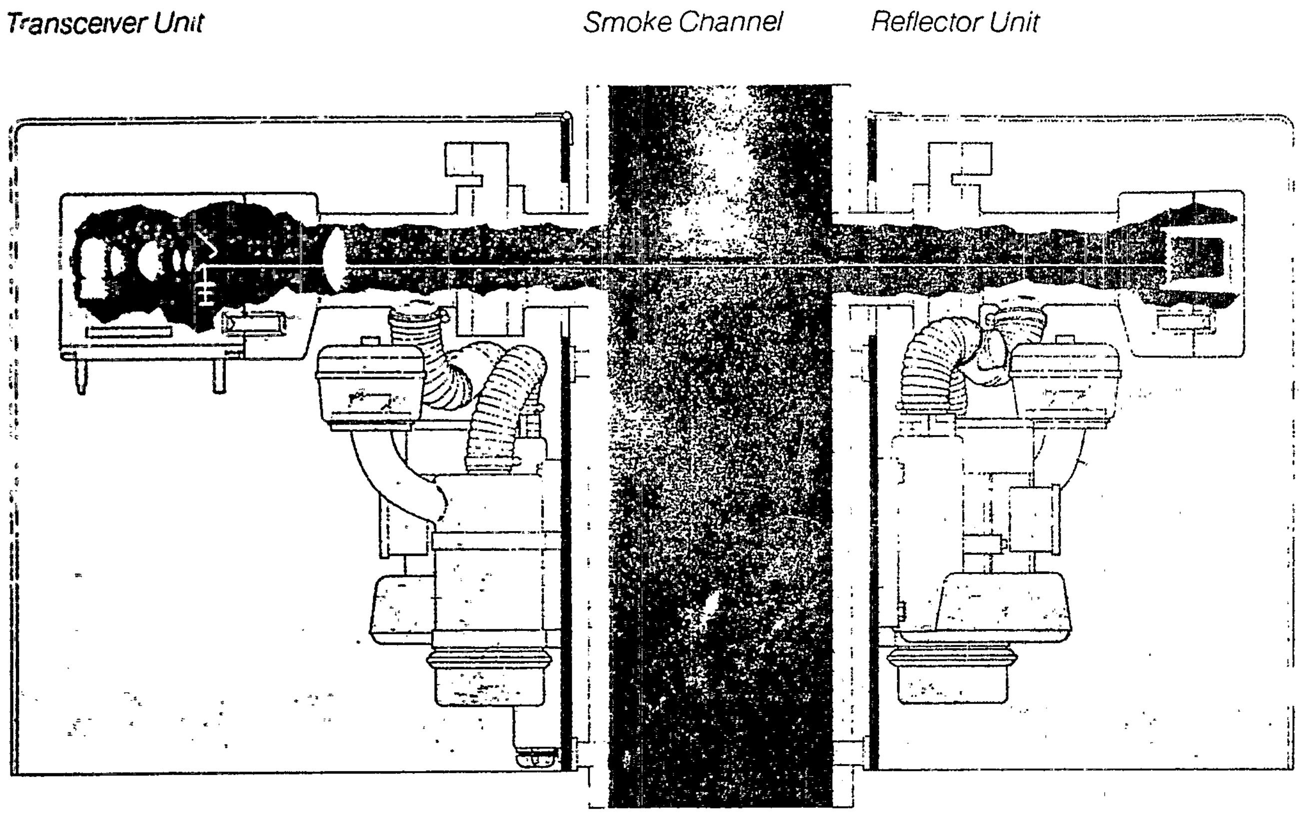


Figure 3-1. Arrangement of LSI RM-41 Transceiver and Retroreflector Components

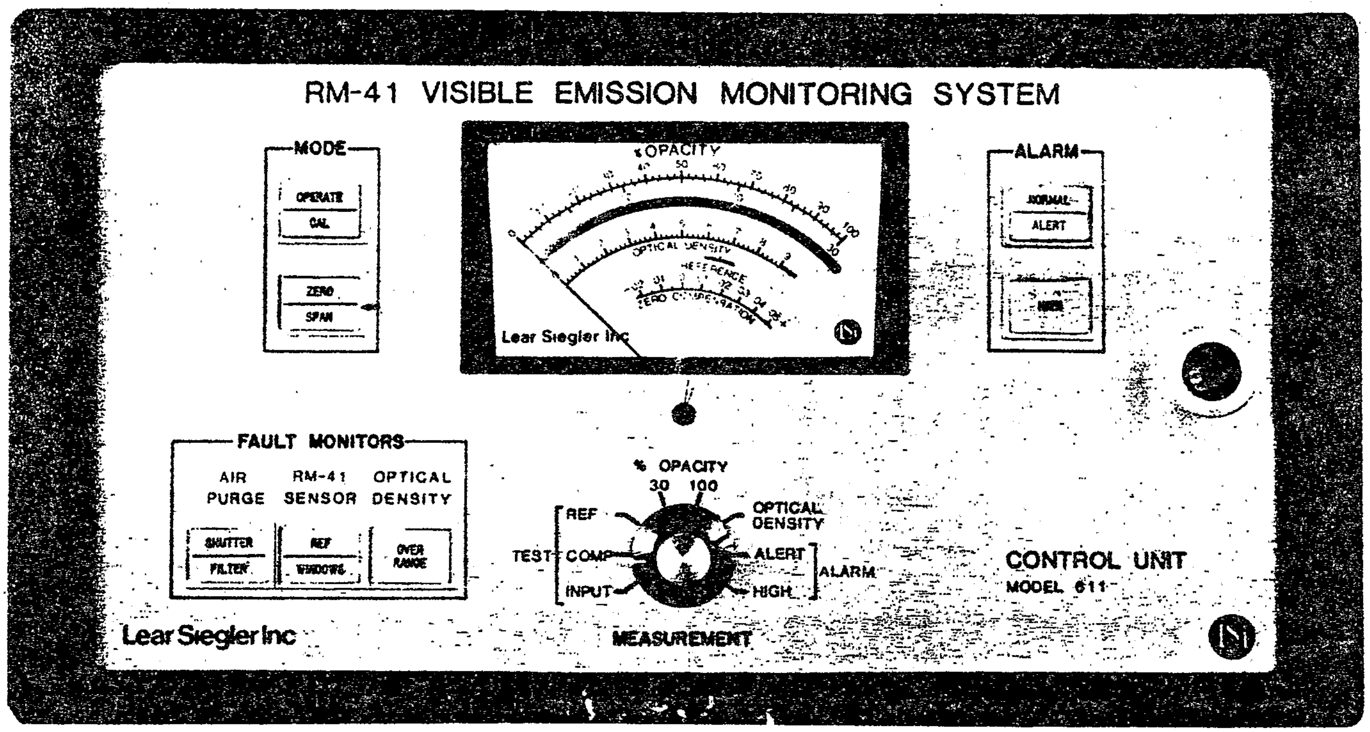


Figure 3-2. LSI RM-41 Control Unit (Model 611)

stack exit opacity. Many control units contain an optional integrator circuit card which compiles the above opacity data and calculates a discrete average over an integration period that is set by the source (typically six minutes). This function may not be used at facilities employing a computer to reduce and record opacity data because the computer may perform the integration.

The opacity monitor measures the amount of light transmitted through the effluent from the transceiver to the retroreflector and back again. The control unit uses this double-pass transmittance to calculate the optical density of the effluent stream at the monitor location, or the "path" optical density. In order to provide stack exit opacity data, the path optical density must be corrected by multiplying by the ratio of the stack exit diameter to the measurement pathlength. This ratio is called the "optical pathlength ratio" by Lear Siegler, and is abbreviated as the "OPLR." This value is set within the control unit circuitry and the correction is automatically applied to the path optical density mesasurements. The following equations illustrate the relationships between the OPLR, path optical density, and exit opacity.

$$OP_x = 1 - 10^{-(OPLR)(OD)}$$

where: OP_x = stack exit opacity (%)

$$OPLR = \frac{L_x}{L_t} = \text{optical pathlength ratio}$$

L_x = stack exit inside diameter (ft)

L_t = measurement pathlength (ft) = two times the effluent depth at the monitor location

OD = transmissometer optical density (path)

3.1.2 Performance Audit Procedures

Preliminary Data

1. Obtain the stack exit (inside) diameter and transmissometer measurement pathlength (two times the stack or duct inside diameter or width at monitor location) and record on blanks 1 and 2, respectively, of the Lear Siegler RM-41 Performance Audit Data Sheet.

   Note: Effluent handling system dimensions may be acquired from the following sources listed in descending order to reliability: (1) physical measurements; (2) construction drawings; (3) opacity monitor installation/certification documents; and (4) source personnel recollections.

2. Calculate the OPLR, (divide the value on blank 1 by the value on blank 2), and record the value on blank 3.

3. Record the source-cited OPLR value on blank 4.

   Note: The OPLR is preset by the manufacturer using information supplied by the source. The value recorded in blank 4 should be that which the source personnel agree should be set inside the monitor. Typically, this value is cited from monitor installation or certification data, as well as from service reports.

4. Obtain the present values that the monitor should measure for the zero and span calibrations and record on blank 5 and blank 6, respectively.

Note: These values are set during monitor calibration, and therefore may not be equal to values recorded at installation and/or certification. Records of the zero and span values resulting from the most recent monitor calibration should exist.

Control Unit Checks

5. Inspect the opacity data recorder (strip chart or computer) to ensure proper operation. Annotate the data record with the auditor's name, plant, unit, date, and time.

Fault Lamp Checks

The following list describes the fault lamps that are found on the Lear Siegler Model 611 control unit panel. Unless otherwise noted, the audit analysis can continue with illuminated fault lamps, provided that the source has been informed of the fault conditions.

6. Record the status (ON or OFF) of the FILTER fault lamp on blank 7.

Note: An illuminated FILTER fault lamp indicates that the transceiver and/or retroreflector purge air flow rate is reduced, either because a blower may not be working properly or one of the purge air filter elements is dirty, thereby reducing the airflow. This fault does not preclude the completion of the audit.

7. Record the status (ON or OFF) of the SHUTTER fault lamp on blank 8.

Note: An illuminated SHUTTER fault lamp indicates that one of the protective shutters is blocking the optical path; therefore, no measurement of the stack opacity is being made. The performance audit can continue, but the shutter fault condition precludes performance of cross-stack audit analyses relating to the retroreflector and transceiver window checks.

8. Record the status (ON or OFF) of the REF fault lamp on blank 9.

Note: An illuminated REF fault lamp indicates a reference signal decrease which may be due either to a fault in the automatic gain control (AGC) circuit or to a fault in the associated transceiver electronics (e.g., low line voltage, burned-out or improperly installed lamp, etc.).

9. Record the status (ON or OFF) of the WINDOW fault lamp on blank 10.

Note: An illuminated WINDOW fault lamp indicates that the zero compensation exceeds the maximum preset limit of 4% opacity. The zero compensation circuit electronically corrects the monitor's opacity responses for dust accumulation on the transceiver optics (both the primary lens and the zero mirror). Exceeding the zero compensation limit may bias the opacity data, as well as the zero and span calibration values.

10. Record the status (ON or OFF) of the OVER RANGE fault lamp on blank 11.

    Note: An illuminated OVER RANGE fault lamp indicates that the optical density of the effluent exceeds the range selected on the optical density circuit board, which in turn affects the recorded opacity data. If this fault lamp remains illuminated for an extended period of time, switch to a higher optical density range (note the original range before changing) on the optical density circuit board located in the control unit (see Figure 3-3).

Control Unit Adjustment Checks

11. Open the control unit and remove the main power fuse.

    Note: The following checks should be performed only by qualified personnel and with the approval of source personnel.

12. Locate and pull the CAL TIMER circuit board inside the control unit (see Figure 3-3) and record the position of the S1 switch on blank 12.

    Note: The S1 switch has six positions.

13. Rotate the S1 switch to the sixth position, if necessary, and replace the board.

    Note: This adjustment will deactivate the automatic calibration timer, thereby preventing the initiation of a calibration cycle during the audit that may result in damage to the zero mirror mechanism.

14. Locate and pull the optical density board and record the position of the S1 switch on blank 13.

15. Rotate the S1 switch to the fifth position, if necessary, and replace the board.

    Note: This adjustment will expand the optical density measurement range to its maximum, ensuring that all audit filter values will fall within the monitor's optical density measurement range.

16. Locate and pull the opacity board and record the position of the S1 switch on blank 14.

17. Rotate the S1 switch to the fifth position, if necessary, and replace the board.

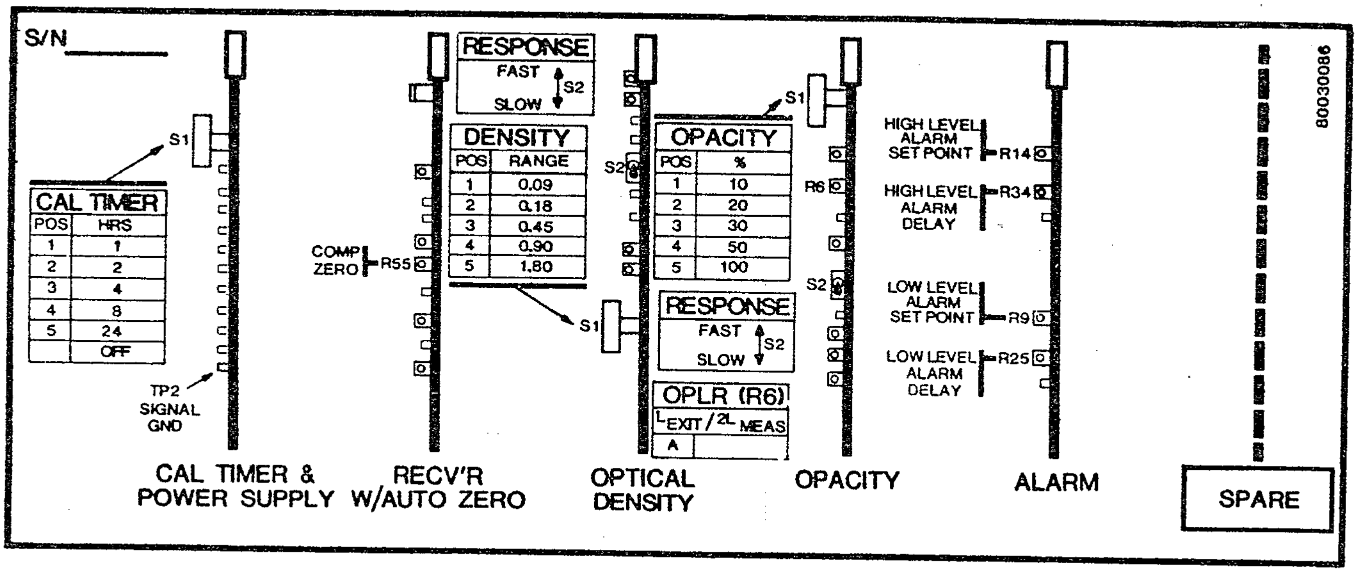


Figure 3-3. Lear Siegler RM41 Control Unit Circuit Board Arrangement

Note: This adjustment will ensure that the range of the opacity output signal from the control unit to the data recorder is at its maximum value of 0 to 100% opacity.

18. Optional OPLR check: Measure the resistance across the R_6 Potentiometer in OHMS, divide this value by 400, and write the result in blank 14a. If R_6 is not measured then enter the value from blank 4 in blank 14a.

19. Reinstall the opacity board and the power fuse and close the control unit panel.

Reference Signal Check

20. Record the original position on blank 15 of the MEASUREMENT switch on the control unit panel.

21. Turn the MEASUREMENT switch to the REF position.

22. Record the milliamp current value on blank 16 that is displayed on the 0-30 scale on the control panel meter.

Note: The reference signal should be within the green area marked "Reference." A reference value outside the green band may indicate a malfunction of the AGC or the measurement lamp.

23. Turn Measurement switch to "100% Op" position.

ZERO CHECK

24. Press the Operate/CAL button on the control panel to initiate the zero mode.

Note: The green OPERATE light should go out when the zero mirror has moved into the optical path. The yellow CAL light and the green ZERO light should remain illuminated.

25. Record the zero value on blank 17 displayed on the panel meter.

26. Record the zero value on blank 18 displayed on the data recorder.

Note: The cross-stack zero is simulated by the transceiver zero mirror. Checking this simulated zero value provides an indication of the amount of dust on the measurement window and on the zero retroreflector, as well as an indication of the status of the electronic alignment of the instrument. It does not, however, provide any indication of cross-stack parameters, such as the clear-path zero value.

Zero Compensation Check

27. Turn the MEASUREMENT switch to the COMP position.

28. Record the zero compensation optical density value on blank 19 that is displayed on the bottom scale of the control panel meter.

Note: The monitor's lamp output is split into two beams:: (1) the reference beam, which produces the reference signal within the monitor, and (2) the measurement beam, which passes through the stack effluent. When the zero mirror is positioned in the measurement beam, the beam passes only through the transceiver's optics, strikes the zero mirror, and is reflected back into the transceiver. The signal produced by the measurement beam is compared with the signal from the reference beam; the difference between the two signals is due to the attenuation of the measurement beam by dust on the transceiver optics and the zero mirror. The monitor automatically compensates for this measured difference and the zero compensation value displayed on the panel meter represents this difference in terms of optical density (OD).

29. Turn the MEASUREMENT switch to the 100% OPACITY position.

Span Check

30. Press the ZERO/SPAN button to initiate the span mode.

31. Record the span value on blank 20 that is displayed on the control panel meter (0-100% Op scale) and record the span value displayed on the data recorder on blank 21.

32. Optional input current check: Turn the MEASUREMENT switch to the INPUT position, and record the control panel meter input current value on blank 21a that is displayed on the 0-30 scale.

33. Return the MEASUREMENT switch to the 100% OPACITY position.

    Note: During the span portion of the calibration cycle, a neutral density filter is automatically inserted into the measurement beam path inside the transceiver while the zero retroreflector is in place. The span measurement provides another check of the monitor electronic alignment and the linearity of the transmissometer opacity response.

34. Press the OPERATE/CAL button to return the monitor to the stack opacity measurement mode. Go to the transmissometer location.

    Note: The OPERATE AND CAL lamps will light to indicate movement of the zero mirror. The OPERATE/CAL button should not be pressed when both the OPERATE and CAL lights are illuminated, as the zero mirror might stop before it has cleared the measurement beam path.

Retroflector Dust Accumulation Check

35. Record the instantaneous effluent opacity prior to cleaning of the retroreflector optics on blank 22.

36. Open the retroreflector housing, inspect and clean the retroreflector optics, and close the housing.

37. Record the post cleaning instantaneous effluent opacity on blank 23. Go to transceiver location.

Transceiver Dust Accumulation Check

38. Record the instantaneous effluent opacity on blank 24.

39. Open the transceiver, inspect and clean the optics (primary lens and zero mirror), and close the transceiver head.

40. Record the post cleaning instantaneous effluent opacity on blank 25.

Note: After the transmissometer optics have been cleaned, the zero compensation has to be reset so that it will not continue to compensate for dust that is no longer present. This operation must be conducted at the control unit, and may involve the assitance of source personnel.

41. Press the OPERATE/CAL button on the control unit.

42. Turn the MEASUREMENT switch to the COMP position.

43. Record the post cleaning zero compensation value on blank 26.

44. Press the OPERATE/CAL button.

45. Turn the MEASUREMENT switch to the 100% opacity position.

Automatic Gain Control Check

46. Determine whether the green light (AGC LED, Figure 3-4) on the transceiver is illuminated, and check the light status (ON or OFF) on blank 27.

Optical Alignment Check

47. Remove the protective cover on the transceiver mode switch located on the bottom right-hand side of the transceiver (see Figure 3-4).

48. Turn the switch one position counter-clockwise until ALIGN can be seen through the switch window.

49. Determine the monitor alignment by looking through the viewing port (Figure 3-4) and observing whether the beam image is in the circular target.

50. Record whether the image is centered inside the circular target (YES or NO) on blank 28.

51. Draw the orientation of the beam image in the circle on the data form.

Note: Instrument optical alignment has no effect on the internal checks of the instrument or on the calibration check using the audit device; however, if the optical alignment is not correct, the stack opacity data will be biased high, since all the light transmitted to the retroreflector is not returned to the detector.

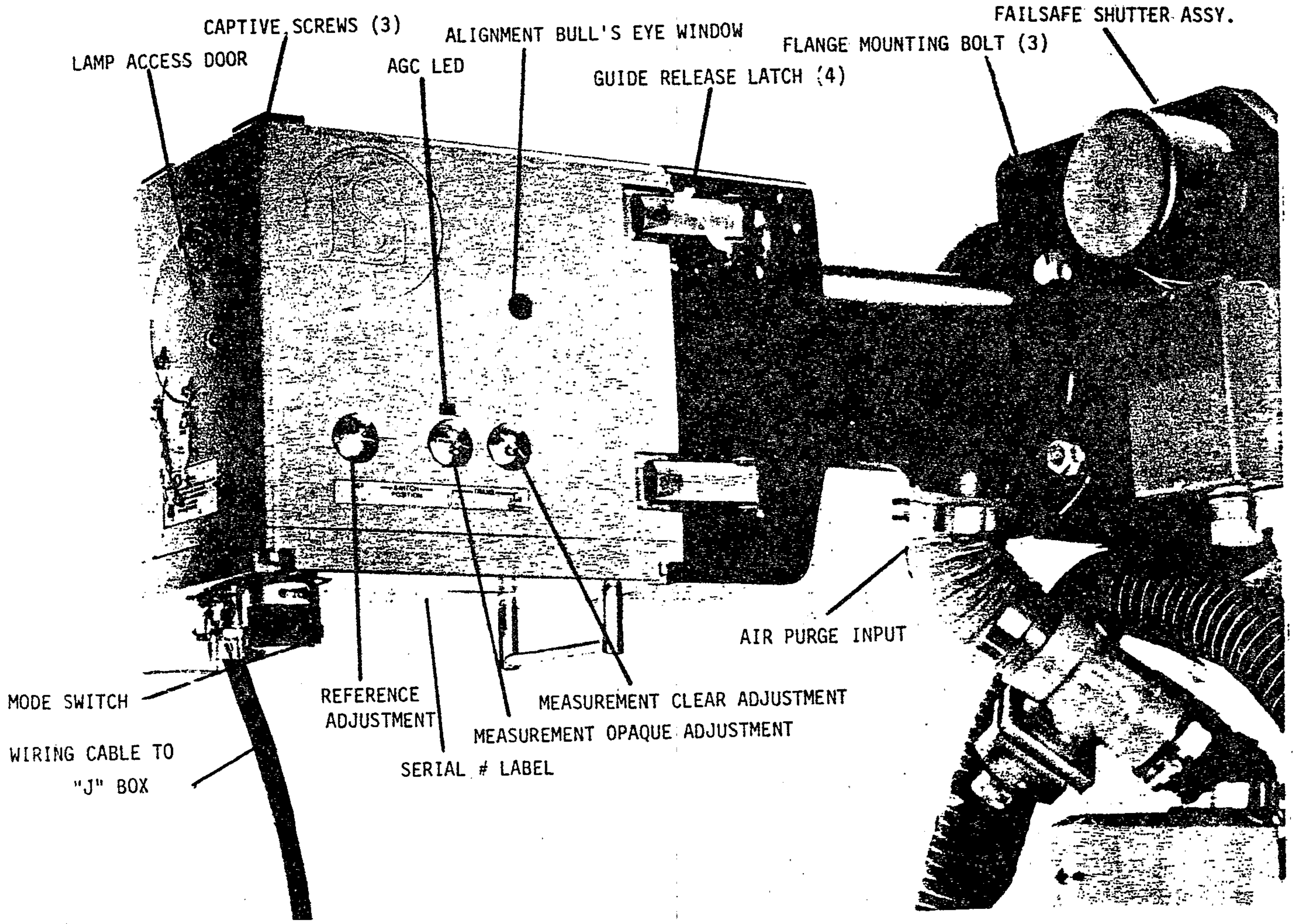


Figure 3-4. Lear Siegler RM41 Transceiver

52. Turn the transceiver mode switch clockwise until OPERATE appears in the window. Replace the mode switch protective cover.

Span Filter Check

53. Record the span filter's optical density value on blank 29 and the output current value on blank 30. These values are written on a nameplate on the underside of the transceiver.

CALIBRATION ERROR CHECK

The calibration error check is performed using three neutral density audit filters and an audit device (or jig) with an adjustable retroreflector iris to simulate clear stack conditions. The audit device and neutral density filters actually determine the linearity of the instrument response with respect to the current clear-path zero value. This calibration error check does not determine the actual instrument clear-pack zero, or the status of any cross-stack parameters.

A true calibration check is performed by removing the on-stack components and setting them up in a location with minimal ambient opacity, making sure that the proper pathlength and alignments are attained, and then placing the calibration filters in the measurement beam path.

54. Install the audit jig by sliding it onto the transceiver projection lens barrel.

    Note: The audit device will not slide on until it is flush with the lens barrel. Care should be taken not to push it against the zero mirror or to pinch the wires serving the zero mirror motor.

55. Adjust the audit jig iris to produce a 19-20 mA output current on the junction box meter (Figure 3-5) to simulate the amount of light returned to the transceiver during clear stack conditions.

    Note: The junction box meter allows the auditor to get the jig zero value near the zero value on the data recorder. The final jig zero adjustments should be based on readings from the data recorder. The jig zero does not have to be exactly 0.0% opacity since the audit filter correction equations can account for an offset in the jig zero. Thus, a jig zero value in the range of 0-2% Op is usually acceptable.

56. Record the audit filter serial numbers and opacity values on blanks 31, 32, and 33.

57. Remove the filters from their protective covers, inspect, and if necessary, clean them.

58. Record the jig zero value from the data recorder.

    Note: The acquisition of monitor responses from the data recorder requires communication between the auditor at the transmissometer location and another person at the data recorder location.

59. Insert the low range neutral density filter into the audit jig.

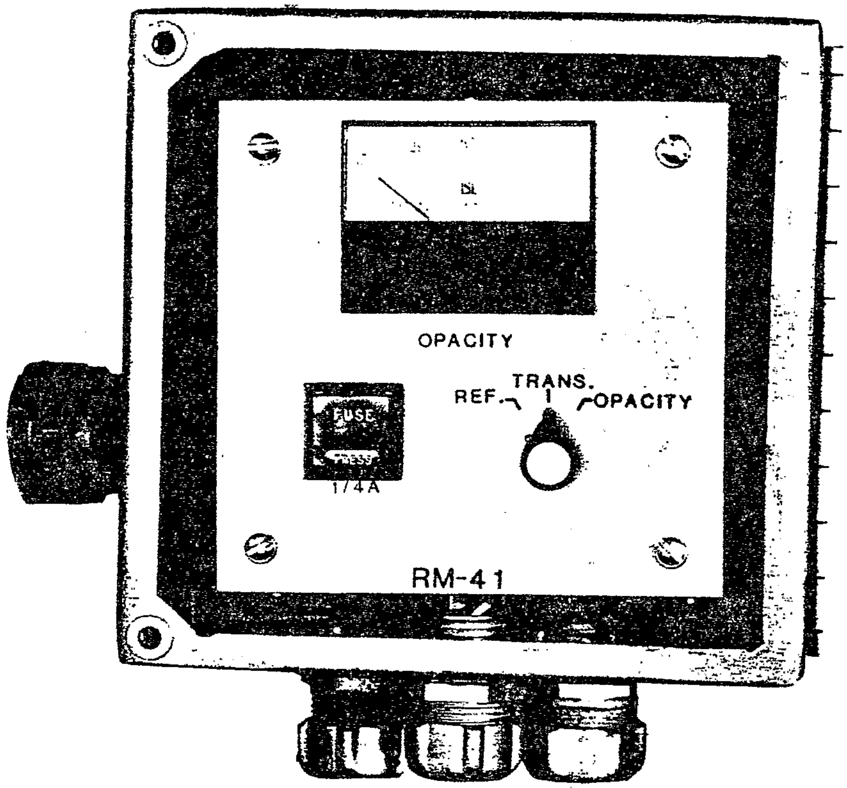


Figure 3-6. Lear Sielger RM41 Junction Box

60. Wait for approximately two minutes or until a stable value has been recorded and displayed on the data recorder.

Note: The audit data should be taken from a data recording/reporting device that presents instantaneous opacity (or opacity data with the shortest available integration period).

61. Record the monitor's response to the low range neutral density filter.

62. Remove the low range filter from the audit jig and insert the mid range neutral density filter.

63. Wait the approximately two minutes and record the monitor's response from the opacity data recorder.

64. Remove the mid range filter from the audit jig and insert the high range filter.

65. Wait approximately two minutes and record the monitor's response from the opacity data recorder.

66. Remove the high range filter, wait for approximately two minutes and record the jig zero value from the opacity data recorder.

Note: If the final jig zero value differs from the initial value by more than 1% opacity, the jig zero should be adjusted to agree with the initial value and the three-filter run (i.e., low, mid, and high) should be repeated.

67. Repeat steps 58-66 above until a total of five opacity readings are obtained for each neutral density filter.

68. If six-minute integrated opacity data must be recorded, repeat steps 58-66 above once more, but change the waiting periods to at least 13 minutes.

69. Record the six-minute integrated data.

Note: In order to acquire six-minute integrated opacity data, each filter must remain in the jig for at least two consecutive six-minute periods. the first period is invalid because it was in progress when the filter was inserted. Only at the conclusion of two successive six-minute integration periods can the monitor's response be recorded. Thus, a waiting period of 13 minutes or more is recommended.

70. Once the calibration error check is finished, remove the audit jig, close the protective cover on the junction box and close the transceiver head.

Zero Compensation Check

71. Return to the control unit location and initiate the monitor zero mode by pressing the OPERATE/CAL button.

72. Turn the MEASUREMENT switch to the COMP position.

73. Record the zero compensation optical density value from the control panel meter -0.02 to +0.05 O.D. scale on blank 34.

74. Return the monitor to the operate mode by pressing the OPERATE/CAL button again.

Control Unit Adjustment Reset

75. Return the CAL timer, optical density, and opacity board S1 switches and the MEASUREMENT switch to their original positions, as recorded on blanks 12, 13, 14, and 15.

76. Obtain a copy of the audit data from the data recorder.

77. Transcribe the calibration error responses from the data record to the data form blanks 35 to 60, and complete the audit data calculations.

3.1.3 INTERPRETATION OF AUDIT RESULTS

This section pertains to the interpretation of the performance audit analyses peculiar to the RM-41. The interpretation of the more general analyses is fully discussed in the Section 2.0 of this manual.

Stack Exit Correlation Error Check

The pathlength correction errors on blanks 61 and 62 should be within ±2%. This error expontentially affects the opacity readings, resulting in over- or under-estimation of the stack exit opacity. The most common error in computing the OPLR is the use of the flange-to-flange distance rather than the stack/duct inside diameter at the monitor location. This error will result in an under-estimation of the stack exit opacity and can be identified by comparing the monitor optical pathlength to the flange-to-flange distance, which should be the greater by approximately two feet.

Control Panel Meter Error (Optional)

The accuracy of the control panel meter is important at sources using the meter during monitor adjustment and calibration. In such cases, the control panel meter opacity and input readings are compared to the specified values for the internal zero and span filter. Errors in the control panel meter should not affect the opacity data reported by the monitoring system unless the control panel meter is used to adjust the zero and span functions. The percent error values associated with the control panel meter are found on blanks 64, 66, and 67a. At sources using the panel meter data, the panel meter should be adjusted so that the error is less than 2%. Since the control panel meter error is determined by using the span filter, any change in the specified values for the span filter will cause an erroneous assessment of the control panel meter errors. The span filter value may change due to aging, replacement, etc. Each time the monitor is thoroughly calibrated, the internal span filter should be renamed, and new specified values for the optical density and output current should be recorded and used in all subsequent adjustments.

Reference Signal Error Check

The reference signal is an indicator of the status of the automatic gain control, the measurement lamp, the photodiode detector, and/or the preamplifier. A reference signal error greater than 10% is indicative of a malfunction in one of these component systems. Because the reference signal is critical to maintaining the accuracy of the transmissometer opacity measurements, corrective actions should be taken as soon as possible.

Internal Zero and Span Check

The RM-41 internal zero should be set to indicate 0% opacity. A zero error greater than 4% opacity is usually due to excessive dust accumulation on the optical surfaces, electronic drift, or data recorder electronic or mechanical offset. Excessive dust on the optical surfaces sufficient to cause a significant zero error also would be indicated by the zero compensation reading. A malfunction of the transceiver electronics resulting in a zero error would be indicated by a reference signal error. Instrument span error may be caused by the same problems that cause zero errors and may be identified in a similar fashion. Also, a span error may be caused by an inaccurate span filter value.

If the zero and span errors are due to a data recorder offset, both errors will be in the same direction and will have the same magnitude. The opacity data will be offset in the same manner.

Zero Compensation Check

The amount of zero compensation the instrument is generating to compensate for dust on transceiver optics should not exceed 4% opacity, which is approximately equivalent to an optical density of 0.018%. The zero compensation values recorded on blanks 68, 69, and 70 should not exceed ±0.018 OD. Post-cleaning values in excess of this indicate either excessive dust remaining on monitor optics or a malfunction in the zero compensation circuitry.

A residual positive zero compensation after a thorough cleaning of transmissometer optics is normally the result of an incorrect zero compensation circuit adjustment. If the zero compensation goes negative after the transceiver optical surfaces are cleaned, it is probable that the zero compensation circuit was last adjusted at a time when the optical surfaces were not clean. Often when this situation occurs (adjustments during dirty window conditions), the internal zero will also have benn adjusted to read 0% opacity, and thus, the zero will be offset in the negative direction. Under these conditions, the internal zero and the zero compensation circuit will need to be adjusted after the optics are cleaned.

Transmissometer Dust Accumulation Check

The total opacity equivalent to the dust on the transmissometer optical surfaces (blank 73) should not exceed 4%. A dust accumulation value of more than 4% opacity indicates that the airflow of the purge system and/or the cleaning frequency of the optical surfaces are inadequate. When determining the optical surface dust accumulation, the auditor should note whether the effluent opacity is fairly stable (within ±2% opacity) before and after the cleaning of the optical surfaces. If the effluent opacity is fluctuating more than ±2%, the dust accumulation analysis should be omitted.

Calibration Error Check

Excessive calibration error results (blanks 83, 84, and 85) are indicative of a non-linear calibration and/or a miscalibration of the monitor. However, the absolute calibration accuracy of the monitor can be determined only when the clear path zero value is known. If the zero and span are not within the proper range, the calibration check data will often be biased in the same direction as the zero and span errors. Even if the zero and span errors are within the proper ranges, the monitor may still be inaccurate due to possible error in the clear path zero. The optimum calibration procedure involves using neutral density filters during a clear-stack or off-stack calibration. This procedure would establish both the absolute calibration accuracy and linearity. If this procedure is not practical, and if it is reasonable to assume that the clear path zero is indeed zero, the monitor's calibration linearity can be set using either neutral density filters or the internal zero and span values.

3.2 LEAR SIEGLER, INC. MODEL RM-4 TRANSMISSOMETER

3.2.1 CEMS Description

The RM-4 opacity CEMS consists of three major components: the transmissometer, the air-purging and shutter system, and the remote control and data acquisition unit. The transmissometer component consists of a transceiver unit mounted on one side of a stack or duct and a retroreflector unit mounted on the opposite side. The transceiver unit contains a light source, a photodiode detector, and the optical, mechanical, and electronic components used in monitor operation and calibration. The output signal from the transceiver (single-pass, corrected optical density) is transmitted to the control unit.

Figure 3-6 illustrates the general arrangement of the transceiver and retroreflector units on the stack, and provides further details of the chopped, dual-beam measurement technique. In this technique, the reference beam signal is monitored continuously by the automatic gain control (AGC) circuit, which compensates for changes in lamp intensity so that the reference signal remains constant. Since the AGC circuit affects both the reference signal and the measurement signal amplitude equally, lamp intensity changes are theoretically elimiated from the measurement signal.

The air purging system serves a threefold purpose: (1) it provides an air window to keep exposed optical surfaces clean; (2) it protects the optical surfaces from condensation of stack gas moisture; and (3) it minimizes thermal conduction from the stack to the instrument. A standard installation has one air-purging system for the transceiver unit and one for the retroreflector unit; each system has a blower providing filtered air.

The shutters (optional) automatically provide protection for the transceiver and retroreflector exposed optical surfaces from smoke, dust, and stack gas. Whenever the purge airflow decreases below a predetermined rate (due to blower monitor failure, clogged filter, broken hose, or stack power failure), the shutter mechanism holding it open is deactivated by an airflow sensor installed in the connecting hose between the air-purge blower and the instrument mounting flange. Under stack power failure conditions, the shutters are reset automatically upon restoration or power to the blowers; however, each solenoid may have to be reset manually under high negative or high positive stack pressure conditions.

The converter control unit (Figure 3-7) converts the optical density output from the transceiver exit opacity by using the ratio of the stack exit diameter to the stack inside diameter (or duct width) at the transmissometer, commonly referred to as the optical pathlength ratio (OPLR) by Lear Siegler. The converter has a calibration mode switch, fault lamps, and a measurement parameter and scaling switch. The measurement and mode switches allow the automatic gain control (AGC) current, the zero value, and span value to be checked in units of milliampere (Ma) current, opacity and optical density, respectively. A potentiometer mounted on the converter front panel permits the adjustment of the optical density zero value to compensate for minor dust accumulation on transceiver optics.

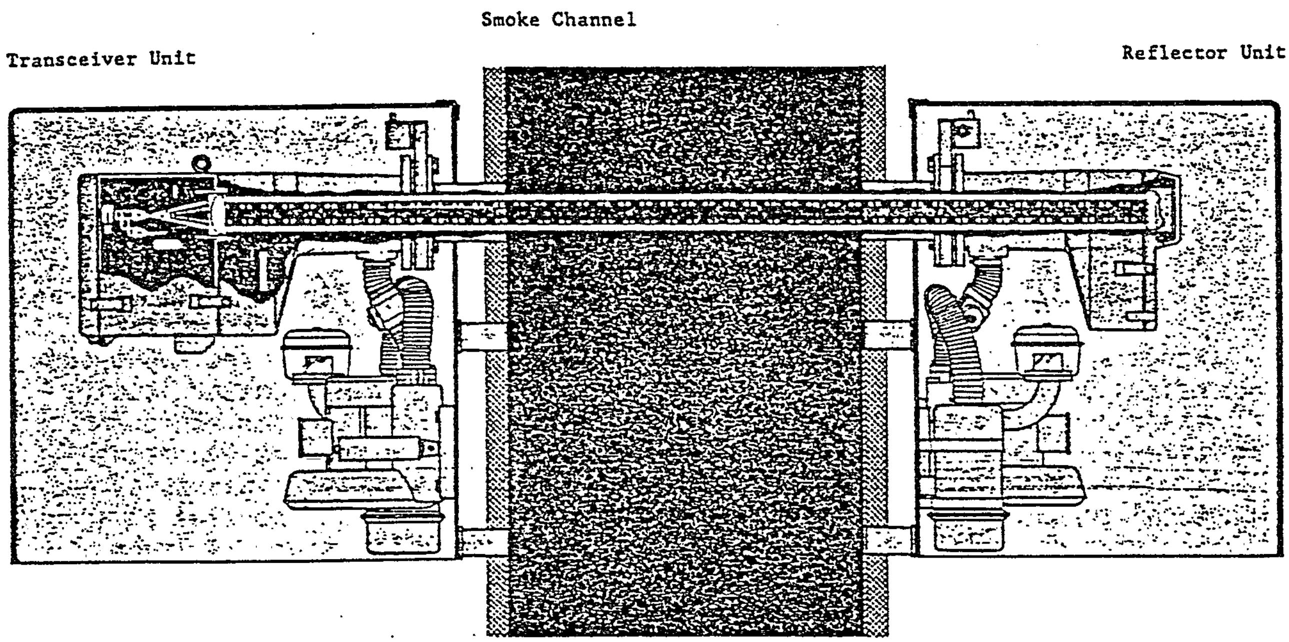
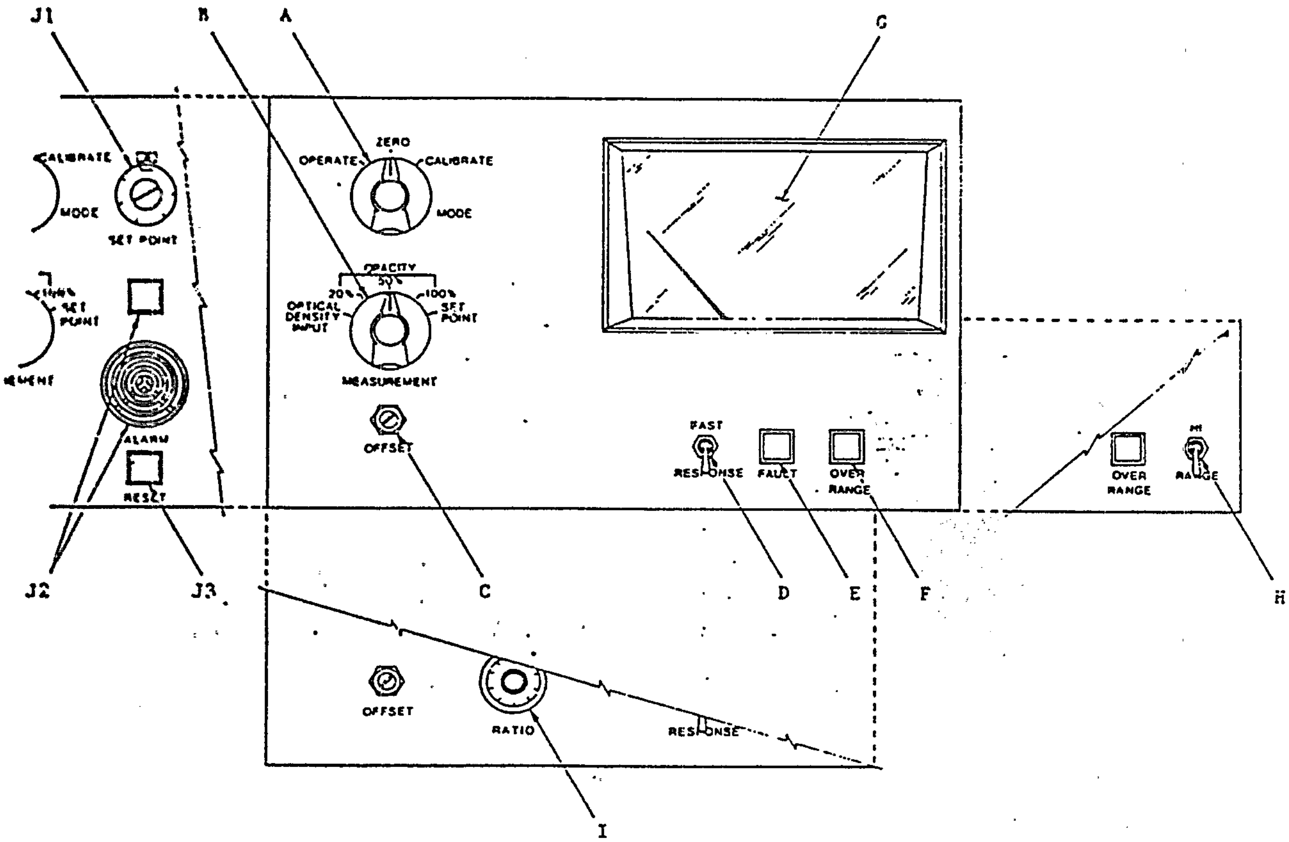


Figure 3-6. Arrangement of LSI RM-4 Transceiver and Retroreflector Components.



A. Mode Switch
B. Measurement Switch
C. Offset Adjustment
D. Response Rate Switch
E. Fault Indicator
F. Over-Range Indicator
G. Panel Meter
H. Range Switch
I. Ratio Adjustment
J1. Set Point Adjustment
J2. Sonalert Alarm
J3. Reset Switch

Figure 3-7. LSI RM-4 Converter Control Unit.

The opacity monitor measures the amount of light transmitted through the effluent from the transceiver to the retroreflector and back again. The transceiver calculates the optical density of the effluent stream at the monitor location, or the "path" optical density. In order to provide stack exit opacity data, the path optical density must be corrected by multiplying by the ratio of the stack exit inside diameter to the stack inside diameter (or duct width) at the transmissometer, known as the OPLR. The following equations illustrate the relationships between the OPLR, path optical density, and exit opacity.

$$OP_x = 1 - 10^{-(OPLR)(OD)}$$

where: OP_x = stack exit opacity (%)

OD = transmissometer optical density (path)

$$OPLR = \frac{L_x}{L_t}\text{; optical pathlength ratio}$$

where: L_x = stack exit inside diameter (ft)

L_t = two times the stack inside diameter (or duct width)

3.2.2 Performance Audit Procedures

Preliminary Data

1. Obtain the stack exit inside diameter and the stack inside diameter (or duct width) at the transmissometer and record on blanks 1 and 2, respectively, of the Lear Siegler RM-4 Performance Audit Data Sheet.

   Note: Effluent handling system dimensions may be acquired from the following sources listed in descending order to reliability: (1) physical measurements; (2) construction drawings; (3) opacity monitor installation/certification documents; and (4) source personnel recollections.

2. Calculate the OPLR, (divide the value on blank 1 by the value on blank 2), and record the value on blank 3.

3. Record the source-cited OPLR value on blank 4.

   Note: The OPLR is preset by the manufacturer using information supplied by the source. The value recorded in blank 4 should be that which the source personnel agree should be set inside the monitor. Typically, this value is cited from monitor installation or certification data, as well as from service reports.

4. Obtain the present values that the monitor should measure for the zero and span calibrations and record on blank 5 and blank 6, respectively.

Note: These values are set during monitor calibration, and therefore may not be equal to values recorded at installation and/or certification. Records of the zero and span values resulting from the most recent monitor calibration should exist.

Converter Control Unit Checks

5. Inspect the opacity data recorder (strip chart or computer) to ensure proper operation. Annotate the paper with the auditor's name, plant, unit, date, and time.

Fault Lamp Checks

The following list describes the fault lamps that are found on the Lear Siegler RM-4 converter control unit panel. Unless otherwise noted, the audit analysis can continue with illuminated fault lamps, provided that the source has been informed of the fault conditions.

6. Record the status (ON or OFF) of the FAULT fault lamp on blank 7.

   Note: An illuminated FAULT fault lamp indicates that the transceiver AGC current has fallen below 10 milliamps. This condition indicates a malfunction of the measurement lamp, a chopper motor failure, or a fault in the reference signal circuitry.

7. Record the status (ON or OFF) of the OVER RANGE fault lamp on blank 8.

   Note: An illuminated OVER RANGE fault lamp indicates that the optical density of the effluent exceeds the range selected on the optical density circuit board, which in turn affects the recorded opacity data. If this fault lamp remains illuminated for an extended period of time, switch to a higher optical density range.

Control Unit Check

8. Record the original position on blank 9 of the MEASUREMENT switch on the control unit panel.

Zero Check

9. Turn the MEASUREMENT switch to the 20% OPACITY position.

10. Turn the MODE switch on the control panel to the ZERO position to initiate the zero mode.

11. Record the value on blank 10 displayed on the panel meter 0-20 mA scale.

12. Record the zero value on blank 11 displayed on the opacity data recorder.

   Note: The cross-stack zero is simulated by the transceiver zero mirror. Checking this simulated zero value provides an indication of the amount of dust on the measurement window and on the zero retroreflector, as well as an indication of the status of the electronic alignment of the instrument. It does not, however, provide any indication of cross-stack parameters.

Span Check

13. Turn the MEASUREMENT switch to the 100% OPACITY position.

14. Turn the MODE switch to the CALIBRATE position.

15. Record the span value on blank 12 that is displayed on the control panel meter (0-100% Op scale) and record the span value displayed on the opacity data recorder on blank 13.

16. Turn the MEASUREMENT switch to the OPACITY INPUT position (optional).

17. Record the control panel meter value on blank 14 that is displayed on the 0-20 milliamp scale.

18. Return the MEASUREMENT switch to the 100% OPACITY position.

    Note: Steps 16-18 comprise the optional input signal check.

19. Return the mode switch to the OPERATE position.

    Note: During the span portion of the calibration cycle, a neutral density filter is automatically inserted into the measurement beam path inside the transceiver while the zero retroreflector is in place. The span measurement provides another check of the monitor electrical alignment and the linearity of the transmissometer opacity response.

20. Go to the transmissometer location.

Retroreflector Dust Accumulation Check

21. Record the instantaneous effluent opacity from the opacity data recorder on blank 15 prior to cleaning the retroreflector optics.

22. Open the retroreflector housing, inspect and clean retroreflector optics, and close the housing.

23. Record the post cleaning instantaneous effluent opacity on blank 16.

Transceiver Dust Accumulation Check

24. Record the instantaneous effluent opacity on blank 17.

25. Open the transceiver head, inspect and clean the optics (primary lens and zero mirror), and close the transceiver head.

26. Record the post cleaning instantaneous effluent opacity on blank 18.

    Note: After the transmissometer optics have been cleaned, the zero offset has to be reset manually so that it will not continue to compensate for dust that is no longer present. This operation must be conducted at the control unit.

Fault/Test Check

27. Depress the transceiver Fault/Test momentary-action switch and record the milliamp value displayed on the transceiver milliampmeter (0-20 mA) on blank 19.

    Note: This combination indicator and momentary-action switch serving two related functions: 1) When the current within the instrument AGC circuit falls below 10 milliamperes, the FAULT indicator lights. This condition will occur only if the light source burns out, the chopper motor falls out of synchronous speed, or some other fault condition occurs that causes the reference signal to fall below a preset level: and 2) a fault indication (closure) is also transmitted on lead 6 to the remote control room equipment. When the momentary-action switch is depressed, the milliampmeter indicates the actual current within the AGC circuit, which should be between 11 and 16 milliamperes.

Optical Alignment Check

28. Determine the monitor alignment by looking through the viewing port and observing whether the beam image is in the circular target.

29. Record whether the image is centered inside the circular target (YES or NO) on blank 20.

30. Draw the orientation of the beam image in the circle on the data form.

    Note: Instrument optical alignment has no effect on the internal checks of the instrument or on the calibration check using the audit device; however, if the optical alignment is not correct, the stack opacity data will be biased high, since all the light transmitted to the retroreflector is not returned to the detector.

Span Filter Data Check

31. Record the span filter's optical density value on blank 21 from the front of the transceiver control panel.

CALIBRATION ERROR CHECK

The calibration error check is performed using three neutral density audit filters and an audit device (or jig) with an adjustable retroreflector and iris to simulate clear stack conditions. The audit device and neutral density filters actually determine the linearity of the instrument response with respect to the current clear-stack zero value. This calibration error check does not determine the actual instrument clear-stack zero, or the status of any cross-stack parameters.

A true calibration check is performed by removing the on-stack components and setting them up in a location with minimal ambient opacity, making sure that the proper pathlength and alignments are attained, and then placing the calibration filters in the measurement beam path.

32. Install the audit jig by sliding it onto the transceiver primary lens barrel.

Note: The audit device will not slide on until it is flush with the monitor. Care should be taken not to push it against the zero mirror reflector or to pinch the wires serving the zero mirror motor.

33. Adjust the audit jig iris to produce a 2.0 mA output current on the front panel meter to simulate the amount of light returned to the transceiver during clear stack conditions.

Note: This allows the auditor to obtain a jig zero value near the zero value on the opacity data recorder. The final jig zero adjustments should be based on readings from the data recorder. The jig zero does not have to be exactly 0.0% opacity since the audit filter correction equations can account for an offset in the jig zero. Thus, a jig zero value in the range of 0-2% Op is usually acceptable.

34. Record the audit filter serial numbers and opacity values on blanks 22, 23, and 24.

35. Remove the filters from their protective covers, inspect, and if necessary, clean them.

36. Record the jig zero value from the opacity data recorder.

Note: The acquisition of monitor responses from the opacity data recorder requires communication between the auditor at the transmissometer location and another person at the data recorder location.

37. Insert the low range neutral density filter into the audit jig.

38. Wait for approximately two minutes or until a clear value has been recorded and displayed on the data recorder.

Note: The audit data should be taken from a data recording/reporting device that presents instantaneous opacity (or opacity data with the shortest available integration period).

39. Record the monitor's response to the low range neutral density filter.

40. Remove the low range filter from the audit device and insert the mid range neutral density filter.

41. Wait approximately two minutes and record the monitor's responses.

42. Remove the mid range filter from the audit jig and insert the high range filter.

43. Wait approximately two minutes and record the monitor's response.

44. Remove the high range filter, wait approximately two minutes, and record the jig zero value.

Note: If the final jig zero value differs from the initial value by more than 1% opacity, the jig zero should be adjusted to agree with the initial value and the three-filter run (i.e., low, mid, and high) should be repeated.

45. Repeat steps 37-44 above until a total of five opacity readings are obtained for each neutral density filter.

46. If six-minute integrated opacity data are recorded, repeat steps 37-44 above once more, but change the waiting periods to 13 minutes.

47. Record the six-minute integrated data.

Note: In order to acquire six-minute averaged opacity data, each filter must remain in the jig for at least two consecutive six-minute periods. The first period is invalid because it was in progress when the filter was inserted. Only at the conclusion of two successive six-minute integration periods can the monitor's response be recorded.

48. Once the calibration error check is finished, remove the audit jig, close the transceiver panel cover and close the transceiver head.

Zero Milliamp Check (Optional)

Note: This is an optional check to evaluate the effects of cleaning the monitor optics.

49. Return to the control unit location and turn the MODE switch to ZERO and the MEASUREMENT switch to 20% OPACITY.

50. Record the final zero current value on blank 25.

51. Turn the MODE switch to OPERATE and the MEASUREMENT switch to the position recorded in blank 9.

52. Obtain a copy of the audit data from the data recorder.

53. Transcribe the calibration error response data from the data recorder from blanks 26 to 51, and complete the audit data calculations.

3.2.3 INTERPRETATION OF AUDIT RESULTS

This section pertains to the interpretation of the performance audit analyses peculiar to the RM-4. The interpretation of the more general analyses is fully discussed in the introduction of this manual.

Stack Exit Correlation Error Check

The pathlength correction error on blank 52 should be within $\pm 2\%$. This error expontentially affects the opacity readings, resulting in over- or under-estimation of the stack exit opacity. The most common error in computing the OPLR is the use of the flange-to-flange distance rather than the stack/duct inside diameter at the monitor location. This error will result in an under-estimation of the stack exit opacity and can be identified by comparing the monitor optical pathlength to the flange-to-flange distance, which should be the greater by approximately two feet.

Control Panel Meter Error (Optional)

The accuracy of the control panel meter is important at sources using the meter during monitor adjustment and calibration. In such cases, the control panel meter opacity and input readings are compared to the specified values for the internal zero and span filter. Errors in the control panel meter should not affect the opacity data reported by the monitoring system unless the control panel meter is used to adjust the zero and span functions. At sources using the panel meter data, the panel meter should be adjusted so that the error is less than 2%. Since the control panel meter error is determined by using the zero and span values, any change in these values will cause an erroneous assessment of the control panel meter errors. The span filter value may change due to aging, replacement, etc. Each time the monitor is thoroughly calibrated, the internal zero and span values should be renamed, and a new value for the input current should be recorded and used in all subsequent adjustments.

Internal Zero and Span Check

The RM-4 internal zero should be set to indicate 0% opacity and 2.0 mA. A zero error greater than 4% opacity is usually due to excessive dust accumulation on the optical surfaces, electronic drift, or data recorder electronic or mechanical offset. Excessive dust on the optical surfaces sufficient to cause a significant zero error also would be indicated by an elevated zero offset reading.

If the zero and span errors are due to a data recorder offset, both errors will be in the same direction and will have the same magnitude. The opacity data will be offset in the same manner.

Transmissometer Dust Accumulation Check

The total opacity equivalent to the dust on the transmissometer optical surfaces (blank 60) should not exceed 4%. A dust accumulation value of more than 4% opacity indicates that the airflow of the purge system and/or the cleaning frequency of the optical surfaces are inadequate. When determining the optical surface dust accumulation, the auditor should note whether the effluent opacity is fairly stable (within ±2% opacity) before and after the cleaning of the optical surfaces. If the effluent opacity is fluctuating more than ±2%, the dust accumulation analysis should be omitted.

Calibration Error Check

The comparison of monitor responses to the opacity values of the neutral density filters requires that the filter values be corrected to stack exit conditions and that any zero offset be factored into the corrected filter value.

Excessive calibration error results (blanks 70, 71, and 72) are indicative of a non-linear calibration and/or a miscalibration of the monitor. However, the absolute calibration accuracy of the monitor can be determined only when the clear path zero value is known. If the zero and span are not within the proper range, the calibration check data will often be biased in the same direction as the zero and span errors. Even if the zero and span errors are within the proper ranges, the monitor may still be inaccurate due to possible error in the clear path zero. The optimum calibration procedure involves using neutral density filters during clear-stack or off-stack calibration. This procedure would establish both the absolute calibration accuracy and linearity. If this procedure is not practical, and if it is reasonable to assume that the clear path zero is indeed zero, the monitor's calibration linearity can be set using either neutral density filters or the internal zero and span values.

SECTION 4

PERFORMANCE AUDIT PROCEDURES FOR DYNATRON OPACITY MONITOR

4.1 DYNATRON MODEL 1100 TRANSMISSOMETER

4.1.1 CEMS Description

The Dynatron Model 1100 opacity CEMS consists of three major components: the transmissometer, the air-purging system, and the control unit. The transmissometer component consists of a transceiver unit mounted on one side of a stack or duct and a retroreflector unit mounted on the opposite side. The Dynatron monitor employs an electonically modulated light source to eliminate interference from ambient light. The modulated beam is split into reference and measurement beams with the reference beam going via fiber optics to a photodetector (see Figure 4-1). The measurement beam crosses through the effluent to the retroreflector and is reflected back into the transceiver where it encounters a photodetector identical to the reference detector. Because the monitor uses the ratio of the reference and measurement signals to determine opacity, variations in the beam intensity are factored out. The Dynatron monitor is calibrated internally by turning off the measurement light source and alternately turning on two calibration light sources, each with a different neutral density filter in its optical path. When individually viewed by the photodetectors, these sources produce internal zero and span signals.

The air purging system serves a threefold purpose: (1) it provides an air curtain to keep protective windows clean; (2) it keeps protective windows from accumulating condensed stack gas moisture; and (3) it minimizes thermal conduction from the stack to the instrument. A standard installation has one air-purging system for the transceiver unit and one for the retroreflector unit; each system has a blower providing filtered air.

The control unit of the Dynatron Model 1100 has a digital display and a display selector to select either opacity or optical density. Fault lamps for "lamp," "window," and "air purge" warn of monitor malfunctions and a selector knob allows the setting of the automatic calibration frequency. A zero/span switch allows the monitor to be put into a manual calibration mode. The control unit integrates the stack exit opacity data on an adjustable time basis (typically six-minutes).

Dynatron has recently updated the Model 1100 opacity monitor to the Model 1100M. Both monitors are basically identical, but the Model 1100M has a microprocessor-based digital control unit and a built-in optical alignment sight on the transceiver. The Model 1100M control unit has only two fault lamps, and zero, span, and "M" factor values can be displayed on the control unit meter by manipulating switches inside the control unit. Otherwise, the Models 1100 and 1100M monitors are audited according to the same procedures.

The Dynatron opacity monitor measures the amount of light transmitted through the effluent from the transceiver to the retroreflector and back again. The control unit uses this double-pass transmittance to calculate the optical density of the effluent stream at the monitor location, or the "path" optical density. In order to provide stack exit opacity data, the path optical density must be corrected by multiplying by the ratio of the stack exit diameter to the stack inside diameter (or duct width) at the transmissometer

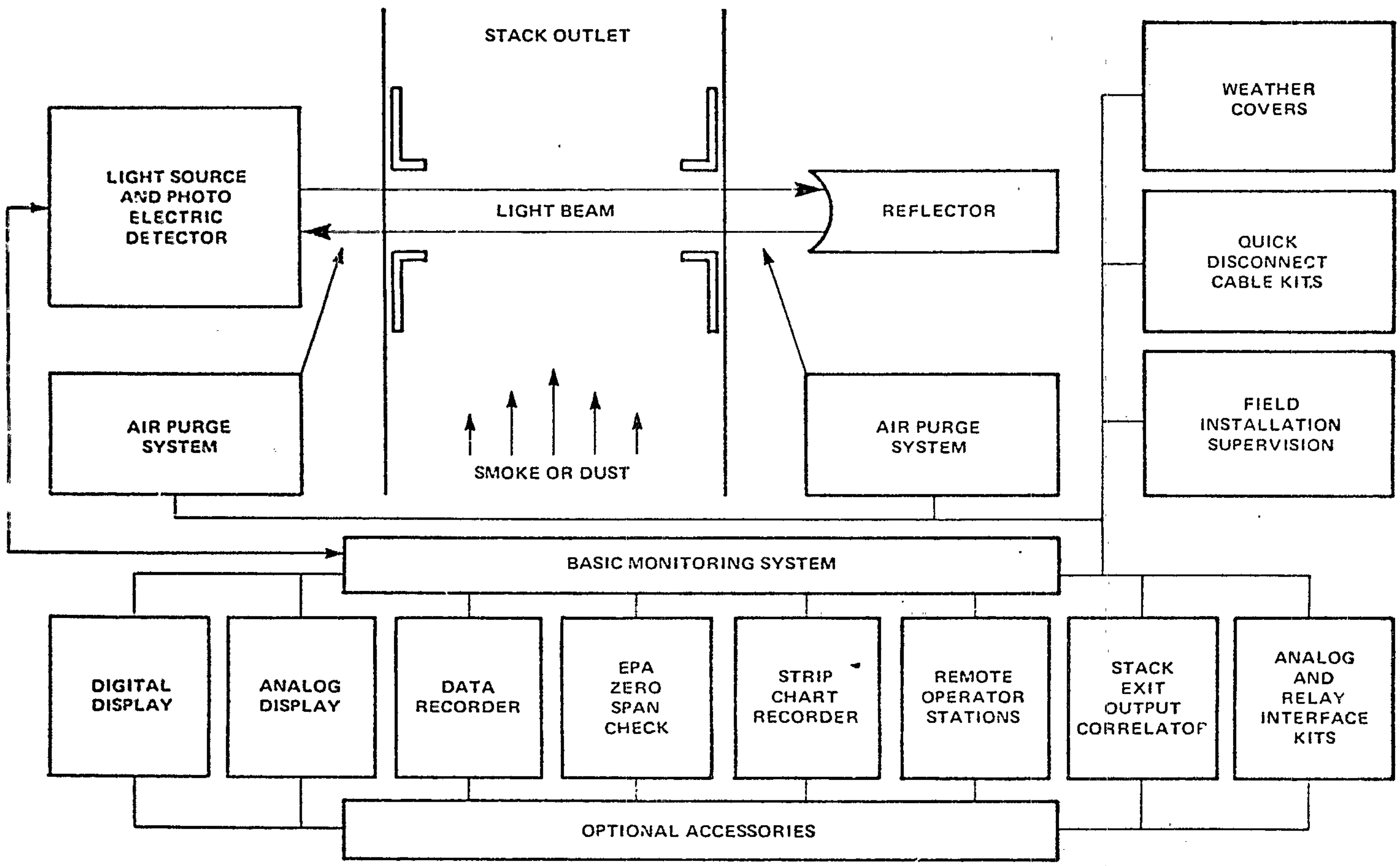


Figure 4-1. Dynatron 1100 Transceiver and Retroreflector Arrangement

location. This ratio is called the M Factor by Dynatron. The following equations illustrate the relationships between the M Factor, path optical density, and exit opacity.

$$OP_x = 1 - 10^{-(M)(OD)}$$

where: OP_x = stack exit opacity (%)

OD = transmissometer optical density (path)

$$M = \frac{L_x}{Lt} = \text{"M" Factor}$$

where: L_x = stack exit inside diameter (ft)

L_t = measurement pathlength (ft) = two times the stack inside diameter (or the duct width) at the monitor location

4.1.2 Performance Audit Procedures

Preliminary Data

1. Obtain the stack exit inside diameter and the stack inside diameter (or duct width) at the transmissometer and record on blanks 1 and 2, respectively, of the Dynatron 1100 Performance Audit Data Sheet.

   Note: Effluent handling system dimensions may be acquired from the following sources listed in descending order to reliability: (1) physical measurements; (2) construction drawings; (3) opacity monitor installation/certification documents; and (4) source personnel recollections.

2. Calculate the M Factor, (divide the value on blank 1 by the value on blank 2), and record the value on blank 3.

3. Record the source-cited M Factor value on blank 4.

   Note: The M Factor is preset by the manufacturer using information supplied by the source. The value recorded in blank 4 should be that which the source personnel agree should be set inside the monitor. Typically, this value is cited from monitor installation or certification data, as well as from service reports. For the Model 1100M monitor, source personnel can adjust switches in the control unit which will cause the "M" Factor to be displayed on the panel meter.

4. Obtain the present values that the monitor should measure for the zero and span calibrations and record on blank 5 and blank 6, respectively.

Note: These values are set during monitor calibration, and therefore may not be equal to values recorded at installation and/or certification. Records of the zero and span values resulting from the most recent monitor calibration should exist. Source personnel can adjust switches in the Model 1100M control unit, which will cause the present zero and span values to be displayed on the panel meter.

5. Go to the control unit location and inspect the opacity data recorder (strip chart or computer) to ensure proper operation. Annotate the paper with the auditor's name, plant, unit, date, and time.

Fault Lamp Checks

The following list describes the fault lamps that are found on the Dynatron Model 1100 control unit panel. Unless otherwise noted, the audit analysis can continue with illuminated fault lamps, provided that the source has been informed of the fault conditions. The Model 1100M monitor control unit has two fault lamps: "WINDOW" (indicating excessive dust on transceiver window) and "FAULT" (indicating other internal malfunctions which can be identified by source personnel through manipulating switch positions within the control unit).

6. Record the status (ON or OFF) of the LAMP fault lamp on blank 7.

   Note: An illuminated LAMP fault lamp indicates that the intensity of the measurement lamp is outside of a specific range. This fault is a conservative indicator of possible fluctuations in the lamp voltage. Because the LAMP fault lamp is obscured by the control unit cover frame, it is frequently overlooked during cursory inspections.

7. Record the status (ON or OFF) of the WINDOW fault lamp on blank 8.

   Note: An illuminated WINDOW fault lamp indicates that the quantity of dust on the transceiver optics has exceeded the limit preset within the control unit. Monitor opacity data may be biased high by the opacity of the dust on the optics, and the auditor should pay particular attention to cleaning the protective window during subsequent audit steps.

8. Record the status (ON or OFF) of the AIR FLOW lamp on blank 9.

   Note: An illuminated AIR FLOW fault lamp indicates a reduction in the flow of purge air to either the transceiver or retroreflector. This condition could jeopardize both the cleanliness of the monitor optics and the continued operation of the transmissometer as a result of exposure to hot, corrosive stack gas. Plant personnel should be notified immediately of this condition.

9. Record the original position on blank 10 of the AUTOMATIC CALIBRATION TIME (CYCLE TIME) knob on the control unit panel.

   Note: The AUTOMATIC CALIBRATION TIME (CYCLE TIME) knob is used to adjust the frequency of calibration cycles.

10. Turn the cycle time knob to the MANUAL position.

11. Record the original position on blank 11 of the METER DISPLAY knob on the control panel.

    Note: The METER DISPLAY knob permits the selection of either the opacity or optical density of the stack exit to be displayed on the panel meter. Optical density data is useful during maintenance and calibration.

12. Turn the METER DISPLAY knob to the opacity position, if necessary.

Zero Span Check

13. Press the zero/span switch.
    Note: The green zero light should go on during the zero period and the yellow span light should be lit during the span period. The monitor automatically switches from zero to span after approximately three minutes. After a similar period in the span mode, the monitor reverts to normal operation.

14. Record the zero value on blank 12 displayed on the panel meter.

15. Record the zero value on blank 13 displayed on the data recorder.

    Note: The cross-stack zero is simulated by the transceiver internal zero optics. The measurement light source is turned off and a zero light source is turned on. Checking this simulated zero value provides an indication of the accuracy of the monitors calibration, assuming that the clear path zero value is correct, as well as an indication of the status of the electronic alignment of the instrument. It does not, however, provide any indication of cross-stack parameters, such as the present clear path zero or optical alignment.

16. Record the span value on blank 14 that is displayed on the control panel meter.

17. Record the span value displayed on the data recorder on blank 15.

    Note: During the span portion of the calibration cycle, the measurement light source is turned off and a span light source is illuminated which has a neutral density filter in its beam path inside the transceiver. The span measurement provides an upscale check of the monitor's calibration accuracy with respect to its clear path zero value. Also, when evaluated in combination with the zero calibration value, the span permits an evaluation of the linearity of the monitor's calibration.

18. Go to the transmissometer location.

    Note: The acquisition of real-time monitor response data requires that there be communication between the transmissometer location and the opacity data recorder location.

Retroreflector Dust Accumulation Check

19. Record the instantaneous effluent opacity prior to cleaning of the retroreflector protective window on blank 16.

20. Remove, inspect, clean, and replace the retroreflector protective window.

21. Record the post cleaning instantaneous effluent opacity on blank 17.

Transceiver Dust Accumulation Check

22. Record the instantaneous effluent opacity on blank 18.

23. Remove, inspect, clean, and replace the transceiver protective window.

24. Record the post cleaning instantaneous effluent opacity on blank 19.

Optical Alignment Check

25. If an alignment tube is available, determine the monitor alignment by looking through the tube and observing whether the beam image is centered around the retroreflector port on the opposite side of the stack or duct.

    Note: The Dynatron Model 1100 does not have a built-in alignment check system. Many sources have installed sighting tubes near the transceiver to observe the orientation of the measurement beam with respect to the retroreflector port in the stack or duct. Frequently, these sighting tubes are blocked with accumulated particulate. The auditor should note such a condition, if found. The Model 1100 M has an alignment sight on the transceiver which allows an alignment check when the "target light" switch is activated.

26. Record whether the image is centered inside the circular target (YES or NO) on blank 20.

27. Draw the orientation of the retroreflector port in the beam circle on the data form.

    Note: Instrument optical alignment has no effect on the internal checks of the instrument or on the calibration check using the audit jig; however, if the optical alignment is not correct, the stack opacity data will be biased high, since all the light transmitted to the retroreflector is not returned to the detector.

CALIBRATION ERROR CHECK (JIG PROCEDURE)

The calibration error check is performed using three neutral density audit filters and an audit device (or jig) with an adjustable retroreflector and iris to simulate clear stack conditions. The jig audit device and neutral density filters actually determine the linearity of the instrument response with respect to the current clear-path zero value. This calibration error check does not determine the actual instrument clear-path zero, or the status of any cross-stack parameters.

If the audit jig is not available or if the jig cannot be installed in the transceiver then an incremental calibration error procedure should be used. This procedure factors out the opacity attributed to the transceiver protective window and that of the effluent. Due to its complexity and possible inaccuracy, the incremental calibration error procedure should be used only as a last resort.

Note: A true calibration check is performed by *removing the* on-stack components and setting them up in a location with minimal ambient opacity, making sure that the proper pathlength and alignments are attained, and then placing the calibration filters in the measurement beam path.

28. Remove the transceiver dirty window detector on the left forward side of the transceiver. Install the audit jig by inserting it into the dirty window detector opening (with the iris opening facing toward the light source) and tighting the thumb screws.

    Note: If the transceiver does not have a dirty window detect or if, for whatever reason, the audit jig will not fit into the available opening, then the incremental calibration error procedure should be used.

29. Remove the transceiver protective window.

30. Adjust the audit jig iris to produce a 0-2% opacity value on the opacity data recorder. This adjustment simulates the amount of light returned to the transceiver during clear stack conditions.

    Note: The audit jig zero adjustment depends on the procedure used in calibrating the neutral density filters employed in the audit. Some older filter sets intended for incremental calibration checks of Dynatron monitors have an 8-10% "assumed" window opacity value added to the actual filter opacity. Thus, a filter marked as "20% Op" might have a total true opacity of 26% (8% Op + 20% Op). With the audit jig zero (without the protective window) being set at 0-2% opacity as described above, it becomes imperative that the auditor know the actual opacity of each filter, including any added window opacity. In general, it is recommended that both assumed filter values (based on the sum of filter opacity and assumed window opacity) and actual filter values be known. This information should be supplied by the firm certifying the filter calibration values.

31. Install the transceiver protective window and record the measured window opacity value in Blank 21.

32. Remove the transceiver protective window.

33. Record the audit filter serial numbers and opacity values on blanks 22, 23, and 24.

34. Remove the filters from their protective covers, inspect, and if necessary, clean them.

35. Record the jig zero value from the opacity data recorder.

    Note: The acquisition of monitor response from the data recorder requires communication between the auditor at the transmissometer location and another person at the data recorder location.

36. Insert the low range neutral density filter into the monitor.

37. Wait for approximately two minutes or until a clear value has been recorded and displayed on the opacity data recorder.

Note: The audit data should be taken from a data recording/reporting device that presents instantaneous opacity (or opacity data with the shortest available integration period).

38. Record the monitor's response to the low range neutral density filter.

39. Remove the low range filter from the monitor and insert the mid range neutral density filter.

40. Wait approximately 2 minutes and record the monitor's responses.

41. Remove the mid range filter and insert the high range filter.

42. Wait approximately 2 minutes and record the monitor's response.

43. Remove the high range filter, wait approximately 2 minutes, and record the jig zero value.

    Note: If the final jig zero value differs from the initial value by more than 1% opacity, the jig zero should be adjusted to agree with the initial value and the three-filter run (i.e., low, mid, and high) should be repeated.

44. Repeat steps 36-43 above until a total of five opacity readings are obtained for each neutral density filter.

45. If six-minute integrated opacity data are recorded, repeat steps 36-43 above once more, changing the waiting periods to 13 minutes.

46. Record the six-minute integrated data, if available.

47. Once the calibration error check is finished, remove the audit jig, replace the dirty window detector and the projective window, and close the transceiver protective housing.

48. Return to the control unit location.

49. If necessary, return the AUTOMATIC CALIBRATION (CYCLE) TIMER, and the METER DISPLAY knob to their original positions, as recorded on blanks 10 and 11.

50. Obtain a copy of the audit data from the data recorder.

51. Transcribe the calibration error response data from the data recorder from blanks 25 to 50, and complete the audit data calculations.

CALIBRATION ERROR CHECK (Incremental Procedure)

The incremental calibration error check is included herein to address older Dynatron monitors that do not permit the use of the audit jig. The incremental calibration error check is performed by substituting three neutral density filters in place of the the transceiver protective window. These filters should include an assumed protective window opacity value of approximately 8% opacity (or a more appropriate value, as cited by the source or monitor manufacturer). Thus, a filter with a true total of 26% Op would be "named" as 20% Op. This check should be performed only when the stack opacity is fairly steady, varying by no than ±2% opacity. The calibration error check provides a determination of the linearity of the instrument response and the on-stack alignment status, since it utilizes all of the components of the measurement system. This calibration check does not provide a test of the actual instrument clear-path zero.

Only under clear stack conditions will the calibration check provide a check of the actual instrument zero and instrument calibration. A true calibration check can also be obtained by removing the on-stack components and setting them up in an area with minimal ambient opacity, making sure that the on-stack pathlength and alignment are duplicated.

I-28. Record the audit filter serial numbers and opacity values on <u>blanks I-21, I-22, and I-23</u>

I-29. Remove the low range filter from its protective cover, inspect, and if necessary clean them.

I-30. Wait approximately two minutes and record the effluent opacity as indicated by the opacity data recorder.

I-31. Remove the transceiver protective window and insert the low range neutral density filter.

I-32. Wait approximately two minutes and record the filter opacity value indicated on the opacity data recorder.

I-33. Remove the low range audit filter and replace the transceiver protective window.

I-34. Wait approximately two minutes and record the indicated effluent opacity value.

I-35. Remove the transceiver protective window and insert the mid range audit filter.

I-36. Wait approximately two minutes and record the indicated filter opacity value.

I-37. Remove the mid range filter and replace the transceiver protective window.

I-38. Wait approximately two minutes and record the indicated effluent opacity.

I-39. Remove the transceiver protective window and insert the high range audit filter.

I-40. Wait approximately two minutes and record the indicated filter opacity.

I-41. Remove the high range audit filter.

I-42. Replace the transceiver protective window.

I-43. Wait approximately two minutes and record the indicated effluent opacity.

3.3.4 Monitor Response Repeatability

I-44. Repeat the procedures steps I-31 through I-43 until a total of five opacity readings is obtained for each neutral density filter.

I-45. If six-minute integrated opacity data are recorded, repeat steps I-31 through I-43 once more, changing the waiting periods to 13 minutes.

I-46. Record the six-minute integrated data, if available.

I-47. Replace the transceiver measurement window for the last time. Ensure that the transceiver protective window is properly installed and close the transceiver housing.

I-48. Return to the control unit location.

I-49. If necessary, return the AUTOMATIC CALIBRATION (CYCLE) TIMER and the METER DISPLAY to the positions recorded in blanks 10 and 11, respectively.

I-50. Obtain a copy of the audit data from the opacity data recorder.

I-51. Transcribe the calibration error response data from the opacity data recorder to audit data sheet blanks I-24 through I-61.

4.1.3 DYNATRON 1100 PERFORMANCE AUDIT DATA INTERPRETATION

This section pertains to the interpretation of the performance audit data analyses peculiar to the Dynatron Model 1100 (and also the Model 1100M, where applicable). The interpretation of the more general analyses is fully discussed in the introduction of this manual.

Stack Exit Correlation Error Check

The pathlength correction error on blank 51 should be within ±2%. This error expontentially affects the opacity readings, resulting in over- or under-estimation of the stack exit opacity. The most common error in computing the M Factor is the use of the flange-to-flange distance rather than the stack/duct inside diameter at the monitor location. This error will result in an under-estimation of the stack exit opacity and can be identified by comparing the monitor optical pathlength to the flange-to-flange distance; the flange to flange distance should be the greater by approximately two feet.

Control Panel Meter Error Check

The accuracy of the control panel meter is important at sources using the meter during monitor adjustment and calibration. In such cases, the control panel meter opacity readings are compared to the specified values for the internal zero and span. Errors in the control panel meter should not affect the opacity data reported by the monitoring system unless the control panel meter is used to adjust the zero and span functions. The percent error values associated with the control panel meter are found on blanks 52 and 54. At sources using the panel meter data, the panel meter should be adjusted so that the error is less than 2%. Since the control panel meter error is determined by using the internal zero and span values, any change in the specified values for the zero or span will cause an erroneous assessment of the control panel meter errors. The zero and span values may change due to aging, replacement, etc. Each time the monitor is thoroughly calibrated, the internal zero and span values should be renamed, and the new values should be recorded and used in all subsequent adjustments.

Internal Zero and Span Check

The Dynatron Model 1100 monitor internal zero is typically set to indicate 2-10% opacity because the monitor will not indicate negative opacity values. A zero error greater than 4% opacity is usually due to electronic drift, or data recorder electronic or mechanical offset. Excessive dust on the optical surfaces sufficient to cause a significant zero error also would be indicated by the dirty window fault lamp. Instrument span error may be caused by the same problems that cause zero errors and may be identified in a similar fashion.

If the zero and span errors are due to a data recorder offset, both errors will be in the same direction and will have the same magnitude. The opacity data will be offset in the same manner.

Transmissometer Dust Accumulation Check

The total opacity equivalent to the dust on the transmissometer optical surfaces (blank 58) should not exceed 4%. A dust accumulation valve of more than 4% opacity inidicates that the airflow of the purge system and/or the cleaning frequency of the optical surfaces are inadequate. When determining the optical surface dust accumulation, the auditor should note whether the effluent opacity is fairly stable (within ±2% opacity) before and after the cleaning of the optical surfaces. If the effluent opacity is fluctuating more than ±2%, the dust accumulation analysis should be omitted.

Calibration Error Check

Excessive calibration error results (blanks 68, 69, and 70 or blanks I-89, I-90, I-91) are indicative of a non-linear calibration and/or a miscalibration of the monitor. However, the absolute calibration accuracy of the monitor can be determined only when the clear path zero value is known. If the zero and span are not within the proper range, the calibration check data will often be biased in the same direction as the zero and span errors. Even if the zero and span errors are within the proper ranges, the monitor may still be inaccurate due to possible error in the clear path zero. The optimum calibration procedure involves using neutral density filters during clear-stack or off-stack calibration. This procedure would establish both the absolute calibration accuracy and linearity. If this procedures is not practical, and if it is reasonable to assume that the clear path zero is indeed zero, the monitor's calibration linearity can be set using either neutral density filters or the internal zero and span values.

SECTION 5

PERFORMANCE AUDIT PROCEDURES FOR THERMO ELECTRON (CONTRAVES GOERZ) OPACITY MONITOR

5.1 THERMO ELECTRON (CONTRAVES GOERZ) MODEL 400 TRANSMISSOMETER AND MODEL 500 CONTROL UNIT

5.1.1 CEMS Description

The Thermo Electron, Inc. (formally the Contraves Goerz) Model 400 opacity CEMS consists of three major components: the transmissometer, the air-purging system, and the Model 500 control unit. The transmissometer component consists of a transceiver unit mounted on one side of a stack or duct and a retroreflector unit mounted on the opposite side. The transceiver unit contains a light source, a photodiode detector, and the optical, mechanical, and electronic components used in monitor operation and calibration.

Figure 5-1 illustrates the general arrangement of the transceiver and retroreflector units on the stack. The transceiver uses a single lamp single detector system, employing both internal and external choppers. The internal chopper modulates the measurement beam to eliminate interference from ambient light. The external three-segmented chopper produces alternating calibration and stack opacity measurements. Also, since the external chopper is exposed to stack conditions, it automatically compensates for dust accumulation on transceiver optics. The output signal from the transceiver (double-pass, uncorrected transmittance) is transmitted to the control unit.

The air purging system serves a threefold purpose: (1) it provides an air window to keep exposed optical surfaces clean; (2) it protects the optical surfaces from condensation of stack gas moisture; and (3) it minimizes thermal conduction from the stack to the instrument. A standard installation has one air-purging system for the transceiver unit and one for the retroreflector unit; each system has a blower providing filtered air.

The Model 500 digital control unit (Figure 5-2) converts the double-pass transmittance output from the transceiver to linear optical density measurements which are corrected according to the ratio of the stack exit diameter to the transmissometer pathlength, referred to as the stack taper ratio (STR). The resultant stack exit optical density is converted to instantaneous, single-pass stack exit opacity. The control unit also contains an integrator which compiles the above opacity data and calculates a discrete average over an integration period that is set by the source (typically six minutes). This function may not be used at facilities employing a computer to reduce and record opacity data because the computer may perform the integration. Also, the Model 500 control unit has a lamp test button that lights all fault and control lamps, and the STR setting can be checked by manipulating a switch inside the control unit.

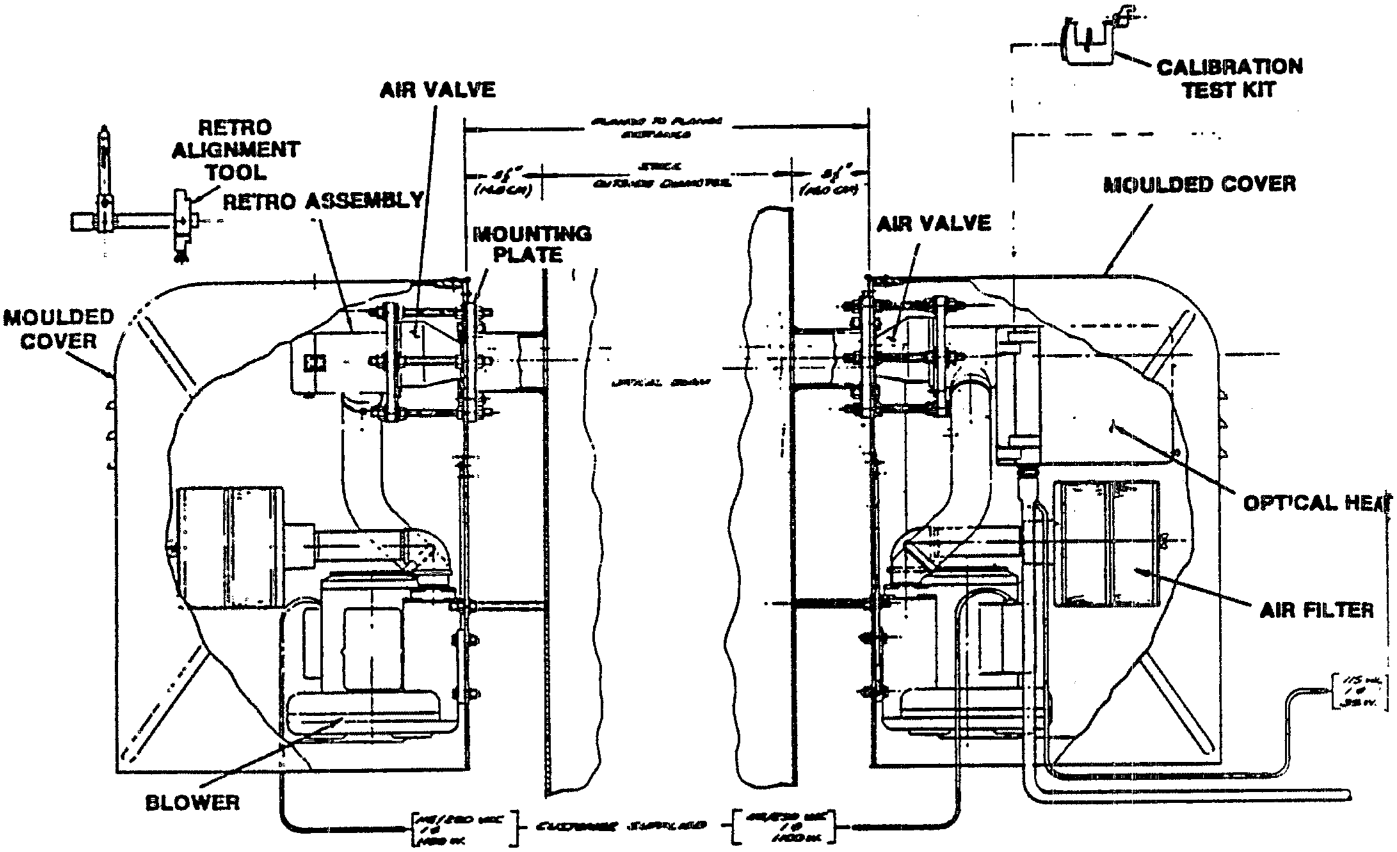


Figure 5-1.

Arrangement of Thermo Electron (Contraves Goerz) Model 400 Transceiver and Retroreflector.

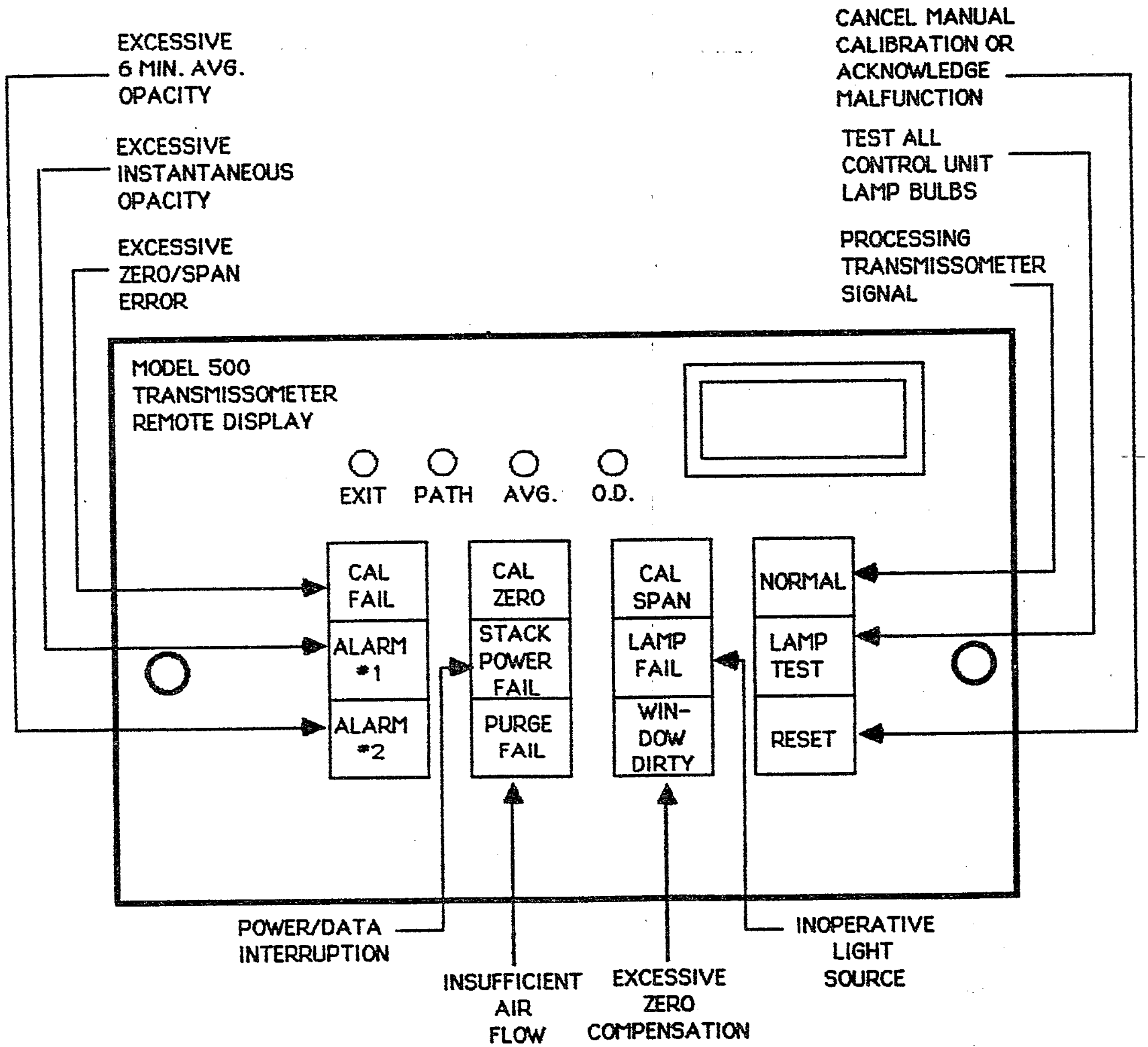


Figure 5-2. Thermo Electron (Contraves Goerz) Model 500 Control Unit

The following equations illustrate the relationships between the STR, path optical density, and exit opacity.

$$OP_x = 1 - 10^{-(STR)(OD)}$$

where:

OP_x = stack exit opacity (%)

STR = stack taper ratio = L_x/L_t

L_x = stack exit inside diameter (ft)

L_t = measurement pathlength (ft) = the stack or duct inside diameter at the monitor location

OD = transmissometer optical density (path)

5.1.2 Performance Audit Procedures

Preliminary Data

1. Obtain the stack exit (inside) diameter and the stack or duct inside diameter (or width) at the transmissometer location and record on blanks 1 and 2, respectively, of the Thermo Electron (Contraves Goerz) Model 400 Performance Audit Data Sheet.

   Note: Effluent handling system dimensions may be acquired from the following sources listed in descending order to reliability: (1) physical measurements; (2) construction drawings; (3) opacity monitor installation/certification documents; and (4) source personnel recollections. The monitor measurement pathlength is the length of the inside diameter (or width) of the stack (or duct) at the monitor installation location.

2. Calculate the STR, (divide the value on blank 1 by the value on blank 2), and record the value on blank 3.

3. Record the source-cited STR value on blank 4.

   Note: The STR is preset by the manufacturer using information supplied by the source. The value recorded in blank 4 should be that which the source personnel agree should be set inside the monitor. Typically, this value is cited from monitor installation or certification data, as well as from service reports. Source personnel can adjust a switch inside the control unit which will cause the STR value to appear on the digital display.

4. Obtain the present values that the monitor should measure for the zero and span calibrations and record on blank 5 and blank 6, respectively.

   Note: These values are set during monitor calibration, and therefore may not be equal to values recorded at installation and/or certification. Records of the zero and span values resulting from the most recent monitor calibration should exist.

Control Unit Checks

5. Inspect the opacity data recorder (strip chart or computer) to ensure proper operation. Annotate the paper with the auditor's name, plant, unit, date, and time.

Fault Lamp Checks

The following list describes the fault lamps that are found on the Model 500 control unit panel. Unless otherwise noted, the audit analysis can continue with illuminated fault lamps, provided that the source has been informed of the fault conditions.

6. Record the status (ON or OFF) of the CAL FAIL lamp on blank 7.

Note: An illuminated CAL FAIL lamp indicates that the most recent monitor automatic zero and/or span calibration values are not within a preset range.

5. Record the status (ON or OFF) of the DIRTY WINDOW fault lamp on blank 8.

Note: An illuminated dirty window fault lamp indicates that the quantity of dirt accumulated on transceiver optics has exceeded preset limits. Such a fault condition can jeopardize the quality of the monitoring data.

6. Record the status (ON or OFF) of the PURGE AIR fault lamp on blank 9.

Note: An illuminated purge air fault lamp indicates that the transceiver and/or retroreflector purge air flow rate is reduced either because a blower may not be working properly or one of the purge air filter elements is dirty, thereby restricting the flow of purge air. This fault does not preclude the completion of the audit.

7. Record the status (ON or OFF) of the STACK POWER fault lamp on blank 10.

Note: An illuminated stack power fault lamp indicates a lack of power for the transmissometer. Power must be restored before the audit can continue.

8. Record the status (ON or OFF) of the LAMP FAILURE fault lamp on Blank 11.

Note: An illuminated lamp failure fault lamp indicates that the measurement beam intensity is insufficient to make accurate cross-stack measurements. This fault will jeopardize the quality of the monitoring data, and should be corrected immediately. However, if the measurement lamp is replaced the audit should be postponed for several hours to permit equilibration of the measurement system.

9. Record the status (ON or OFF) of the ALARM fault lamp on Blank 12.

Note: An illuminated alarm fault lamp indicates that the opacity of the effluent exceeds a value selected by the source. Such a fault has no effect on the accuracy of the monitoring data or on the completion of the audit.

10. Press the CAL ZERO switch on the control panel to initiate the zero mode.

    Note: The green normal light should go out when the zero mode is initiated. The yellow CAL light and the green ZERO light should remain illuminated.

11. Record the zero value on Blank 13 displayed on the panel meter.

12. Record the zero value on Blank 14 displayed on the data recorder.

    Note: The cross-stack zero is simulated by the zero reflector segment of the external chopper. Checking this simulated zero value provides an indication of the amount of dust on the measurement window and on the zero retroreflector, as well as an indication of the status of the electronic alignment of the instrument. It does not, however, provide any indication of cross-stack parameters.

13. Press the CAL SPAN switch to initiate the span mode.

14. Record the span value on Blank 15 that is displayed on the control panel meter and record the span value displayed on the data recorder on Blank 16. Go to the transceiver location.

    Note: During the span portion of the calibration cycle, the span segment of the external chopper is monitored, resulting in an upscale calibration check. The span measurement provides another check of the monitor electronic alignment and the linearity of the transmissometer opacity response.

Retroreflector Dust Accumulation Check

15. Record the instantaneous effluent opacity on blank 17 prior to cleaning of the retroreflector optics.

16. Open the retroreflector, inspect and clean retroreflector optics, and close the retroreflector.

17. Record the post cleaning instantaneous effluent opacity on blank 18.

Transceiver Dust Accumulation Check

18. Record the pre-cleaning effluent opacity on blank 19.

19. Open the transceiver, turn off the chopper motor switch, stop the chopper, clean the primary lens, turn on the chopper monitor switch, and close the transceiver.

    Note: The chopper motor is stopped by turning off the toggle switch in the lower left corner of the transceiver control panel. This switch also turns-off the measurement beam.

20. Record on blank 20 the post cleaning instantaneous effluent opacity.

Optical Alignment Check

21. Determine the monitor alignment by looking through the viewing port on the back of the transceiver and observing whether the beam image is in the center of the target cross-hairs.

22. Record whether the image is centered inside the target (YES or NO) on blank 21.

23. Draw the orientation of the beam image in the circle on the data form.

Note: Instrument optical alignment has no effect on the internal checks of the instrument or on the calibration check using the audit device; however, if the optical alignment is not correct, the stack opacity data will be biased high, since all the light transmitted to the retroreflector is not returned to the detector.

CALIBRATION ERROR CHECK

The calibration error check is performed using three neutral density audit filters and an audit device (or jig) with a built-in retroreflector and iris to simulate clear stack conditions. The audit device and neutral density filters actually determine the linearity of the instrument response with respect to the current clear-stack zero value. This calibration error check does not determine the actual instrument clear-stack zero, or the status of any cross-stack parameters.

A true calibration check is performed by removing the on-stack components and setting them up in a location with minimal ambient opacity, making sure that the proper pathlength and alignments are attained, and then placing the calibration filters in the measurement beam path.

Note: Thermo Electron (Contraves Goerz) supplies an audit jig whose internal iris setting is fixed for a specific monitor. If the source has such a dedicated audit device, it should be used in the audit because its jig zero value has been fixed to correspond to the given measurement path conditions, and these calibration error procedures are predicated on this assumption. If such a device is not available, the auditor should supply a similar device with an adjustable iris. following the installation of this audit device, the iris should be adjusted such the jig zero value reads 1-2% opacity on the opacity data recorder.

24. Stop the chopper and install the audit jig by placing it over the primary lens and tightening the attached set-screw.

Note: The audit device is not properly installed until it is flush with the monitor. Care should be taken that the chopper will not contact the audit jig while in operation. Also do not bend the chopper blades.

25. Restart the chopper and allow the transceiver 2-3 minutes to warm-up.

Note: The jig zero value is based on readings from the data recorder. The jig zero does not have to be exactly 0.0 since the audit filter correction equations can account for an offset in the jig zero. Thus, a jig zero value in the range of 0-2% Op is typical.

26. Record on Blanks 22, 23, and 24 the audit filter serial numbers and opacity values.

27. Remove the filters from their protective covers, inspect, and if necessary, clean them.

28. Record the jig zero value from the data recorder.

    Note: The acquisition of monitor response from the data recorder requires communication between the auditor at the transmissometer location and another person at the data recorder location.

29. Insert the low range neutral density filter into the audit jig.

30. Wait for approximately two minutes or until a clear value has been recorded and displayed on the data recorder.

    Note: The audit data should be taken from a data recording/reporting device that presents instantaneous opacity (or opacity data with the shortest available integration period).

31. Record the monitor's response to the low range neutral density filter.

32. Remove the low range filter from the audit device and insert the mid range neutral density filter.

33. Wait approximately two minutes and record the monitor's responses.

34. Remove the mid range filter from the audit jig and insert the high range filter.

35. Wait for approximately two minutes and record the monitor's response.

36. Remove the high range filter, wait approximately two minutes, and record the jig zero value.

    Note: If the final jig zero value differs from the initial value by more than 1% opacity, the jig zero should be checked to determine the source of the fluctuation, and the 3-filter run should be repeated.

37. Repeat steps 29-36 above until a total of five opacity readings are obtained for each neutral density filter.

38. If six-minute integrated opacity data are recorded, repeat steps 29-36 above once more, but change the waiting periods to 13 minutes.

39. Record the six-minute integrated data.

40. Once the calibration error check is finished, stop the chopper, remove the audit jig, restart the chopper and close the transceiver head.

41. Return to the control unit/data recorder location and obtain a copy of the audit data from the data recorder.

42. Transcribe the calibration error response data from the data recorder to Blanks 25 to 50.

5.1.3 THERMO ELECTRON (Contraves Goerz) Model 400 PERFORMANCE AUDIT DATA INTERPRETATION

This section pertains to the interpretation of the performance audit data analyses peculiar to the Model 400. The interpretation of the more general analyses is fully discussed in the introduction of this manual.

Stack Exit Correlation Error Check

The pathlength correction error on Blank 51 should be within ±2%. This error exponentially affects the opacity readings, resulting in over- or under-estimation of the stack exit opacity. The most common error in computing the STR is the use of the flange-to-flange distance rather than the stack/duct inside diameter at the monitor location. This error will result in an under-estimation of the stack exit opacity and can be identified by comparing the monitor optical pathlength to the flange-to-flange distance, which should be the greater by approximately 2-4 feet.

Internal Zero and Span Check

The internal zero should be set to indicate 0% opacity. A zero error greater than 4% opacity is usually due to excessive dust accumulation on the optical surfaces, electronic drift, or data recorder electronic or mechanical offset. Instrument span error may be caused by the same problems that cause zero errors and may be identified in a similar fashion. Also, a span error may be caused by an inaccurate chopper span segment value.

If the zero and span errors are due to a data recorder offset, both errors will be in the same direction and will have the same magnitude. The stack exit opacity data will be offset in the same manner.

Transmissometer Dust Accumulation Check

The total opacity equivalent to the dust on the transmissometer optical surfaces should not exceed 4%. A dust accumulation value of more than 4% opacity may inidicate that the airflow of the purge system and/or the cleaning frequency of the optical surfaces are inadequate. When determining the optical surface dust accumulation, the auditor should note whether the effluent opacity is fairly stable (within ±2% opacity) before and after the cleaning of the optical surfaces. If the effluent opacity is fluctuating more than ±2%, the dust accumulation analysis should be omitted.

Calibration Error Check

Excessive calibration error results (blanks 68, 69, 70) are indicative of a non-linear calibration and/or a miscalibration of the monitor. However, the absolute calibration accuracy of the monitor can be determined only when the clear path zero value is known. If the zero and span are not within the proper range, the calibration check data will often be biased in the same direction as the zero and span errors. Even if the zero and span errors are within the proper ranges, the monitor may still be inaccurate due to possible error in the clear path zero. The optimum calibration procedure involves using neutral density filters during clear-stack or off-stack calibration. This procedure would establish both the absolute calibration accuracy and linearity. If this procedure is not practical, and if it is reasonable to assume that the clear path zero is indeed zero, the monitor's calibration linearity can be set using either neutral density filters or the internal zero and span values.

SECTION 6

PERFORMANCE AUDIT PROCEDURES FOR THERMO ELECTRON (ENVIRONMENTAL DATA CORPORATION) OPACITY MONITOR

6.1 THERMO ELECTRON CORPORATION (ENVIRONMENTAL DATA CORPORATION) MODEL 1000A

6.1.1 CEMS Description

The Thermo Electron (formally manufactured by Environmental Data Corporation or EDC) opacity CEMS consists of three major components: the transmissometer, the air-purging system, and the data acquisition system. The transmissometer component consists of a transceiver unit mounted on one side of a stack or duct and a retroreflector unit mounted on the opposite side. The transceiver unit contains a light source, a photodiode detector, and the optical, mechanical, and electronic components used in monitor operation and calibration. The output signal from the transceiver (double-pass, uncorrected transmittance) is transmitted to a control unit, or directly to an opacity data recorder. The transceiver zero and span signals are monitored continuously and are electronically compensated through a gain control circuit so that the signals remain constant. Since the electronic gain compensation affects the zero and span signals and the measurement signal amplitude equally, all variations in measurement lamp intensity are concelled out of the measurement signal.

The air purging system serves a threefold purpose: (1) it provides an air window to keep exposed optical surfaces clean; (2) it protects the optical surfaces from condensation of stack gas moisture; and (3) it minimizes thermal conduction from the stack to the instrument. A standard installation has one air-purging system for the transceiver unit and one for the retroreflector unit; each system has a blower providing filtered air.

The opacity monitor measures the amount of light transmitted through the effluent from the transceiver to the retroreflector and back again. The monitor uses this double-pass transmittance to calculate the optical density of the effluent stream at the monitor location, or the "path" optical density. In order to provide stack exit opacity data, the path optical density must be corrected by multiplying by the ratio of the stack exit diameter to the measurement pathlength. The following equations illustrate the relationships between this ratio, path optical density, and exit opacity.

$$OP_x = 1 - 10^{-(L_x/L_t)(OD)}$$

where: OP_x = stack exit opacity (%)

OD = transmissometer optical density (path)

$\frac{L_x}{L_t}$ = optical pathlength correction factor

where: L_x = stack exit inside diameter (ft)

L_t = measurement pathlength (ft) = two times the effluent depth at the monitor location

6.1.2 Performance Audit Procedures

Preliminary Data

1. Obtain the stack exit (inside) diameter and transmissometer measurement pathlength (two times the stack or duct inside diameter at monitor location) and record on blanks 1 and 2, respectively, of the Thermo Electron (EDC) 1000A Performance Audit Data Sheet. If the monitor uses a slotted tube inside the stack or duct, then the optical pathlength (Lt) is equal to the length of the slotted portion of the tube.

   Note: Effluent handling system dimensions may be acquired from the following sources listed in descending order to reliability: (1) physical measurements; (2) construction drawings; (3) opacity monitor installation/certification documents; and (4) source personnel recollections. The monitor pathlength is two times the length of the inside diameter of the stack at the monitor installation location.

2. Calculate the optical pathlength correction factor (divide the value on blank 1 by the value on blank 2), and record the value on blank 3.

3. Record the source-cited optical pathlength correction factor value on blank 4.

   Note: The optical pathlength correction factor is preset by the manufacturer using information supplied by the source. The value recorded in blank 4 should be that which the source personnel agree should be set inside the monitor. Typically, this value is cited from monitor installation or certification data, as well as from service reports.

4. Obtain the present opacity values that the monitor should measure for the zero and span calibrations and record on blank 5 and blank 6, respectively.

   Note: These values are set during monitor calibration, and therefore may not be equal to values recorded at installation and/or certification. Records of the zero and span values resulting from the most recent monitor calibration should exist.

Monitoring System

This section describes checks to gather the pertinent operating parameters necessary to ascertain whether the monitoring system is functioning properly. Since the EDC 1000A does not have a control unit, the zero and span checks may be performed in the control room, but only if the source has installed a CAL-INITIATE button. Otherwise, this check must be performed at the monitoring site.

5. Inspect the opacity data recorder (strip chart or computer) to ensure proper operation. Annotate the data record with the auditor's name, plant, unit, date, and time.

6. If the source has installed a switch to initiate the internal zero and span functions, initiate the zero and span cycle mode by pressing this CAL-INITIATE button.

   Note: The monitor will remain in the zero mode for approximately three minutes, after which the span mode will be automatically initiated. After an additional three minutes, the monitor will automatically return to normal operation. The cross-stack zero is simulated by using the zero mirror in the transceiver. The zero and span checks provide an indication of the status of the electronic alignment of the instrument. They do not, however, indicate optical misalignment, or the true cross-stack zero.

7. Record the zero and span responses on blanks 7 and 8, respectively, that are displayed on the chart recorder.

8. If there is no CAL-INITIATE button in the control room, locate the MODE switch on the front of the transceiver, next to the input/output cable.

9. Move the MODE switch to the up position (ZERO).

10. Allow the monitor to operate at least three minutes (thirteen minutes if the monitoring system processes the data through a six-minute averaging circuit) for the chart recorder to log the zero response.

11. Move the MODE switch to the down position (SPAN).

12. Wait another three or thirteen minutes (depending upon the use of an averaging circuit) for the chart recorder to log the span response.

13. Return the MODE switch to the center position (OPERATE).

14. Record the zero and span responses on blanks 7a and 9, respectively, that are displayed on the data recorder.

Retroreflector Dust Accumulation Check

15. Record the instantaneous effluent opacity prior to cleaning of the retroreflector optics on blank 10.

16. Pull up and clean the window that separates the retroreflector from the stack.

17. Record the post cleaning instantaneous effluent opacity on blank 11.

Transceiver Dust Accumulation Check

18. Record the pre-cleaning effluent opacity on blank 12.

19. Pull up and clean the window that separates the light source from the stack.

20. Record on blank 13 the post cleaning instantaneous effluent opacity.

CALIBRATION ERROR CHECK

The calibration error check is performed by installing an EDC filter holder assembly (P/N 32269) in front of the corner cube retroreflector and then securing the filter holder assembly by means of two Allen head screws. The neutral density filter slides (mounted in EDC filter housings) are then placed into the filter holder assembly in the order described below. This check should be performed only when the stack opacity is fairly steady. The calibration check provides a determination of the linearity of the instrument response and utilizes all of the components of the measurement system. This calibration check does not provide a test of the actual instrument zero.

A true calibration check is performed by removing the on-stack components and setting them up in a location with minimal ambient opacity, making sure that the proper pathlength and alignments are attained, and then placing the calibration filters in the measurement beam path.

21. Record the audit filter serial numbers and opacity values on blanks 14, 15, and 16.

22. Remove the low range filter from its protective cover, inspect, and clean it, if necessary.

23. Wait approximately two minutes and record the effluent opacity as indicated by the opacity data recorder.

24. Insert the low range neutral density filter.

25. Wait approximately two minutes and record the opacity value indicated on the opacity data recorder.

26. Remove the low range audit filter, wait approximately two minutes, and record the indicated effluent opacity value.

27. Remove the mid range filter from its protective cover, inspect, and if necessary clean it.

28. Insert the mid range audit filter.

29. Wait approximately two minutes and record the indicated opacity value

30. Remove the mid range filter, wait approximatley two minutes and recor the indicated effluent opacity.

31. Remove the high range filter from its protective cover, inspect, and if necessary clean it.

32. Insert the high range audit filter.

33. Wait approximately two minutes and record the indicated opacity.

34. Remove the high range filter.

35. Wait approximately two minutes and record the indicated effluent opacity.

Monitor Response Repeatability

36. Repeat the procedures steps 24 through 35 until a total of five opacity readings is obtained for each neutral density filter.

37. If six-minute integrated opacity data are recorded, repeat steps 24 through 35 once more, changing the waiting periods to 13 minutes.

38. Record the six-minute integrated data, if available.

39. Remove the filter holder and secure the retroreflector. Return to the control unit location.

40. Obtain a copy of the audit data from the opacity data recorder.

41. Transcribe the calibration error response data from the opacity data recorder to audit data sheet blanks 17 and 54, and complete the audit data calculations.

6.1.3 EDC 1000A PERFORMANCE AUDIT DATA INTERPRETATION

This section pertains to the interpretation of the performance audit data analyses peculiar to the 1000A. The interpretation of the more general analyses is fully discussed in the introduction of this manual.

Stack Exit Correlation Error Check

The pathlength correction error on blank 88 should be within ±2%. This error expontentially affects the opacity readings, resulting in over or underestimation of the stack exit opacity. The most common error in computing the optical pathlength correction factor is the use of the flange-to-flange distance rather than the stack/duct inside diameter at the monitor location. This error will result in an underestimation of the stack exit opacity and can be identified by comparing the monitor optical pathlength to the flange-to-flange distance, which should be the greater by approximately 2-4 feet.

Internal Zero and Span Check

The 1000A internal zero should be set to indicate 0% opacity. A zero error greater than 4% opacity is usually due to excessive dust accumulation on the optical surfaces, electronic drift, or data recorder electronic or mechanical offset. Instrument span error may be caused by the same problems that cause zero errors and may be identified in a similar fashion. Also, a span error may be caused by an inaccurate span filter value.

If the zero and span errors are due to a data recorder offset, both errors will be in the same direction and will have the same magnitude. The opacity data will be offset in the same manner.

Transmissometer Dust Accumulation Check

The total opacity equivalent to the dust on the transmissometer optical surfaces (blank 93) should not exceed 4%. A dust accumulation value of more than 4% opacity indicates that the airflow of the purge system and/or the cleaning frequency of the optical surfaces are inadequate. When determining the optical surface dust accumulation, the auditor should note whether the effluent opacity is fairly stable (within ±2% opacity) before and after the cleaning of the optical surfaces. If the effluent opacity is fluctuating more than ±2%, the dust accumulation analysis should be omitted.

Calibration Error Check

The comparison of monitor responses to the opacity values of the neutral density filters requires that the filter values be corrected to stack exit conditions and that any zero offset be factored into the corrected filter value.

Excessive calibration error results (blanks 82, 83, and 84) are indicative of a non-linear calibration and/or a miscalibration of the monitor. However, the absolute calibration accuracy of the monitor can be determined only when the clear path zero value is known. If the zero and span are not within the proper range, the calibration check data will often be biased in the same direction as the zero and span errors. Even if the zero and span errors are within the proper ranges, the monitor may still be accurate due to possible error in the clear path zero. The optimum calibration procedure involves using neutral density filters during clear-stack or off-stack calibration. This procedure would establish both the absolute calibration accuracy and linearity. If this procedure is not practical, and if it is reasonable to assume that the clear path zero is indeed zero, the monitor's calibration linearity can be set using either neutral density filters or the internal zero and span values.

SECTION 7

PERFORMANCE AUDIT PROCEDURES FOR ENVIROPLAN (THERMO ELECTRON CORPORATION) OPACITY MONITOR

7.1 ENVIROPLAN (THERMO ELECTRON CORPORATION) MODEL D-R280 AV "DURAG"

7.1.1 CEMS Description

The Enviroplan (formally distributed by Thermo Electron) D-280 AV opacity monitor system consists of four major components: the transmissometer, the on-stack control unit, the air-purging system, and the remote control unit and data acquisition equipment. (The most recent version of this monitor is the Enviroplan Model CEMOP-281; this system is the same as the D-R280, except that the remote control unit has digital readouts). The transmissometer component consists of an optical transmitter/ receiver (transceiver) unit mounted on one side of a stack or duct and a retroreflector unit mounted on the opposite side. The transceiver unit contains a light source, a photodiode detector, and their associated electronics. The on-stack control unit provides a readout of the milliamp signal from the transceiver and initiates the internal zero and span checks. Figure 7-1 illustrates the general arrangement of the transmissometer transceiver, on-stack control unit, and retroreflector units on the stack. The transceiver uses a single-lamp, single-detector system to determine stack opacity. A chopper, located inside the optical compartment, modulates the light beam to eliminate interference from ambient light. The modulated beam is alternated between reference and measurement states so that optical and electronic fluctuations are cancelled out.

The air purging system serves a threefold purpose: (1) it provides an air window to keep exposed optical surfaces clean; (2) it protects the optical surfaces from condensation of stack gas moisture; and (3) it minimizes thermal conduction from the stack to the instrument. A standard installation has one air-purging system for both the transceiver and the retroreflector unit; one blower providing filtered air.

The remote control unit (Figure 7-2) converts the nonlinear transmittance output from the tranceiver (a milliamp signal) into linear opacity. It also corrects the opacity measurement according to the ratio of the stack exit diameter to the transmissometer pathlength.

The opacity monitor measures the amount of light transmitted through the effluent from the transceiver to the retroreflector and back again. The control unit uses this double-pass transmittance to calculate the optical density of the effluent stream at the monitor location, or the "path" optical density. In order to provide stack exit opacity data, the path optical density must be corrected by multiplying by the ratio of the stack exit diameter to the measurement pathlength. This ratio is called the "optical pathlength correction factor." The following equations illustrate the relationships between this ratio, path optical density, and exit opacity.

$$OP_x = 1 - 10^{-(L_x/L_t)(OD)}$$

where: OP_x = stack exit opacity (%)

OD = transmissometer optical density (path)

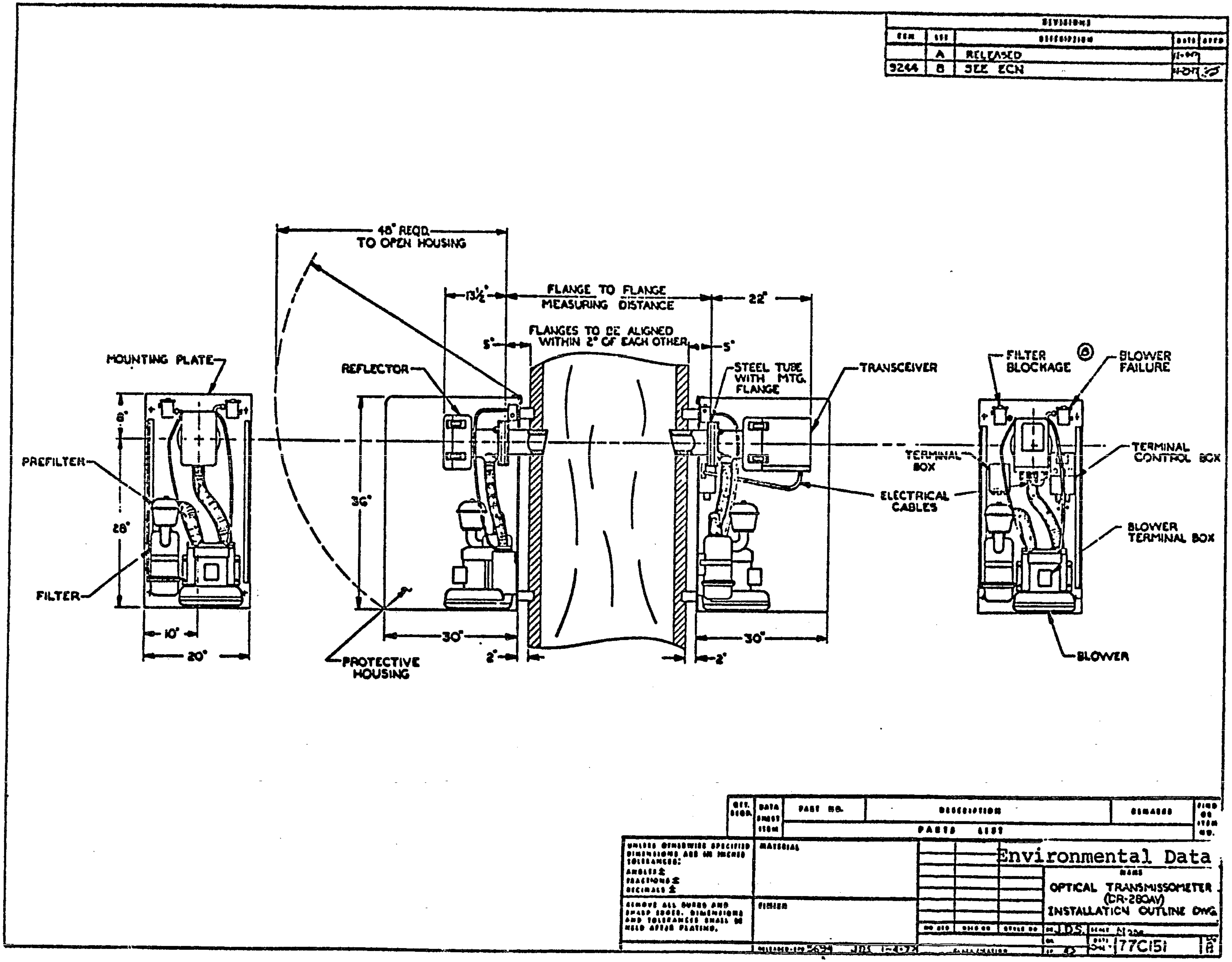


Figure 7-1. Arrangement of Enviroplan (Thermo Electron) Model D-R280 AV Transceiver and Retroreflector

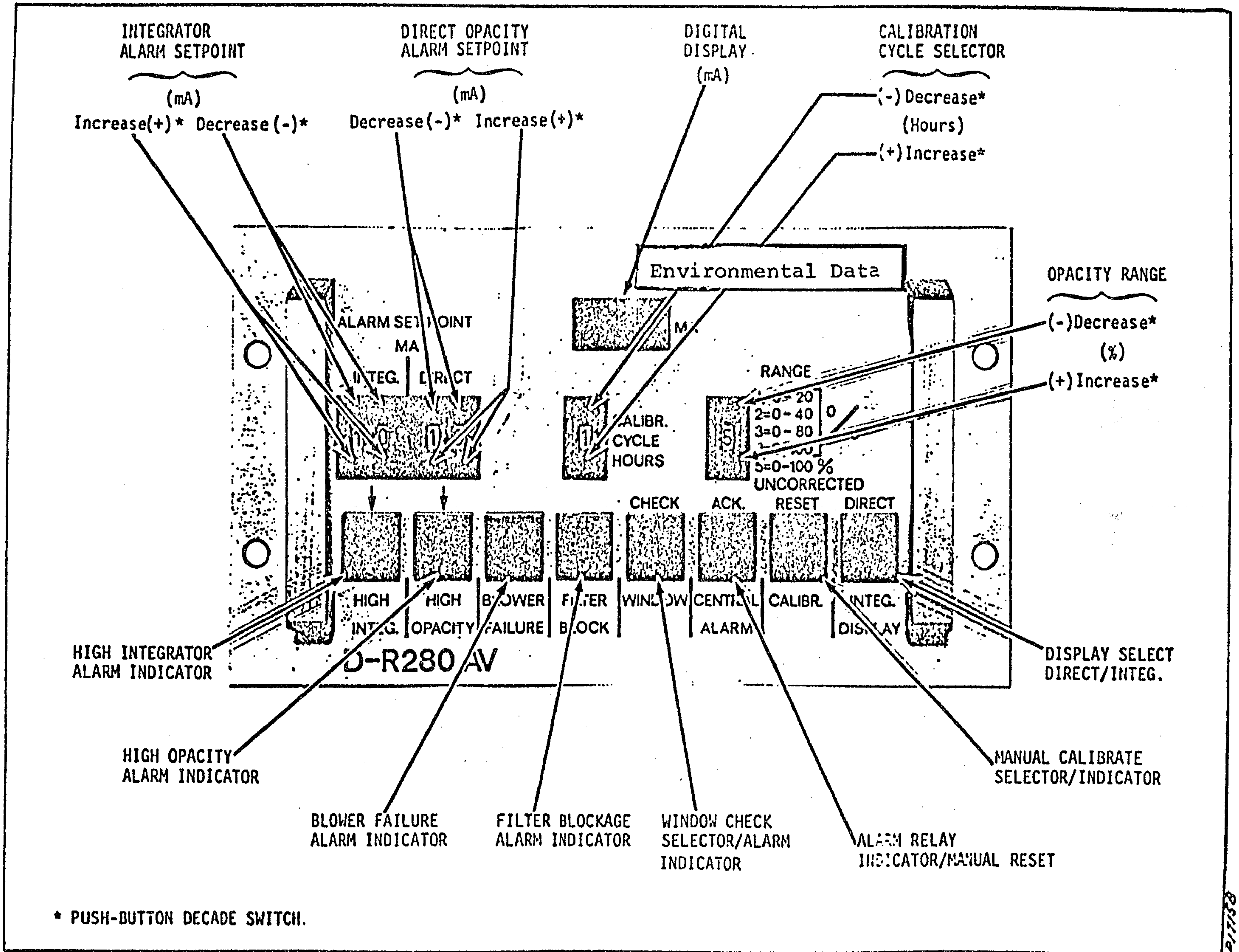


Figure 7-2. Enviroplan (Thermo Electron) Model D-R280 AV Control Unit

$$\frac{L_x}{Lt} = \text{optical pathlength correction factor}$$

where: L_x = stack exit inside diameter (ft)

L_t = measurement pathlength (ft) = the effluent depth at the monitor location

7.1.2 Performance Audit Procedures

Preliminary Data

1. Obtain the stack exit (inside) diameter and transmissometer measurement pathlength (equal to the stack or duct inside diameter or width at the monitor location) and record on blanks 1 and 2, respectively, of the Enviroplan D-R280 AV Performance Audit Data Sheet.

   Note: Effluent handling system dimensions may be acquired from the following sources listed in descending order to reliability: (1) physical measurements; (2) construction drawings; (3) opacity monitor installation/certification documents; and (4) source personnel recollections.

2. Calculate the optical pathlength correction factor, (divide the value on blank 1 by the value on blank 2), and record the value on blank 3.

3. Record the source-cited optical pathlength correction factor value on blank 4.

   Note: The optical pathlength correction factor is preset by the manufacturer using information supplied by the source. The value recorded in blank 4 should be that which the source personnel agree should be set inside the monitor. Typically, this value is cited from monitor installation or certification data, as well as from service reports.

4. Obtain the present values that the monitor should measure for the zero and span calibrations and record on blank 5 and blank 6, respectively.

   Note: These values are set during monitor calibration, and therefore may not be equal to values recorded at installation and/or certification. Records of the zero and span values resulting from the most recent monitor calibration should exist.

Control Unit Checks

5. Inspect the opacity data recorder (strip chart or computer) to ensure proper operation. Annotate the data record with the auditor's name, plant, unit, date, and time.

Fault Lamp Checks

The following list describes the fault lamps that are found on the Enviroplan (Thermo Electron) transmissometer remote control unit front panel.

Unless otherwise noted, the audit analysis can continue with illuminated fault lamps, provided that the source has been informed of the fault conditions.

6. Record the status (ON or OFF) of the BLOWER FAILURE fault lamp on blank 7.

   Note: An illuminated BLOWER FAILURE fault lamp indicates no power to the transceiver or to purge air blowers. If this condition exists, the audit should be halted and the source should be notified immediately, since the monitor may be damaged by the stack gases.

7. Record the status (ON or OFF) of the FILTER BLOCK fault lamp on blank 8.

   Note: The FILTER BLOCK fault lamp indicates inadequate purge airflow to maintain optical surface cleanliness. If the FILTER BLOCK fault lamp is illuminated, the purge air filter element may be dirty or a crimped hose may be restricting the airflow. Plant personnel should be informed if this lamp is on so corrective measures can be initiated at the conclusion of the audit. (This fault lamp is not an indicator of dirt on the measurement window.)

8. Record the status (ON or OFF) of the WINDOW fault lamp on blank 9.

   Note: An illuminated WINDOW fault lamp indicates that the opacity of the measurement window exceeds the preset limit of 3% opacity. When the dirty window limit has been exceeded, the opacity data may be biased. This lamp indicates a need to clean the dirty window surfaces; however, it only monitors the transceiver window.

Control Unit Adjustment Checks

9. Check the opacity range switch indicator located on the remote control panel above the ACK/CENTRAL ALARM lamp (see Figure 7-2) to determine the range selected.

10. Record the range on blank 10.

11. Set the opacity range switch to range "4".

Reference Signal, Zero and Span Checks

12. Initiate the calibration cycle by pushing the CALIBR button on the control panel.

    Note: The green CALIBR lamp will light, and the monitor will automatically cycle through the internal and external zero and span modes.

13. Record the internal zero millamp value on blank 11 displayed on the control panel.

    Note: The internal zero simply checks the reference beam inside the tranceiver and provides a check of the electronic alignment of the instrument. After two minutes in the internal zero mode, the monitor will automatically switch to the external zero mode.

14. Record the external zero value displayed on the panel meter on blank 12a and the zero value displayed on the opacity data recorder on blank 12b.

Note: The external zero is simulated by using the zero reflector. The external zero value displayed on the panel meter provides an indication of the amount of dust on the transceiver measurement window. The external zero value displayed on the opacity data recorder is the monitor zero after compensation for dust accumulation on the transceiver optics. Neither the panel meter nor data recorder external zero values provide an indication of dirty window conditions at the measurement retroreflector, of optical misalignment, or of the true cross-stack zero. After two minutes in the external zero mode, the monitor cycles into the internal span function; the milliamp signal on the control unit corresponds to the span opacity value.

15. Record the span milliamp value on blank 13 displayed on the control panel meter, the span percent opacity value on blank 14 displayed on the data recorder. Go to the transmissometer location.

Note: The transceiver automatically spans the monitor using the span filter and the external zero reflector. The span measurement provides another check of the electrical alignment and the linearity of the transmissometer response to opacity.

After the completion of the zero and span calibration cycle, the monitor will automatically return to the stack opacity measurement mode.

Retroreflector Dust Accumulation Check

16. Record the instantaneous effluent opacity prior to cleaning the retroreflector optics on blank blank 15.

17. Open the transceiver housing, inspect and clean retroreflector optics, and close the housing.

18. Record the post cleaning instantaneous effluent opacity on blank 16.

Transceiver Dust Accumulation Check

19. Record the pre-cleaning effluent opacity on blank 17.

20. Open the transceiver head, clean the optics (primary lens and zero mirror), and close the transceiver head.

21. Record the post-cleaning instantaneous effluent opacity on blank 18.

Alignment Check

22. Determine the monitor alignment by looking through the bull's eye on the side of the transceiver (Figure 7-3).

23. Observe whether the images are centered on either side of the cross hairs and record this information (YES or NO) on blank 19.

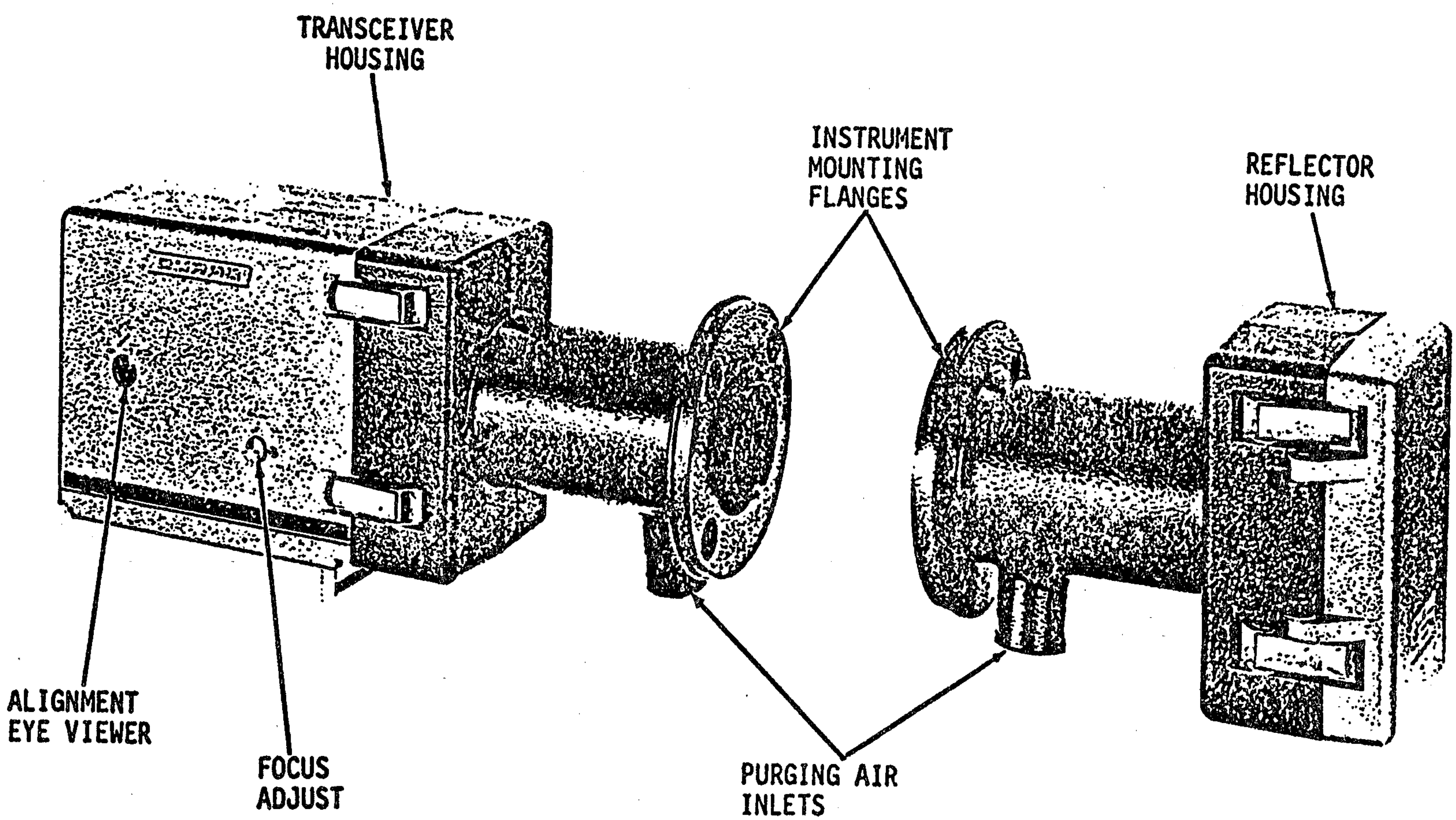


Figure 7-3. Enviroplan (Thermo Electron) Model D-R280 AV Transmissometer Components

Note: There are two types of retroreflectors used for the monitor, and the resulting alignment images are different, as indicated in Figure 7-4. Instrument optical alignment has no affect on the internal checks of the instrument or the calibration error determination; however, if the instrument is misaligned, the opacity data will be biased high, since all the light transmitted to the retroreflector is not returned to the detector.

Span Filter Check

24. Record the span filter milliamp value on blank 20 and the span filter opacity value on blank 21, both supplied by the monitor manufacturer.

Note: The span values are recorded on the Instrument Data Sheet supplied with the monitor. If the manufacturer did not supply the source with the opacity value of the internal span, the following equation should be used to compute the span opacity value.

$$(\text{Blank } 21) = 6.25\ [(\text{Blank } 20) - 4.0]$$

CALIBRATION ERROR CHECK

The calibration error check is performed using three neutral density audit filters and an audit device (or jig) with an adjustable retroreflector iris to simulate clear stack conditions. The audit device and neutral density filters actually determine the linearity of the instrument response with respect to the current clear-stack zero value. This calibration error check does not determine the actual instrument clear-stack zero, or the status of any cross-stack parameters.

A true calibration check is performed by removing the on-stack components and setting them up in a location with minimal ambient opacity, making sure that the proper pathlength and alignments are attained, and then placing the calibration filters in the measurement beam path.

25. Install the audit jig.

26. Adjust the audit jig iris to produce a 4 mA output current on the junction box meter (see Figure 7-4) to simulate the amount of light returned to the transceiver during clear stack conditions.

> Note: This allows the auditor to get the jig zero value near the zero value on the data recorder. The final jig zero adjustments should be based on readings from the data recorder. The jig zero does not have to be exactly 0.0% opacity since the audit filter correction equations can account for an offset in the jig zero. Thus, a jig zero value in the range of 0-2% Op is usually acceptable.

27. Record the audit filter serial numbers and opacity values on blanks 22, 23, and 24.

28. Remove the filters from their protective covers, inspect, and if necessary, clean them.

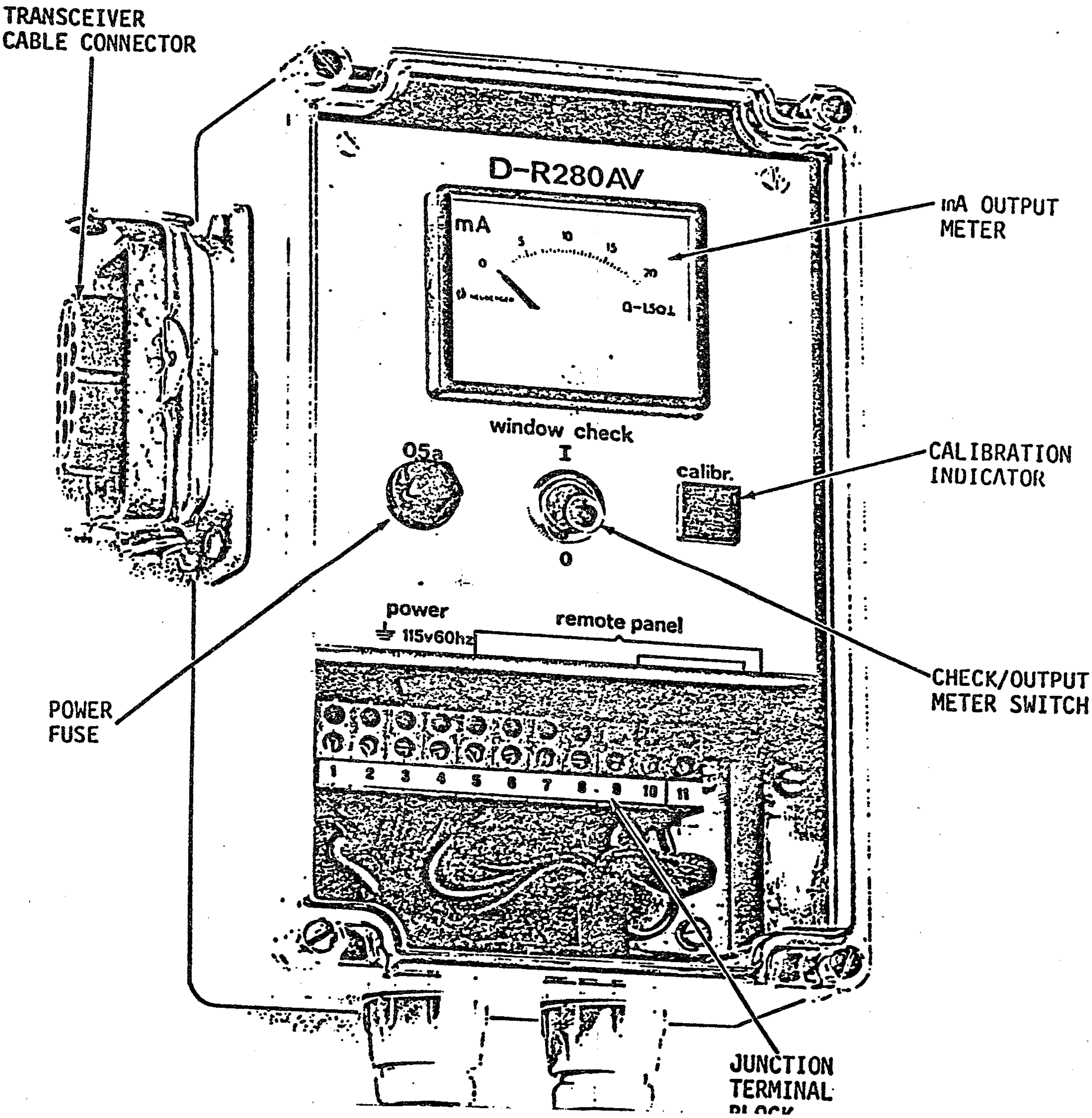


Figure 7-4. Enviroplan (Thermo Electron) Model D-R280 AV

29. Record the jig zero value from the data recorder on blank 21a.

Note: The acquisition of monitor response from the data recorder requires communication between the auditor at the transmissometer location and another person at the data recorder location.

30. Insert the low range neutral density filter into the audit jig.

31. Wait for approximately two minutes or until a clear value has been recorded and displayed on the data recorder.

Note: The audit data should be taken from a data recording/reporting device that presents instantaneous opacity (or opacity data with the shortest available integration period).

32. Record the monitor's response to the low range neutral density filter.

33. Remove the low range filter from the audit jig and insert the mid range neutral density filter.

34. Wait for approximately two minutes and record the monitor's responses.

35. Remove the mid range filter from the audit jig and insert the high range filter.

36. Wait for approximately two minutes and record the monitor's response.

37. Remove the high range filter, wait for approximately two minutes, and record the jig zero value.

Note: If the final jig zero value differs from the initial value by more than 1% opacity, the jig zero should be adjusted to agree with the initial value and the three-filter run (i.e., low, mid, and high) should be repeated.

38. Repeat steps 30-37 above until a total of five opacity readings are obtained for each neutral density filter.

39. If six-minute integrated opacity data are recorded, repeat steps 30-37 above once more, but change the waiting periods to 13 minutes.

40. Record the six-minute integrated data.

Note: In order to acquire six-minute averaged opacity data, each filter must remain in the jig for at least two consecutive six-minute periods. the first period is invalid because it was in progress when the filter was inserted. Only at he conclusion of two successive six-minute integration periods can the monitor's response be recorded.

41. Once the calibration error check is finished, remove the audit jig, and close the transceiver head and the weather cover.

Final Control Unit Adjustment Reset

42. Return to the control unit location and reset the opacity range switch to its original position (Blank 10), if necessary.

43. Obtain a copy of the audit data from the data recorder.

44. Transcribe the calibration error response data from the data recorder to data form blanks 25 to 50, and complete the audit data calculations.

7.1.3 ENVIROPLAN (THERMO ELECTRON) D-R280 AV INTERPRETATION OF AUDIT RESULTS

This section pertains to the interpretation of the performance audit analyses peculiar to the D-R280AV. The interpretation of the more general analyses is fully discussed in the introduction of this manual.

Stack Exit Correlation Error Check

The pathlength correction error on blanks 51 should be within ±2%. This error expontentially affects the opacity readings, resulting in over- or under-estimation of the stack exit opacity. The most common error in computing the optical pathlength correction factor is the use of the flange-to-flange distance rather than the stack/duct inside diameter at the monitor location. This error will result in an under-estimation of the stack exit opacity and can be identified by comparing the monitor optical pathlength to the flange-to-flange distance, which should be the greater by approximately 2-4 feet.

Control Panel Meter Error (Optional)

The accuracy of the control panel meter is important at sources using the meter during monitor adjustment and calibration. In such cases, the control panel meter opacity readings are compared to the specified values for the internal zero and span filter. Errors in the control panel meter should not affect the opacity data reported by the monitoring system unless the control panel meter is used to adjust the zero and span functions. At sources using the panel meter data, the panel meter should be adjusted so that the error is less than 2%. Since the control panel meter error is determined by using the span filter, any change in the specified values for the span filter will cause an erroneous assessment of the control panel meter errors. The span filter value may change due to aging, replacement, etc. Each time the monitor is thoroughly calibrated, the internal span filter should be renamed, and new specified values for the optical density and output current should be recorded and used in all subsequent adjustments.

Internal Zero and Span Check

The D-R280 AV internal zero should be set to indicate 0% opacity (equivalent to 3.7 - 4.3mA). A zero error greater than 4% opacity is usually due to excessive dust accumulation on the optical surfaces, electronic drift, or data recorder electronic or mechanical offset. Excessive dust on the optical surfaces sufficient to cause a significant zero error also would be indicated by the difference in the internal and external zero values. Instrument span error may be caused by the same problems that cause zero errors and may be identified in a similar fashion. Also, a span error may be caused by an inaccurate span filter value.

If the zero and span errors are due to a data recorder offset, both errors will be in the same direction and will have the same magnitude. The opacity data will be offset in the same manner.

The external zero displayed on the control unit panel meter is an indication of the dust deposition upon the zero retroreflector and transceiver measurement window, and thus, the external zero response (blank 12a), converted to percent opacity, should equal the amount of dust found on the transceiver optics (blank 57). To convert the panel meter mA response to percent opacity, use the following equation:

Meter response in % opacity = 6.25 [(Blank 12a) - (Blank 11)]

If the monitor's internal zero response (blank 11) is within the recommended range (3.7 mA to 4.3 ma mA), the accuracy to the monitor's external zero function can be checked through the use of the dust accumulation analysis results.

Transmissometer Dust Accumulation Check

The total opacity equivalent to the dust on the transmissometer optical surfaces (blank 58) should not exceed 4%. A dust accumulation value of more than 4% opacity indicates that the airflow of the purge system and/or the cleaning frequency of the optical surfaces are inadequate. When determining the optical surface dust accumulation, the auditor should note whether the effluent opacity is fairly stable (within ±2% opacity) before and after the cleaning of the optical surfaces. If the effluent opacity is fluctuating more than ±2%, the dust accumulation analysis should be omitted.

Calibration Error Check

The comparison of monitor responses to the opacity values of the neutral density filters requires that the filter values be corrected to stack exit conditions and that any zero offset be factored into the corrected filter value.

Excessive calibration error results (blanks 68, 69, and 70) are indicative of a non-linear calibration and/or a miscalibration of the monitor. However, the absolute calibration accuracy of the monitor can be determined only when the clear path zero value is known. If the zero and span are not within the proper range, the calibration check data will often be biased in the same direction as the zero and span errors. Even if the zero and span errors are within the proper ranges, the monitor may still be inaccurate due to possible error in the clear path zero. The optimum calibration procedure involves using neutral density filters during clear-stack or off-stack calibration. This procedure would establish both the absolute calibration accuracy and linearity. If this procedure is not practical, and if it is reasonable to assume that the clear path zero is indeed zero, the monitor's calibration linearity can be set using either neutral density filters or the internal zero and span values.

SECTION 8

PERFORMANCE AUDIT PROCEDURES FOR OPACITY CEMS WITH COMBINERS

The audit procedures described in the previous sections of this manual presume that the opacity CEMS includes only a single transmissometer which is installed to view the total emissions from a source. However, at many sources, the CEMS includes multiple transmissometers which are installed to view separate effluent streams that are subsequently combined and released to the atmosphere through a common stack. This situation is encountered frequently in the electric utility industry where the boiler effluent is divided evenly, routed through twin preheaters, twin ESPs, twin I.D. fans, and subsequently recombined in a single exhaust stack. At many such sources, transmissometers are installed in each duct to facilitate use of the monitoring data for control equipment evaluation and to provide convenient access to transmissometers for maintenance and quality assurance activities.

Opacity CEMS's with multiple transmissometers include analog or digital devices that automatically determine the equivalent stack-exit opacity for the entire effluent stream based on the individual duct opacity measurements provided by the transmissometers. These devices are typically referred to as "combiners." The combiner device may a separate device or may incorporate some or all of the functions normally associated with the monitor control unit.

Performance audits of opacity CEMS's with combiners necessitate the use of modified audit procedures. However, these procedures rely heavily on the monitor-specific procedures detailed in Sections 3 through 7 of this manual. This Section describes a generic approach for conducting audits of opacity CEMS's with combiners. The approach requires that the auditor evaluate (1) the ability of each transmissometer to provide accurate and precise effluent opacity measurements at their respective monitoring locations, and (2) the accuracy of the stack-exit opacity values recorded by the CEMS. To accomplish this, the auditor must first conduct evaluations of each of the individual transmissometers using standard audit procedures with minor procedural modifications to accomodate equipment differences between combiner and single transmissometer monitoring systems. After the audits of the individual transmissometers are completed, the accuracy of the combiner system is determined using either a one-point or a multi-point audit technique, depending on the type of monitoring system.

8.1 CALCULATION OF STACK-EXIT OPACITY FOR COMBINER SYSTEMS

Both the single-point and multi-point audit techniques require the calculation of "correct" or "expected" stack-exit opacity values as a function of the opacity at each monitoring location. The appropriate equations for calculating the stack-exit opacity values depend on source-specific conditions. Therefore, several equations ranging from the most general approach to commonly applicable simplifications are presented below. The auditor must select the form of equation which is appropriate for the particular situation. It is recognized that the various methods for calculating the stack-exit opacity involve some assumptions which are not necessarily accurate under all conditions. However, the calculation method that is selected should be consistent with the design and implementation of the opacity monitoring program at the facility which is being audited.

The general relationship between multiple duct mounted transmissometer measurements and stack-exit opacity values is most conveniently expressed in units of optical density. (Conversions between opacity and optical density values will be discussed later.) The relationship is based on conservation of mass and an assumed linear relationship between the optical density and the mass concentration of the aerosol. The relationship for double-pass transmissometers is described by Equation (8-1):

$$V_E A_E K_E \frac{OD_E}{L_E} = \sum_{i=1}^{N} V_i A_i K_i \frac{OD_i}{2L_i} \qquad (8\text{-}1)$$

where:

V = average velocity at measured location or stack-exit
A = cross-sectional area at measurement location or stack-exit
K = idealized constant relating optical density to mass concentration
OD = optical density (single pass)

subscripts:
L = measurement pathlength (e.g., internal duct dimension or stack exit internal diameter)
E = stack-exit location
i = transmissometer locations; 1,2...N

In practice, the value of the idealized constant "K" cannot be determined, a function of particle size distribution and other aerosol characteristics. Therefore, it is generally assumed that for any instant in time, the aerosol characteristics are constant between the monitoring locations and the stack, and are the same for all monitoring locations (i.e., $K_E = K_1 = K_2 = K_N$). Thus, this factor is eliminated from the general equation.

Additional simplifications of the general equation are usually apparent where the duct monitoring locations are geometrically similar. This is most often the case where twin ducts/monitoring locations are simply mirror images of each other. For the case of two monitoring locations with identical duct cross sections (i.e., $L_1 = L_2 = L$ and $A_1 = A_2 = A$). The general equation becomes:

$$OD_E = \frac{A}{2L} \frac{L_E}{V_E A_E} (V_1 OD_1 + V_2 OD_2) \qquad (8\text{-}2)$$

For most multiple-transmissometer/combiner applications, incompressible flow may reasonably be assumed (i.e., constant temperature, pressure, and quality) between the various measurement and stack-exit locations). Assuming incompressible flow and that there is no significant air inleakage, bypass flow, etc., then continuity requires:

$$V_E A_E = A\,(V_1 + V_2) \tag{8-3}$$

Thus:

$$OD_E = \frac{L_E}{2L}\,\frac{\left(V_1 OD_1 + V_2 OD_2\right)}{\left(V_1 + V_2\right)} \tag{8-4}$$

In most cases, measurement of the velocity or volumetric flow rate at the transmissometer installation locations is not attempted. If the flow rates can be assumed to be equal in both ducts (i.e., $V_1 = V_2$), Equation (8-4) can be simplified to the most commonly used form:

$$OD_E = \frac{L_E}{2L}\,\frac{\left(OD_1 + OD_2\right)}{2} \tag{8-5}$$

A filter inserted in the light path at the monitoring location attenuates the light beam twice in a double pass transmissometer; thus:

$$OD_N = 2\,OD_{FN} \tag{8-6}$$

where:

OD_{FN} = single pass optical density of the filter inserted at the N monitoring location

Thus:

$$OD_E = \frac{L_E}{2L}\,(OD_{F1} + OD_{F2}) \tag{8-7}$$

For Lear Siegler monitors, the factor $L_E/2L$ is referred to as the "OPLR,", and for Dynatron monitors this same term is referred to as the "M factor." For TECO monitors (formally Contraves-Goerz monitors), the term L_E/L is referred to as the "STR." These terms are useful for modifying the above equations to be consistent with the manufacturer's technology.

Equations (8-2), (8-4), and (8-5) may be used to calculate the optical density at the stack-exit based on the optical density seen by the multiple transmissometers under the conditions described above. Equation (8-7) may be used to calculate the optical density at the stack-exit based on the single pass optical density values of calibration attenuators inserted into the transmissometer light beams under the specified conditions. Many other combinations and arrangements of the above equations are possible. In any case, the form of the equation which is selected should provide for calculation of the equivalent optical density at the stack-exit as a function of the optical density at each monitoring location. The optical density values may be easily converted to units of opacity as follows:

$$Opacity_E = 1 - 10^{-OD_E} \qquad (8-8)$$

Conversely, if the opacity values at the monitoring location are known, the optical density values can be calculated as follows:

$$OD_E = -\log_{10}(1-Opacity_E) \qquad (8-9)$$

The calculated stack-exit opacity values can be compared to the actual CEMS responses as described in the single- and multi-point checks described in Section 8.2.

8.2 GENERAL AUDIT PROCEDURES

8.2.1 Audit Procedures for Individual Duct Transmissometers

Performance audits of each duct-mounted transmissometer must be conducted using the standard audit procedures for single transmissometer opacity CEMS's. These audits are straightforward if each transmissometer is provided with a separate control unit and data recording device. However, if the control unit or data recording device is time shared between several transmissometers, or if the control unit functions are incorporated into the combiner unit, some modifications to the standard audit procedures may be necessary in order to isolate the individual monitors and obtain access to the appropriate signals and responses. The auditor may need to refer to the operator's manual or seek assistance from source personnel familiar with the opacity CEMS to obtain the necessary data.

As an example of the above considerations, the applicable procedural modifications for the Lear Siegler Model 622 Emission Monitor Combiner and two RM 41 duct-mounted transmissometers are described here. However, the reader is cautioned that these procedures are not necessarily applicable to other opacity CEMS with combiners. The analog combiner also serves as the control unit for both transmissometers and contains several features not included on the typical RM 41 control unit. The two most important are:

(a) the analyzer switch - located on the front panel, this switch allows selection of measurements from: analyzer #1, analyzer #2, or "stack-exit" values, and

(b) the out-of-service switch - located inside the combiner control unit on the upper right hand side of the card rack, this switch allows either the A or B side monitors to be taken out of service. The remaining monitor will function normally.

In order for the measurements necessary for the audit to be obtained, the above switches must be positioned correctly. The most important considerations are as follow:

- Fault Lamps - With the analyzer switch in the "exit" position, any fault condition existing for either monitor should result in the illumination of the appropriate fault lamp. The fault lamp will flash when the analyzer switch is positioned for the monitor causing the problem.

- Measurements of reference current, zero compensation, or input current are obtained by placing the measurement select switch in the proper position (same procedure as used for single RM41 applications). The analyzer switch must be placed in the position corresponding to the individual monitor for which these measurements are desired. Measurements of test functions (e.g., reference current, zero compensation, or input current) are not meaningful if the analyzer switch is left in the "exit" position.

- In order for stack-exit opacity measurements to be obtained from the panel meter, the analyzer switch must be placed in the "exit" position. To obtain the combined stack-exit opacity, both the A- and B-side monitors must remain in service. To obtain the stack-exit opacity for either the A- or B-side monitors independently, the alternate monitor must be removed from service. When either monitor is removed from service, the information recorded on the strip chart represents the independent stack-exit opacity for the monitor remaining in service.

For all opacity CEMS's with combiners, the zero and span errors (and the opacity scale factor, if applicable) can usually be determined for either transmissometer independently or for the combined measurement system. Source personnel will usually evaluate the day to day operation of the CEMS by observing the combined system calibration, and will check the calibration of each monitor individually when excessive drift and/or other problems are indicated. Although a check of the zero and span errors for each transmissometer provides the best information for comparison with the calibration error test results, the results of a combined system calibration provide an adequate assessment of performance when the total zero or span drift is small. It is extremely unlikely that a major zero or span shift in one monitor would be completely offset by an opposite and equal shift in the other monitor. Thus, it is very unlikely that a correct value for the combined system calibration would disguise problems with either or both monitors. It is recommended that the auditor (1) perform the zero and span error determinations for the combined system, and (2) perform additional zero and span error checks for each transmissometer when the errors observed for the combined system calibration exceed $\pm$ 1% opacity.

8.2.2 Audit Procedures for Combiner Stack-Exit Opacity Values

After evaluating the performance of each of the individual transmissometers, the auditor must evaluate the accuracy of the combiner stack-exit opacity values. Two approaches are described below: the single-point check and the multi-point check methods. For computerized data acquisition systems, the single-point check is sufficient to detect programming errors. The single-point check may also be used for "screening checks" of analog systems; if problems are indicated, a multi-point check can be performed. The multi-point check should be used to evaluate the performance of analog combiner systems over the full range of operating conditions.

(1) Single-Point Check - The single-point check is the simplest method of checking the operations of the combiner device. The procedure requires only that the auditor (1) determine the outputs of all of the duct-mounted transmissometers for any convenient time period (e.g., simultaneous instantaneous measurements or six-minute averages); (2) calculate the "expected" stack-exit opacity values using the appropriate equations in Section 8.1; and (3) compare the expected values to the opacity values indicated by the CEMS permanent data recorder. The combiner responses and expected values should agree within ± 3 percent opacity. (If periods with varying opacity levels are available, the single-point check procedure may be repeated to provide a multi-point evaluation of the combiner operation.)

(2) Multi-Point Check - For an opacity CEMS with two duct-mounted transmissometers, the multi-point check requires the use of two audit devices and two sets of audit filters. Additional audit devices and filter sets are needed if the opacity CEMS includes more than two transmissometers; however, the multi-point check method becomes overly cumbersome in such situations. In order to conduct the test in a practical manner, the assistance of several people is necessary. Typically, one person at each monitoring location and one person at the combiner location are needed.

The multi-point check procedure involves: (1) installation of audit devices on both transceivers, (2) adjustment of the audit device irises to obtain the correct zero response for each monitor independently, (3) placing various combinations of audit filters in the two monitors to simulate varying opacity levels at the two monitoring locations, (4) calculation of the "expected" stack exit opacity for each combination of filters using the equations in Section 8.1 above, and (5) comparing the calculated "expected" values to the actual combined stack exit opacity values provided by the opacity CEMS. An example of the data and results of such an audit is shown in Table 8-1. As shown in Table 8-1, a multi-point check of a combiner with two transmissometers involves 16 sets of measurements since zero, low-, mid-, and high-range filters are used at each monitoring location. Therefore, it is important that instantaneous or 1-minute averages of the combiner responses be obtained for the multi-point check. Again, the combiner responses and the corresponding expected values should agree within ± 3 percent opacity.

SECTION 9

ZERO ALIGNMENT CHECKS

The zero alignment of an opacity CEMS is the relationship of the opacity CEMS response to the clear path condition (i.e., zero opacity) relative to its response to the simulated zero condition (or low range calibration check) used for the daily zero/span checks of the CEMS calibration. The zero alignment is important because the accuracy of the CEMS calibration is based directly on this relationship. The zero alignment cannot normally be verified during a performance audit. Therefore, the calibration error check included in the audit assumes that the response to the simulated zero condition is accurate.

Generic procedures for conducting zero alignment checks are described in this Section because of the importance of this factor. However, because of practical constraints and the amount of time required to perform the zero alignment, this check is not included as a performance audit procedure. Several approaches for conducting zero alignment checks are presented in the following subsections.

9.1 OFF-STACK ZERO ALIGNMENT

Performance Specification 1 of 40 CFR 60 requires that an off-stack zero alignment be performed prior to installing the transmissometer at the monitoring location. The procedures for conducting this check are described briefly in "7.1.1, Equipment Preparation." In short, the procedures require that the transmitter and receiver (single pass systems) or transceiver and reflector (double pass systems) be set up in a laboratory or other opacity-free environment at the same separation distance as when the same components are installed at the monitoring location. It is emphasized that the separation distance is the flange-to-flange distance or the actual distance between optical components, rather than the duct or stack internal diameter at the monitoring location. After establishing the proper separation distance, the optical alignment is optimized, the pathlength correction factor is set, and necessary zero and span adjustments are made to assure proper calibration of the system. Following the successful completion of these steps, the zero alignment is performed by balancing the response of the CEMS so that the simulated zero check coincides with the actual clear path check performed across the temporary monitor pathlength.

The off-stack zero alignment check can be repeated after the CEMS has been installed and operating for some time; however, this approach is inherently very cumbersome and time consuming. Typically, the transceiver must be electrically disconnected and both the transceiver and reflector components must be transported to a clean environment. In order to evaluate the entire system, the control unit and data recording device must also be removed and transported to the test location. Substitute signal and power cables, as well as test stands, must be fabricated or obtained to allow the various components to be electrically reconnected and set-up at the test location. Reasonable precautions must be taken to ensure that ambient dust levels and other potential interferents are minimized at the test location while the tests are performed.

After the off-stack zero alignment is completed, each of the opacity CEMS components must be electrically disconnected, transported to its normal location, mechanically reinstalled, and electrically reconnected. The optical alignment of the transceiver and reflector components must also be reestablished or at least verified to complete the procedure. All of the above activities must be performed with extraordinary care in order to ensure that the off-stack zero alignment procedure provides a reasonable assurance of accuracy. Nevertheless, there is always a chance that transporting the transceiver to the monitoring location and/or reinstallation activities will adversely impact the accuracy of the zero alignment procedure. Many source personnel believe that the likelihood of such problems are much greater than the likelihood that the zero alignment has shifted, and are therefore extremely hesitant to attempt off-stack zero alignment checks.

9.2 ON-STACK ZERO ALIGNMENT

Performance Specification 1 recognizes the difficulties and problems associated with the off-stack zero alignment approach; "7.2.1, Optical and Zero Alignment" requires that the optical alignment and the zero alignment performed prior to installation be verified and adjusted, if necessary, when the facility is not operating and "clear stack" conditions exist. If the facility is operating at the time when the opacity CEMS is installed, Performance Specification 1 requires that the zero alignment be verified the first time a clear stack condition is obtained after the operational test period is completed.

The on-stack zero alignment approach avoids virtually all of the problems associated with the off-stack procedure. However, the on-stack procedure requires that clear stack conditions be present in order to accomplish the zero alignment procedure. Two major problems are commonly encountered. First, some sources, such as major base-loaded electric utility steam generating units, operate nearly continuously with very infrequent outages. These units may operate continuously except for emergency outages and a one or two week annual maintenance outage per year. For such units, the maintenance and repair activities that must be performed for the boiler and control equipment during the infrequent outages require substantial overtime work by the same personnel who typically service and calibrate the monitoring equipment. Therefore, it is unlikely that the zero alignment of the opacity CEMS can be performed at such sources. The problem is further complicated where there are several generating units served by a common exhaust stack with a single opacity monitor since it is less likely that all units will be off-line simultaneously.

The second problem associated with the on-stack zero alignment procedure relates to the presence of residual opacity when the source is not operating. At many sources, clear stack conditions do not occur at the monitoring location when the facility is not in operation. Residual opacity may exist because of (1) boiler, air heater, ESP, or duct maintenance being conducted with the fans running at a low rate to protect personnel, (2) fan operation or natural draft conditions resulting in aspirated material remaining in the ducts, stack, or control equipment for long periods after the facility is off-line, or (3) rain or other precipitation entering the stack. For many sources, residual effluent opacities are greater than the opacity observed during operation since the control equipment is not operated during unit outages.

The presence of residual opacity during an on-stack zero alignment check will result in the simulated zero device being set at the level of the residual opacity rather than at the zero opacity level. For most opacity CEMS's, this error will bias all subsequent opacity measurements low by the amount of the residual opacity. Therefore, it is fundamentally important to determine if residual opacity is present before performing an on-stack zero alignment check. Performance Specification 1 recommends that the instantaneous output of the opacity CEMS be examined to determine whether fluctuations from zero opacity are occurring before a clear path condition is assumed to exist. Visible emission observations should also be performed to detect residual opacity; however, it should be kept in mind that effluent opacities of less than 5 percent are nearly impossible for the human observer to detect. The on-stack zero alignment procedures should not be performed during periods of precipitation for stack-mounted transmissometers.

Finally, if an on-stack zero alignment is performed, the optical alignment should be checked and all optical surfaces should be cleaned before adjusting the simulated zero level. After the zero alignment procedure is completed and the facility is again operating, the optical alignment should be rechecked since thermal expansion is likely to affect the optical alignment.

9.3 ALTERNATE ZERO ALIGNMENT APPROACHES

Alternate approaches for conducting zero alignment checks are available for some opacity CEMS. The applicability of these procedures depends on certain monitor- and source-specific constraints.

For certain TECO monitors (DIGI 1400, formally manufactured by Environmental Data Corporation) that combine the opacity CEMS with the SO_2, NO_x, and CO_2 monitoring channels and which also include a "zero-pipe," the zero alignment procedure is quite simple. For these systems, the zero-pipe can be closed so that the flow of effluent through the slotted tube is obstructed and the measurement path is filled with filtered air from the purge air system. Thus, each time the zero pipe is closed, the zero alignment can be checked and adjusted, if necessary, under clear path conditions.

Another simple approach is often available for other opacity CEMS's which allow access for cleaning of the transceiver and reflector windows through a hinged support system. Monitors which utilize this design include LSI Models RM-4 and RM-41, TECO Model 400 (formally manufactured by Contraves Goerz), and Enviroplan Model 280 AV (formally distributed by TECO). For many applications of these types of opacity CEMS's, zero alignment checks can be performed at the monitoring location without electrically disconnecting the transceiver. The following basic procedures are followed where this approach is applicable.

(1) The transceiver is opened as if to clean the optical window.

(2) The reflector is opened and removed from its hinges; the optical alignment adjustment bolts must not be disturbed.

(3) All external optical surfaces of the transceiver and reflector components are thoroughly cleaned.

(4) The reflector is mounted on the test stand at the appropriate separation distance from the transceiver, as shown in Figure 9-1. (This is most easily accomplished by use of a zero alignment jig which maintains the correct separation distance and prevents interference from ambient dust or precipitation. It is most often convenient to orient the measurement path tangent to the outside of the stack or duct.)

(5) Correct optical alignment is established and verified through direct observation of the light beam on the reflector surface and by means of the transmissometer optical alignment sight.

(6) If necessary, appropriate adjustments are made to establish the accuracy of the transmissometer calibration in accordance with the manufacturer's instructions.

(7) The zero alignment is checked and adjusted, if necessary, in accordance with the procedures specified by the manufacturer.

(8) The reflector is reinstalled on its hinges and both the reflector and transceiver are closed and returned to normal operation. The optical alignment must be rechecked and adjusted, if necessary.

Because of the design features which allow for cleaning of the transceiver and reflector optics without requiring alignment adjustments, the above procedures can usually be accomplished rather quickly. The procedure avoids the problems associated with both the off-stack and on-stack zero alignment procedures. However, problems in maintaining the exact separation distance and optical alignment during the zero alignment check can be encountered due to spatial constraints, physical limitations, and the presence of extreme vibration at the monitoring location. In some cases, spatial limitations can be overcome by removing the transceiver from its hinges to allow greater freedom in orienting the light path in a convenient direction. For example, the alternate zero alignment approach can sometimes be used for opacity CEMS's installed in the annular space between the stack liner and stack shell by orienting the light path vertically, parallel to the access ladder, and positioning the reflector at a different elevation.

Great care must be used to avoid contamination of the optical surfaces and damage to the transmissometer components if the alternate approach is used. In addition, adequate measures to establish the exact separation distance and optical alignment must be used. Because of the risk of damage to the opacity CEMS and personal safety considerations, it is recommended that the alternate zero alignment technique be performed only by experienced and qualified personnel.

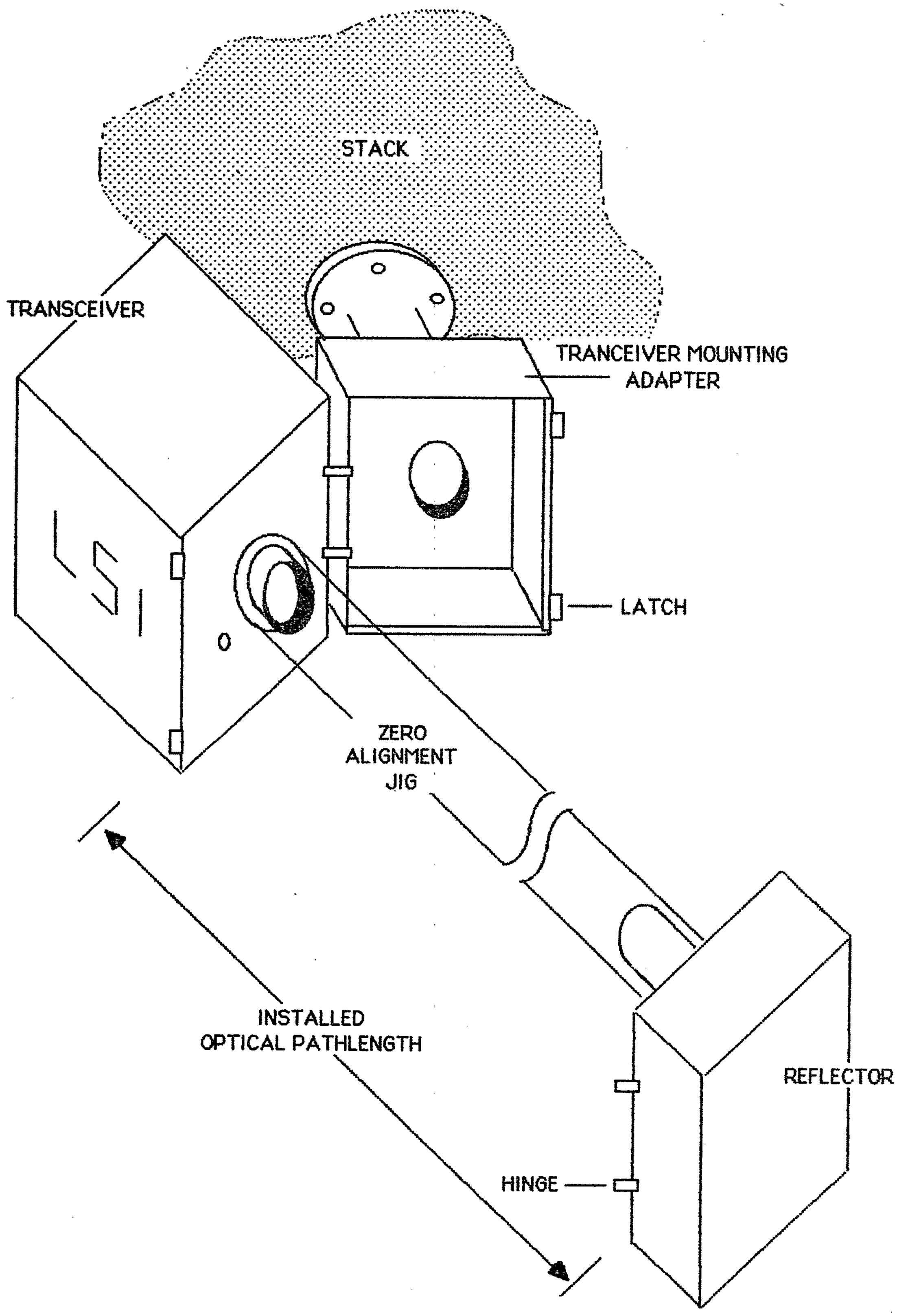


FIGURE 9.1 ZERO ALIGNMENT JIG.

APPENDIX A.

LEAR SIEGLER, INC. MODEL RM-41 AUDIT DATA FORMS

AUDIT DATA SHEET
LSI RM-41 TRANSMISSOMETER AND MODEL 611 CONTROL UNIT

SOURCE IDENTIFICATION: ____________ CORPORATION: ____________

PROCESS UNIT/STACK IDENTIFICATION: ____________ PLANT/SITE: ____________

AUDITOR: ____________ REPRESENTING: ____________

ATTENDEES: ____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

DATE: ____________

PRELIMINARY DATA

1 Stack exit inside diameter (FT) = L_x = ____________

2 [Stack (or duct) inside diameter (or width) at transmissometer location (FT)]*2 = L_t ____________

3 Calculated OPLR = L_x / L_t = ____________

4 Source-cited OPLR value ____________

5 Source-cited zero automatic calibration values (% opacity) ____________

6 Source-cited span automatic calibration value (% opacity) ____________

[GO TO DATA RECORDER LOCATION]

[INSPECT DATA RECORDING SYSTEM AND MARK WITH "OPACITY AUDIT," AUDITOR'S NAME, DATE, SOURCE, PROCESS UNIT/STACK IDENTIFICATION, AND THE TIME OF DAY.]

[GO TO CONTROL UNIT LOCATION]

FAULT LAMP INSPECTION

		ON	OFF
7	FILTER [status of purge air blowers]		
8	SHUTTER [status of protective shutters]		
9	REF [AGC fault and/or excessive reference signal error]		
10	WINDOW [excessive zero compensation]		
11	OVER RANGE [exceeding optical density range setting]		

CONTROL UNIT ADJUSTMENT CHECKS [TO BE DONE ONLY BY QUALIFIED PERSONNEL]

[OPEN CONTROL UNIT AND PULL POWER FUSE]
[PULL CAL TIMER BOARD]

12 CAL timer board S1 switch position ____________
[Turn CAL timer board S1 switch to sixth (6th) position, if necessary, and reinstall board.]
[Pull OPTICAL DENSITY board]

13 OPTICAL DENSITY board S1 switch position ____________
[Turn OPTICAL DENSITY board S1 switch to fifth (5th) position, if necessary, and reinstall board.]
[Pull OPACITY board.]

14 OPACITY Board S1 switch position ____________
[Turn OPACITY board S1 to fifth (5th) position, if necessary.]
[Optional OPLR check: Measure the resistance in OHMs of the "R_6" potentiometer on the OPACITY board, and divide by 400 to get the internally set OPLR value.]

14a R_6 ____________ (OHMs) / 400 = (Optional) ____________
[If R_6 value is not measured, then enter the value from (BLANK 4) in (BLANK 14a).]
[Reinstall the OPACITY board.]
[Reinstall fuse and close control unit.]

15 Original position of "MEASUREMENT" switch ____________

AUDIT DATA SHEET
LSI RM-41 TRANSMISSOMETER AND MODEL 611 CONTROL UNIT
(Continued)

REFERENCE SIGNAL CHECK

[TURN "MEASUREMENT" SWITCH TO "REFERENCE" POSITION AND TAP PANEL METER FACE]

[READ REFERENCE SIGNAL CURRENT VALUE ON 0-30 mA SCALE]

16 Reference signal current value (mA) ____________________
[Turn "MEASUREMENT" switch to "100% Op" position.]

ZERO CHECK

[PRESS THE "OPERATE/CAL" SWITCH]

[TAP THE PANEL METER AND READ THE ZERO CALIBRATION VALUE FROM THE 0-100% Op SCALE.]

17 Panel Meter zero calibration value (% Op) ____________________

18 Opacity data recorder zero calibration value (% Op) ____________________

ZERO COMPENSATION CHECK (INITIAL)

[TURN THE "MEASUREMENT" SWITCH TO THE "COMP" POSITION.]

[TAP THE PANEL METER AND READ THE ZERO COMPENSATION VALUE ON THE -0.02 TO +0.05 O.D. SCALE.]

19 Panel meter zero compensation value (O.D.) ____________________

SPAN CHECK

[PRESS THE "ZERO/SPAN" SWITCH AND TURN THE "MEASUREMENT" SWITCH TO THE "100% Op" POSITION.]

[TAP THE PANEL METER FACE AND READ THE SPAN CALIBRATION VALUE FROM THE 0-100% Op SCALE.]

20 Panel meter span calibration value (% Op) ____________________

21 Opacity data recorder span calibration value (% Op) ____________________

[OPTIONAL CHECK: Turn the "MEASUREMENT" switch to the "INPUT position and read the input current from the panel meter 0-30 mA scale.]

21a Panel meter input current value (mA) (Optional) ____________________
[Turn the "MEASUREMENT" switch back to the "100% OPACITY" position.]

[PRESS THE "OPERATE/CAL" SWITCH.]

[GO TO TRANSMISSOMETER LOCATION.]

RETROREFLECTOR DUST ACCUMULATION CHECK

[GET EFFLUENT OPACITY READING FROM OPACITY DATA RECORDER.]

22 Pre-cleaning effluent opacity (% Op) ____________________
[Open retroreflector, inspect and clean retroreflector optical surface, and close retroreflector.]

23 Post-cleaning effluent opacity (% Op) ____________________
[Go to transceiver location.]

AUDIT DATA SHEET
LSI RM-41 TRANSMISSOMETER AND MODEL 611 CONTROL UNIT
(Continued)

TRANSCEIVER DUST ACCUMULATION CHECK

[GET EFFLUENT OPACITY READING FROM OPACITY DATA RECORDER]

24 Pre-cleaning effluent opacity (% Op) ______________
[Open transceiver,inspect and clean primary lens,inspect and clean zero mirror, and close transceiver.]

25 Post-cleaning effluent opacity (% Op) ______________
[At control unit, press "OPERATE/CAL" switch, turn "MEASUREMENT" switch to "COMP" position, tap meter face, and read zero compensation value from the -0.02 to +0.05 O.D. scale.]

26 Post-cleaning zero compensation value (O.D.) ______________
[At control unit, press "OPERATE/CAL" switch and turn "MEASUREMENT" switch to "100% Op" position.]

AGC CHECK

27 AGC lamp status

ON	OFF

OPTICAL ALIGNMENT CHECK

[REMOVE COVER FROM TRANSCEIVER MODE SWITCH AND TURN SWITCH ONE POSITION COUNTER-CLOCKWISE TO "ALIGN" POSITION.]

[LOOK INTO VIEWING PORT WITH ICON OF HUMAN EYE ABOVE AND OBSERVE POSITION OF BEAM IMAGE WITH RESPECT TO BLACK CIRCLE.]

28 Image centered?

YES	NO

[DRAW LOCATION OF BEAM IMAGE.]
[TURN THE TRANSCEIVER MODE SWITCH CLOCKWISE UNTIL OPERATE APPEARS IN THE WINDOW. REPLACE THE MODE SWITCH PROTECTIVE COVER.]

SPAN FILTER DATA CHECK

[READ SPAN FILTER OPTICAL DENSITY AND OUTPUT CURRENT FROM THE UNDERSIDE OF THE TRANSCEIVER.]

29 Span filter optical density (O.D.) ______________

30 Span filter output current (mA) ______________

CALIBRATION ERROR CHECK

[OPEN THE TRANSCEIVER AND THE J-BOX.]

[INSTALL THE AUDIT JIG ON THE TRANSCEIVER PROJECTION LENS AND ADJUST THE JIG ZERO UNTIL THE J-BOX METER READS BETWEEN 19 AND 20 mA, AND A VALUE BETWEEN 0% AND 2% OPACITY IS READ ON THE OPACITY DATA RECORDER.]

[RECORD AUDIT FILTER DATA.]

	FILTER	SERIAL NO.	% OPACITY
31	LOW		
32	MID		
33	HIGH		

AUDIT DATA SHEET
LSI RM-41 TRANSMISSOMETER AND MODEL 611 CONTROL UNIT
(Continued)

[REMOVE AUDIT FILTERS FROM PROTECTIVE COVERS, INSPECT, AND CLEAN.]

[INSERT EACH FILTER IN THE JIG, WAIT APPROXIMATELY 2 MINUTES PER FILTER FOR A CLEAR RESPONSE, AND RECORD OPACTIY VALUE REPORTED FROM OPACITY DATA RECORDER.]

[REPEAT ABOVE PROCESS FIVE TIMES.]

[IF JIG ZERO VALUES CHANGE BY MORE THAN 1.0% OPACITY BETWEEN THREE (3) FILTER RUNS, READJUST JIG ZERO TO ORIGINAL VALUE AND REPEAT RUN.]

ZERO	LOW	MID	HIGH	ZERO
________	________	________	________	________
	________	________	________	________
	________	________	________	________
	________	________	________	________
	________	________	________	________

[IF SIX-MINUTE INTEGRATED DATA ARE AVAILABLE, THEN ALLOW 13 MINUTES EACH FOR AN ADDITIONAL RUN OF THE ZERO, LOW, MID, HIGH, AND ZERO READINGS IN ORDER TO CHECK SIX-MINUTE AVERAGED CALIBRATION ERROR.]

ZERO	LOW	MID	HIGH	ZERO
________	________	________	________	________

[REMOVE AUDIT JIG AND CLOSE TRANSCEIVER.]

[RETURN TO CONTROL UNIT LOCATION.]

ZERO COMPENSATION CHECK (FINAL)

[PRESS "OPERATE/CAL" SWITCH, TURN "MEASUREMENT" SWITCH TO "COMP" POSITION, AND READ ZERO COMPENSATION VALUE FROM THE -0.02 TO +0.05 O.D. SCALE.]

34 Final zero compensation value (O.D.) ____________________
[Press "OPERATE/CAl" switch .]

CONTROL UNIT ADJUSTMENT RESET (TO BE DONE ONLY BY QUALIFIED PERSONNEL)

[OPEN CONTROL UNIT AND PULL POWER FUSE.]

[IF NECESSARY, PULL THE FOLLOWING CIRCUIT BOARDS AND RESET THE S1 SWITCHES TO THE POSITIONS INDICATED IN THE CORRESPONDING BLANKS.]

BOARD	BLANK NO.
Cal Timer	12
Optical Density	13
Opacity	14

[REINSTALL THE POWER FUSE AND CLOSE THE CONTROL UNIT.]

[TURN THE "MEASUREMENT" SWITCH TO THE POSITION RECORDED IN (BLANK 15).]

[GET A COPY OF THE AUDIT DATA FROM THE OPACITY DATA RECORDER AND ENSURE THAT THE DATA CAN BE CLEARLY READ AND INTERPRETED.]

AUDIT DATA SHEET
LSI RM-41 TRANSMISSOMETER AND MODEL 611 CONTROL UNIT
(Continued)

[READ AND TRANSCRIBE FINAL CALIBRATION ERROR DATA.]

ZERO	LOW	MID	HIGH	ZERO
_____ 35	_____ 36	_____ 37	_____ 38	_____ 39
	_____ 40	_____ 41	_____ 42	_____ 43
	_____ 44	_____ 45	_____ 46	_____ 47
	_____ 48	_____ 49	_____ 50	_____ 51
	_____ 52	_____ 53	_____ 54	_____ 55

[SIX-MINUTE AVERAGE DATA, IF APPLICABLE.]

_____ 56	_____ 57	_____ 58	_____ 59	_____ 60

CALCULATION OF AUDIT RESULTS

STACK EXIT CORRELATION ERROR (%):

61 Source cited $\left[\frac{\text{(BLANK 4)} - \text{(BLANK3)}}{\text{(BLANK 3)}}\right] \times 100 =$ ____________

62 Measured $\left[\frac{\text{(BLANK 14a)} - \text{(BLANK 3)}}{\text{(Blank 3)}}\right] \times 100 =$ (OPTIONAL) ____________

REFERENCE SIGNAL ERROR (%):

63 $\left[\frac{\text{(Blank 16)}}{20} - 1\right] \times 100 =$ ____________

ZERO ERROR (% Op):

64 Panel meter (BLANK 17) - (BLANK 5) = ____________

65 Opacity data recorder (BLANK 18) - (BLANK 5) = ____________

SPAN ERROR (% Op):

66 Panel Meter $\text{(BLANK 20)} - \left[\left[1 - \left[10^{-\left[\text{(BLANK14a)} \times \text{(BLANK 29)}\right]}\right]\right] \times 100\right] =$ ____________

67 Opacity Data Recorder $\text{(BLANK 21)} - \left[\left[1 - \left[10^{-\left[\text{(BLANK14a)} \times \text{(BLANK 29)}\right]}\right]\right] \times 100\right] =$ ____________

67a Input Error $\left[\frac{\text{(Blank 21a)} - \text{(Blank 30)}}{\text{(Blank 30)}}\right] \times 100 =$ (OPTIONAL) ____________

AUDIT DATA SHEET
LSI RM-41 TRANSMISSOMETER AND MODEL 611 CONTROL UNIT
(Continued)

ZERO COMPENSATION (O.D.):

68 Initial ____________ (BLANK 19) = ____________

69 Post-cleaning ____________ (BLANK 26) = ____________

70 Final ____________ (BLANK 34) = ____________

OPTICAL SURFACE DUST ACCUMULATION (% Op):

71 Retroreflector: ____________ (BLANK 22) − ____________ (BLANK 23) = ____________

72 Transceiver: ____________ (BLANK 24) − ____________ (BLANK 25) = ____________

73 Total: ____________ (BLANK 71) + ____________ (BLANK 72) = ____________

OPLR AND ZERO OFFSET CORRECTION OF AUDIT FILTERS (%OP):

74 Low: $$\left[1 - \left[\left[1 - \frac{\text{(BLANK 31)}}{100}\right]^{2 \times \text{(BLANK 14a)}} \times \left[1 - \frac{\text{(BLANK 55)}}{100}\right]\right]\right] \times 100 = \_\_\_\_\_\_\_\_$$

75 Mid: $$\left[1 - \left[\left[1 - \frac{\text{(BLANK 32)}}{100}\right]^{2 \times \text{(BLANK 14a)}} \times \left[1 - \frac{\text{(BLANK 55)}}{100}\right]\right]\right] \times 100 = \_\_\_\_\_\_\_\_$$

76 High: $$\left[1 - \left[\left[1 - \frac{\text{(BLANK 33)}}{100}\right]^{2 \times \text{(BLANK 14a)}} \times \left[1 - \frac{\text{(BLANK 55)}}{100}\right]\right]\right] \times 100 = \_\_\_\_\_\_\_\_$$

CALIBRATION ERROR CALCULATION

n	LOW-RANGE DIFFERENCE	Δ_L	Δ_L^2	ITEM NO.	MID-RANGE DIFFERENCE	Δ_M	Δ_M^2	ITEM NO.	HIGH RANGE DIFFERENCE	Δ_H	Δ_H^2
1	(BLANK 36) - (BLANK 74) =	____	____		(BLANK 37) - (BLANK 75) =	____	____		(BLANK 38) - (BLANK 76) =	____	____
2	(BLANK 40) - (BLANK 74) =	____	____		(BLANK 41) - (BLANK 75) =	____	____		(BLANK 42) - (BLANK 76) =	____	____
3	(BLANK 44) - (BLANK 74) =	____	____		(BLANK 45) - (BLANK 75) =	____	____		(BLANK 46) - (BLANK 76) =	____	____
4	(BLANK 48) - (BLANK 74) =	____	____		(BLANK 49) - (BLANK 75) =	____	____		(BLANK 50) - (BLANK 76) =	____	____
5	(BLANK 52) - (BLANK 74) =	____	____		(BLANK 53) - (BLANK 75) =	____	____		(BLANK 54) - (BLANK 76) =	____	____

$\Sigma\Delta_L$ = ____ $\Sigma\Delta_L^2$ = ____

$\Sigma\Delta_M$ = ____ $\Sigma\Delta_M^2$ = ____

$\Sigma\Delta_H$ = ____ $\Sigma\Delta_H^2$ = ____

LOW-RANGE MEAN ERROR = $\overline{ME}_L$

$\overline{ME}_L = \frac{\Sigma\Delta_L}{n} = \frac{(\_\_\_\_\_\_)}{(\_\_\_\_\_\_)}$

77 $\overline{ME}_L$ = ____

MID-RANGE MEAN ERROR = $\overline{ME}_M$

$\overline{ME}_M = \frac{\Sigma\Delta_M}{n} = \frac{(\_\_\_\_\_\_)}{(\_\_\_\_\_\_)}$

78 $\overline{ME}_M$ = ____

HIGH RANGE MEAN ERROR = $\overline{ME}_H$

$\overline{ME}_H = \frac{\Sigma\Delta_H}{n} = \frac{(\_\_\_\_\_\_)}{(\_\_\_\_\_\_)}$

79 $\overline{ME}_H$ = ____

LOW-RANGE CONFIDENCE INTERVAL = CI_L

$CI_L = ((n \times \Sigma\Delta_L^2) - (\Sigma\Delta_L)^2)^{0.5} \times 0.2776$

$CI_L = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

80 CI_L = ____

MID-RANGE CONFIDENCE INTERVAL = CI_M

$CI_M = ((n \times \Sigma\Delta_M^2) - (\Sigma\Delta_M)^2)^{0.5} \times 0.2776$

$CI_M = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

81 CI_M = ____

HIGH-RANGE CONFIDENCE INTERVAL = CI_H

$CI_H = ((n \times \Sigma\Delta_H^2) - (\Sigma\Delta_H)^2)^{0.5} \times 0.2776$

$CI_H = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

82 CI_H = ____

LOW-RANGE CALIBRATION ERROR = CE_L

$CE_L = |\overline{ME}_L| + CI_L$

$CE_L = |\_\_\_\_| + (\_\_\_\_)$

83 CE_L = ____

MID-RANGE CALIBRATION ERROR = CE_M

$CE_M = |\overline{ME}_M| + CI_M$

$CE_M = |\_\_\_\_| + (\_\_\_\_)$

84 CE_M = ____

HIGH-RANGE CALIBRATION ERROR = CE_H

$CE_H = |\overline{ME}_H| + CI_H$

$CE_H = |\_\_\_\_| + (\_\_\_\_)$

85 CE_H = ____

SIX-MINUTE AVERAGED ERROR

$E(6)_L$ = (BLANK 57) - (BLANK 74)

86 $E(6)_L$ = ____

$E(6)_M$ = (BLANK 58) - (BLANK 75)

87 $E(6)_M$ = ____

$E(6)_H$ = (BLANK 59) - (BLANK 76)

88 $E(6)_H$ = ____

LEAR SIEGLER MODEL RM-41 TRANSMISSOMETER AND
MODEL 611 CONTROL UNIT
OPACITY CEMS PERFORMANCE AUDIT REPORT
DATA SUMMARY

AUDITOR ______________________ DATE ______________________

SOURCE ______________________ UNIT ______________________

RESULTS CHECKED BY ______________________ DATE ______________________

PARAMETER		BLANK NO.	AUDIT RESULT	SPECIFICATION
FAULT LAMPS				
FILTER		7		OFF
SHUTTER		8		OFF
REFERENCE		9		OFF
WINDOW		10		OFF
OVER RANGE		11		OFF
AGC CIRCUIT STATUS		27		ON
STACK EXIT	CITED	61		± 2%
CORRELATION ERROR	MEASURED	62		± 2%
REFERENCE SIGNAL ANALYSIS		63		± 10%
INTERNAL ZERO ERROR	PANEL METER	64		± 4%Op
	DATA RECORDER	65		± 4%Op
INTERNAL SPAN ERROR	PANEL METER	66		± 4% Op
	DATA RECORDER	67		± 4%Op
INPUT ERROR (OPTIONAL)		67		1.00 ± 0.02
MONITOR ALIGNMENT ANALYSIS		28		CENTERED
INITIAL ZERO COMPENSATION		68		± 0.018 OD
POST-CLEANING ZERO COMPENSATION		69		± 0.018 OD
FINAL ZERO COMPENSATION		70		± 0.018 OD
OPTICAL SURFACE DUST ACCUMULATION				
RETROREFLECTOR		71		≤ 2% Op
TRANSCEIVER		72		≤ 2% Op
TOTAL		73		≤ 4% Op
CALIBRATION ERROR ANALYSIS				
MEAN ERROR				
LOW		77		
		86 [a]		
MID		78		
		87 [a]		
HIGH		79		
		88 [a]		
CONFIDENCE INTERVAL				
LOW		80		
MID		81		
HIGH		82		
CALIBRATION ERROR				
LOW		83		≤ 3% Op
MID		84		≤ 3% Op
HIGH		85		≤ 3% Op

[a] ERROR BASED ON SIX-MINUTE AVERAGED DATA, FROM A SINGLE FILTER INSERTION.

APPENDIX B.

LEAR SIEGLER, INC. MODEL RM-4 AUDIT DATA FORMS

AUDIT DATA SHEET
LSI RM-4 TRANSMISSOMETER

SOURCE IDENTIFICATION: ____________ CORPORATION: ____________

PROCESS UNIT/STACK IDENTIFICATION: ____________ PLANT/SITE: ____________

AUDITOR: ____________ REPRESENTING: ____________

ATTENDEES: ____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

DATE: ____________

PRELIMINARY DATA

1 Stack exit inside diameter (FT) = L_x = ____________

2 [Stack (or duct) inside diameter (or width) at transmissometer location (FT)] x2 = L_t = ____________

3 Calculated OPLR = L_x / L_t = ____________

4 Source-cited OPLR value ____________

5 Source-cited zero automatic calibration values (% opacity) ____________

6 Source-cited span automatic calibration value (% opacity) ____________

[GO TO CONVERTER CONTROL UNIT/DATA RECORDER LOCATION]

[INSPECT DATA RECORDING SYSTEM AND MARK WITH "OPACITY AUDIT," AUDITOR'S NAME, DATE, SOURCE, PROCESS UNIT/STACK IDENTIFICATION, AND THE TIME OF DAY.]

FAULT LAMP INSPECTION

	ON	OFF
7 FAULT [low AGC current]		
8 OVER RANGE [exceeding optical density range setting]		

CONTROL UNIT ADJUSTMENT CHECK

9 Original position of "Measurement Switch" ____________

ZERO CHECK

[TURN THE "MEASUREMENT" SWITCH TO THE "20% OPACITY" POSITION]

[TURN THE "MODE" SWITCH TO THE "ZERO" POSITION]

10 Panel Meter zero calibration value (0-20 mA scale) ____________

11 Opacity data recorder zero calibration value (%Op) ____________

SPAN CHECK

[TURN THE "MEASUREMENT" SWITCH TO THE "100% OPACITY" POSITION]

[TURN THE "MODE" SWITCH TO THE "CALIBRATE" POSITION]

12 Panel Meter span calibration value (%Op) ____________

13 Opacity data recorder span calibration value (%Op) ____________

[OPTIONAL CHECK: Turn the "MEASUREMENT" SWITCH to the "OPACITY INPUT" position and read the input current from the panel meter 0-20 mA scale.]

14 Panel meter input current value (mA) (Optional) ____________

[TURN THE "MEASUREMENT" SWITCH BACK TO THE "100% OPACITY" POSITION.]

[TURN THE "MODE" SWITCH TO THE "OPERATE" POSITION AND GO TO THE TRANSMISSOMETER LOCATION.]

AUDIT DATA SHEET
LSI RM-4 TRANSMISSOMETER
(Continued)

RETROREFLECTOR DUST ACCUMULATION CHECK

[GET EFFLUENT OPACITY READINGS FROM THE OPACITY DATA RECORDER.]

15 Pre-cleaning effluent opacity (%Op) ______________
[Open retroreflector, inspect and clean retroreflector optical surface, and close retroreflector.]

16 Post-cleaning effluent opacity (%Op) ______________

[GO TO TRANSCEIVER LOCATION]

TRANSCEIVER DUST ACCUMULATION CHECK

17 Pre-cleaning effluent opacity (% Op)
[Open transceiver, inspect and clean primary lens, clean zero mirror, and close transceiver.] ______________

18 Post-cleaning effluent opacity (% Op) ______________

[OPEN THE TRANSCEIVER CONTROL PANEL]

FAULT/TEST CHECK

[PRESS AND HOLD THE "FAULT/TEST" BUTTON AND READ THE TRANSCEIVER METER CURRENT VALUE ON THE 0-20 mA SCALE]

19 Fault/test current value (mA) ______________

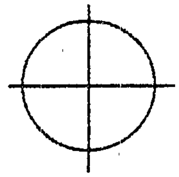
OPTICAL ALIGNMENT CHECK

[LOOK INTO VIEWING PORT ON THE RIGHT SIDE OF THE TRANSCEIVER AND OBSERVE POSITION OF BEAM IMAGE WITH RESPECT TO TARGET CIRCLE]

20 Image centered?

YES	NO

[DRAW LOCATION OF BEAM IMAGE.]



SPAN FILTER DATA CHECK

[READ SPAN FILTER OPTICAL DENSITY FROM THE BOTTOM OF THE TRANSCEIVER CONTROL PANEL]

21 Span filter optical density (O.D) ______________

CALIBRATION ERROR CHECK

[INSTALL THE AUDIT JIG ON THE TRANSCEIVER PROJECTION LENS AND ADJUST THE JIG ZERO UNTIL THE TRANSCEIVER METER READS APPROXIMATELY 2.0 mA AND A VALUE BETWEEN 0% AND 2% OPACITY IS READ ON THE OPACITY DATA RECORDER.]

[RECORD AUDIT FILTER DATA]

	FILTER	SERIAL NO.	% OPACITY
22	LOW	______________	______________
23	MID	______________	______________
24	HIGH	______________	______________

AUDIT DATA SHEET
LSI RM-4 TRANSMISSOMETER
(Continued)

[REMOVE AUDIT FILTERS FROM PROTECTIVE COVERS, INSPECT, AND CLEAN.]

[INSERT EACH FILTER IN THE JIG, WAIT APPROXIMATELY TWO MINUTES, AND RECORD OPACITY VALUES REPORTED FROM OPACITY DATA RECORDER.]

[IF JIG ZERO VALUES CHANGE BY MORE THAN 1.0% OPACITY BETWEEN ANY FILTER RUN, READJUST THE JIG ZERO TO ORIGINAL VALUE AND REPEAT THE RUN.]

ZERO	LOW	MID	HIGH	ZERO
______	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______

[IF SIX-MINUTE INTEGRATED DATA ARE ALSO AVAILABLE, THEN ALLOW 13 MINUTES EACH FOR AN ADDITIONAL RUN OF THE ZERO. LOW. MID. HIGH. AND ZERO READINGS.]

ZERO	LOW	MID	HIGH	ZERO
______	______	______	______	______

[REMOVE AUDIT JIG AND CLOSE TRANSCEIVER.]

[RETURN TO CONVERTER CONTROL UNIT LOCATION.]

ZERO MILLIAMP CHECK **(OPTIONAL)**

[TURN THE MODE SWITCH TO ZERO AND THE "MEASUREMENT" SWITCH TO "20% OPACITY" AND RECORD THE ZERO MILLIAMP VALUE.]

25 Final zero current value, ma (OPTIONAL) ______________

[TURN THE "MODE" SWITCH TO "OPERATE" AND THE "MEASUREMENT" SWITCH TO THE POSITION RECORDED ON BLANK 9.]

[GET A COPY OF THE AUDIT DATA FROM THE OPACITY DATA RECORDER AND ENSURE THAT THE DATA CAN BE READ AND INTERPRETED.]

[READ AND TRANSCRIBE FINAL CALIBRATION ERROR DATA.]

ZERO	LOW	MID	HIGH	ZERO
----- 26	----- 27	----- 28	----- 29	----- 30
	----- 31	----- 32	----- 33	----- 34
	----- 35	----- 36	----- 37	----- 38
	----- 39	----- 40	----- 41	----- 42
	----- 43	----- 44	----- 45	----- 46

[SIX-MINUTE AVERAGE DATA, IF APPLICABLE.]

----- 47	----- 48	----- 49	----- 50	----- 51

AUDIT DATA SHEET
LSI RM-4 TRANSMISSOMETER
(Continued)

CALCULATION OF AUDIT RESULTS

STACK EXIT CORRELATION ERROR (%):

52 Source cited $\left[\dfrac{\text{(BLANK 4)} - \text{(BLANK3)}}{\text{(BLANK 3)}}\right] \times 100 =$ ______________

ZERO ERROR (% Op):

53 Panel meter $\text{(BLANK 10)} - \text{(BLANK 5)} =$ ______________

54 Opacity data recorder $\text{(BLANK 11)} - \text{(BLANK 5)} =$ ______________

SPAN ERROR (% Op):

55 Panel Meter $\text{(BLANK 12)} - \left[\left[1 - \left[10^{-\left[\text{(BLANK 4)} \times \text{(BLANK 21)}\right]}\right]\right] \times 100\right] =$ ______________

56 Opacity data recorder $\text{(BLANK 13)} - \left[\left[1 - \left[10^{-\left[\text{(BLANK 4)} \times \text{(BLANK 21)}\right]}\right]\right] \times 100\right] =$ ______________

57 Final zero mA (optional) $\text{(BLANK 25)} - \text{(BLANK 5)} =$ ______________

OPTICAL SURFACE DUST ACCUMULATION (% Op):

58 Retroreflector: $\text{(BLANK 15)} - \text{(BLANK 16)} =$ ______________

59 Transceiver: $\text{(BLANK 17)} - \text{(BLANK 18)} =$ ______________

60 Total: $\text{(BLANK 58)} + \text{(BLANK 59)} =$ ______________

OPLR AND ZERO OFFSET CORRECTION OF AUDIT FILTERS:

61 Low: $\left[1 - \left[\left[1 - \dfrac{\text{(BLANK 22)}}{100}\right]^{2\,\text{(BLANK 4)}} \times \left[1 - \dfrac{\text{(BLANK 46)}}{100}\right]\right]\right] \times 100 =$ ______________

62 Mid: $\left[1 - \left[\left[1 - \dfrac{\text{(BLANK 23)}}{100}\right]^{2\,\text{(BLANK 4)}} \times \left[1 - \dfrac{\text{(BLANK 46)}}{100}\right]\right]\right] \times 100 =$ ______________

63 High: $\left[1 - \left[\left[1 - \dfrac{\text{(BLANK 24)}}{100}\right]^{2\,\text{(BLANK 4)}} \times \left[1 - \dfrac{\text{(BLANK 46)}}{100}\right]\right]\right] \times 100 =$ ______________

CALIBRATION ERROR CALCULATIONS

Low-Range

ITEM NO.	LOW-RANGE DIFFERENCE		Δ_L	Δ_L^2
1	------- (BLANK 27)	- ------- (BLANK 61) =	______	______
2	------- (BLANK 31)	- ------- (BLANK 61) =	______	______
3	------- (BLANK 35)	- ------- (BLANK 61) =	______	______
4	------- (BLANK 39)	- ------- (BLANK61) =	______	______
5	------- (BLANK 43)	- ------- (BLANK 61) =	______	______

$\Sigma\Delta_L$ = ______ $\Sigma\Delta_L^2$ = ______

MEAN ERROR = $\overline{ME}_L$

$\overline{ME}_L = \frac{\Sigma\Delta_L}{n} = \frac{(\text{------})}{(\text{------})}$

64 $\overline{ME}_L$ = ______

CONFIDENCE INTERVAL = CI_L

$CI_L = ((n \times \Sigma\Delta_L^2) - (\Sigma\Delta_L)^2)^{0.5} \times 0.2776$

$CI_L = ((\_\_\_ \times \_\_\_) - (\_\_\_)^2)^{0.5} \times 0.2776$

67 CI_L = ______

CALIBRATION ERROR = CE_L

$CE_L = |\overline{ME}_L| + CI_L$

$CE_L = |\_\_\_| + (\_\_\_)$

70 CE_L = ______

$E(6)_L$ = ------- (BLANK 48) - ------- (BLANK 61)

73 $E(6)_L$ = ______

Mid-Range

ITEM NO.	MID-RANGE DIFFERENCE		Δ_M	Δ_M^2
	------- (BLANK28)	- ------- (BLANK 62) =	______	______
	------- (BLANK 32)	- ------- (BLANK 62) =	______	______
	------- (BLANK 36)	- ------- (BLANK 62) =	______	______
	------- (BLANK 40)	- ------- (BLANK 62) =	______	______
	------- (BLANK 44)	- ------- (BLANK 62) =	______	______

$\Sigma\Delta_M$ = ______ $\Sigma\Delta_M^2$ = ______

MEAN ERROR = $\overline{ME}_M$

$\overline{ME}_M = \frac{\Sigma\Delta_M}{n} = \frac{(\text{------})}{(\text{------})}$

65 $\overline{ME}_M$ = ______

CONFIDENCE INTERVAL = CI_M

$CI_M = ((n \times \Sigma\Delta_M^2) - (\Sigma\Delta_M)^2)^{0.5} \times 0.2776$

$CI_M = ((\_\_\_ \times \_\_\_) - (\_\_\_)^2)^{0.5} \times 0.2776$

68 CI_M = ______

CALIBRATION ERROR = CE_M

$CE_M = |\overline{ME}_M| + CI_M$

$CE_M = |\_\_\_| + (\_\_\_)$

71 CE_M = ______

SIX-MINUTE AVERAGED ERROR

$E(6)_M$ = ------- (BLANK 49) - ------- (BLANK 62)

74 $E(6)_M$ = ______

High Range

ITEM NO.	HIGH RANGE DIFFERENCE		Δ_H	Δ_H^2
	------- (BLANK 29)	- ------- (BLANK 63) =	______	______
	------- (BLANK 33)	- ------- (BLANK 63) =	______	______
	------- (BLANK 37)	- ------- (BLANK 63) =	______	______
	------- (BLANK 41)	- ------- (BLANK 63) =	______	______
	------- (BLANK 45)	- ------- (BLANK 63) =	______	______

$\Sigma\Delta_H$ = ______ $\Sigma\Delta_H^2$ = ______

MEAN ERROR = $\overline{ME}_H$

$\overline{ME}_H = \frac{\Sigma\Delta_H}{n} = \frac{(\text{------})}{(\text{------})}$

66 $\overline{ME}_H$ = ______

CONFIDENCE INTERVAL = CI_H

$CI_H = ((n \times \Sigma\Delta_H^2) - (\Sigma\Delta_H)^2)^{0.5} \times 0.2776$

$CI_H = ((\_\_\_ \times \_\_\_) - (\_\_\_)^2)^{0.5} \times 0.2776$

69 CI_H = ______

CALIBRATION ERROR = CE_H

$CE_H = |\overline{ME}_H| + CI_H$

$CE_H = |\_\_\_| + (\_\_\_)$

72 CE_H = ______

$E(6)_H$ = ------- (BLANK 50) - ------- (BLANK 63)

75 $E(6)_H$ = ______

LEAR SIEGLER MODEL RM-4 TRANSMISSOMETER
OPACITY CEMS PERFORMANCE AUDIT REPORT
DATA SUMMARY

AUDITOR ______________________ DATE ______________________

SOURCE ______________________ UNIT ______________________

RESULTS CHECKED BY: ______________________ DATE ______________________

PARAMETER		BLANK NO.	AUDIT RESULT	SPECIFICATION
FAULT LAMPS				
FAULT		7		OFF
OVER RANGE		8		OFF
STACK EXIT CORELATION ERROR		52		± 2%
INTERNAL ZERO ERROR	PANEL METER	53		± 4% Op
	DATA RECORDER	54		± 4% Op
INTERNAL SPAN EROR	PANEL METER	55		± 4% Op
	DATA RECORDER	56		± 4% Op
ZERO MILLIAMP ERROR (OPTIONAL)		57		± 2 mA
POST-CLEANING ZERO		25		± 2 mA
MONITOR ALIGNMENT		20		CENTERED
OPTICAL SURFACE DUST ACCUMULATION				
RETROREFLECTOR		58		≤ 2% Op
TRANSCEIVER		59		≤ 2% Op
TOTAL		60		≤ 4% Op
CALIBRATION ERROR ANALYSIS				
MEAN ERROR				
LOW		64		
		73[a]		
MID		65		
		74[a]		
HIGH		66		
		75[a]		
CONFIDENCE INTERVAL				
LOW		67		
MID		68		
HIGH		69		
CALIBRATION ERROR				
LOW		70		≤ 3% Op
MID		71		≤ 3% Op
HIGH		72		≤ 3% Op

[a] ERROR BASED ON SIX-MINUTE AVERAGED DATA FROM A SINGLE FILTER INSERTION.

APPENDIX C.

DYNATRON MODEL 1100 AUDIT DATA FORMS

AUDIT DATA SHEET
DYNATRON MODEL 1100 TRANSMISSOMETER

SOURCE IDENTIFICATION: ______________ CORPORATION ______________

PROCESS UNIT/STACK IDENTIFICATION: ______________ PLANT/SITE ______________

AUDITOR: ______________ REPRESENTING: ______________

ATTENDEES: ______________ REPRESENTING: ______________

______________ REPRESENTING: ______________

______________ REPRESENTING: ______________

______________ REPRESENTING: ______________

DATE: ______________

PRELIMINARY DATA

1 Stack exit inside diameter (FT) = L_x ______________

2 [Stack (or duct) inside diameter (or width) at transmissometer location (FT)]*2 = L_t ______________

3 Calculated "M" Factor = L_x / L_t ______________

4 Source-cited "M" Factor value ______________

5 Source-cited zero automatic calibration values (% opacity) ______________

6 Source-cited span automatic calibration value (% opacity) ______________

[GO TO CONTROL UNIT DATA RECORDER LOCATION]

[INSPECT DATA RECORDING SYSTEM AND MARK WITH "OPACITY AUDIT," AUDITOR'S NAME, DATE, SOURCE, PROCESS UNIT/STACK IDENTIFICATION, AND THE TIME OF DAY.]

FAULT LAMP CHECKS

	ON	OFF
7 LAMP [insufficient measurement lamp output]		
8 WINDOW [excessive dust on transceiver optics]		
9 AIR FLOW [insufficient purge air flow]		

CONTROL UNIT CHECKS

10 Automatic calibration time (cycle time) knob position
[Turn CYCLE TIME knob to "MANUAL" position.] ______________

11 Meter display knob position
[Turn METER DISPLAY knob to "OPACITY" postion, if necessary.] ______________

ZERO CHECK

(PRESS ZERO/SPAN SWITCH)

12 Panel Meter zero calibration value (% Op) ______________

13 Opacity data recorder zero calibration value (% Op) ______________

AUDIT DATA SHEET
DYNATRON MODEL 1100 TRANSMISSOMETER
(Continued)

SPAN CHECK

14 Panel meter span calibration value (% Op) ____________________

15 Opacity data recorder span calibration value (% Op) ____________________

[GO TO TRANSMISSOMETER LOCATION.]

RETROREFLECTOR DUST ACCUMULATION CHECK

[GET EFFLUENT OPACITY READINGS FROM THE OPACITY DATA RECORDER.]

16 Pre-cleaning effluent opacity (% Op) ____________________
[Remove, inspect, clean, and replace protective window.]

17 Post-cleaning effluent opacity (% Op) ____________________
[Go to transceiver location.]

TRANSCEIVER DUST ACCUMULATION CHECK

18 Pre-cleaning effluent opacity (% Op) ____________________
[Remove, inspect, clean, and replace protective window.]

19 Post-cleaning effluent opacity (% Op) ____________________

OPTICAL ALIGNMENT CHECK (OPTIONAL)

[IF ALIGNMENT TUBE IS PRESENT ON TRANSCEIVER SIDE OF STACK OR DUCT, LOOK THROUGH TUBE AND OBSERVE WHETHER BEAM IMAGE IS CENTERED AROUND RETROREFLECTOR PORT.]

20 Image centered?

YES	NO

[DRAW ORIENTIATION OF RETROREFLECTOR PORT IN ALIGNMENT CIRCLE.]

CALIBRATION ERROR CHECK [JIG PROCEDURE]

[REMOVE THE DIRTY WINDOW DETECTOR PHOTOCELL. IF THE TRANSCEIVER DOES NOT HAVE A DIRTY WINDOW PHOTOCELL OR A REMOVABLE ACCESS PANEL COVER AT THAT POSITION, THEN THE INCREMENTAL CALIBRATION ERROR PROCEDURE MUST BE USED.]

[REMOVE THE TRANSCEIVER PROTECTIVE WINDOW.]

[INSTALL THE AUDIT JIG IN THE DIRTY WINDOW DETECTOR LOCATION AND ADJUST THE JIG ZERO UNTIL A VALUE BETWEEN 0% AND 2% OPACITY IS READ ON THE OPACITY DATA RECORDER.]

[INSTALL THE TRANSCEIVER PROTECTIVE WINDOW AND RECORD THE PROTECTIVE WINDOW OPACITY.]

21 Window opacity (including jig zero offset) ____________________

[REMOVE THE TRANSCEIVER PROTECTIVE WINDOW.]

[RECORD AUDIT FILTER DATA.]

	FILTER	SERIAL NO.	% OPACITY
22	LOW	____________	____________
23	MID	____________	____________
24	HIGH	____________	____________

AUDIT DATA SHEET
DYNATRON MODEL 1100 TRANSMISSOMETER
(Continued)

[REMOVE AUDIT FILTERS FROM PROTECTIVE COVERS, INSPECT, AND CLEAN.]
[INSERT EACH FILTER, WAIT APPROXIMATELY TWO MINUTES,AND RECORD OPACITY VALUES REPORTED FROM OPACITY DATA RECORDER.]
[IF JIG ZERO VALUES CHANGE BY MORE THAN 1.0% OPACITY BETWEEN THREE (3) FILTER RUNS, READJUST JIG ZERO TO ORIGINAL VALUE AND REPEAT RUN.]

ZERO	LOW	MID	HIGH	ZERO
______	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______

[IF SIX-MINUTE INTEGRATED DATA ARE ALSO AVAILABLE, THEN ALLOW 13 MINUTES EACH FOR AN ADDITIONAL RUN OF THE ZERO, LOW, MID, HIGH, AND ZERO READINGS.]

ZERO	LOW	MID	HIGH	ZERO
______	______	______	______	______

[REMOVE AUDIT JIG, REPLACE THE DIRTY WINDOW INDICATOR AND THE PROTECTIVE WINDOW, AND CLOSE THE TRANSCEIVER HOUSING.]

[RETURN TO CONTROL UNIT LOCATION.]

CONTROL UNIT ADJUSTMENT RESET

[IF NECESSARY, RESET THE CONTROL UNIT CALIBRATION TIMER AND METER DISPLAY KNOBS TO THE POSITIONS INDICATED IN THE CORRESPONDING BLANKS.]

KNOB	BLANK NO.
Automatic Calibration Timer	10
Meter Display	11

[MARK THE DATA RECORD FOR THE END OF THE AUDIT, GET A COPY OF THE AUDIT DATA FROM THE OPACITY DATA RECORDER, AND ENSURE THAT THE DATA CAN BE CLEARLY READ AND INTERPRETED.]

[READ AND TRANSCRIBE FINAL CALIBRATION ERROR DATA.]

ZERO	LOW	MID	HIGH	ZERO
----- 25	----- 26	----- 27	----- 28	----- 29
	----- 30	----- 31	----- 32	----- 33
	----- 34	----- 35	----- 36	----- 37
	----- 38	----- 39	----- 40	----- 41
	----- 42	----- 43	----- 44	----- 45

[SIX-MINUTE AVERAGE DATA, IF APPLICABLE.]

----- 46	----- 47	----- 48	----- 49	----- 50

AUDIT DATA SHEET
DYNATRON MODEL 1100 TRANSMISSOMETER
(Continued)

CALCULATION OF AUDIT RESULTS

STACK EXIT CORRELATION ERROR (%):

51 $\left[\dfrac{\text{(BLANK 4)} - \text{(BLANK 3)}}{\text{(BLANK 3)}}\right] \times 100$ = ________

ZERO ERROR (% Op):

52 Panel meter ________ (BLANK 12) - ________ (BLANK 5) = ________

53 Opacity data recorder ________ (BLANK 13) - ________ (BLANK 5) = ________

SPAN ERROR (% Op):

54 Panel Meter ________ (BLANK 14) - ________ (BLANK 6) = ________

55 Opacity Data Recorder ________ (BLANK 15) - ________ (BLANK 6) = ________

OPTICAL SURFACE DUST ACCUMULATION (% Op):

56 Retroreflector: ________ (BLANK 16) - ________ (BLANK 17) = ________

57 Transceiver: ________ (BLANK 18) - ________ (BLANK 19) = ________

58 Total: ________ (BLANK 56) + ________ (BLANK 57) = ________

"M" FACTOR AND ZERO OFFSET CORRECTION OF AUDIT FILTERS:

59 Low: $\left[1 - \left[\left[1 - \dfrac{\text{(BLANK 22)}}{100}\right]^{\frac{2\times}{\text{(BLANK 4)}}} \times \left[1 - \dfrac{\text{(BLANK 45)}}{100}\right]\right]\right] \times 100$ = ________

60 Mid: $\left[1 - \left[\left[1 - \dfrac{\text{(BLANK 23)}}{100}\right]^{\frac{2\times}{\text{(BLANK 4)}}} \times \left[1 - \dfrac{\text{(BLANK 45)}}{100}\right]\right]\right] \times 100$ = ________

61 High: $\left[1 - \left[\left[1 - \dfrac{\text{(BLANK 24)}}{100}\right]^{\frac{2\times}{\text{(BLANK 4)}}} \times \left[1 - \dfrac{\text{(BLANK 45)}}{100}\right]\right]\right] \times 100$ = ________

CALIBRATION ERROR CALCULATIONS (JIG PROCEDURE)

ITEM NO. n	LOW RANGE DIFFERENCE	Δ_L	Δ_L^2
1	-------- (BLANK 26) - -------- (BLANK 59) =	______	______
2	-------- (BLANK 30) - -------- (BLANK 59) =	______	______
3	-------- (BLANK 34) - -------- (BLANK 59) =	______	______
4	-------- (BLANK 38) - -------- (BLANK 59) =	______	______
5	-------- (BLANK 42) - -------- (BLANK 59) =	______	______

$\Sigma\Delta_L$ = ______ $\Sigma\Delta_L^2$ = ______

ITEM NO.	MID-RANGE DIFFERENCE	Δ_M	Δ_M^2
	-------- (BLANK 27) - -------- (BLANK 60) =	______	______
	-------- (BLANK 31) - -------- (BLANK 60) =	______	______
	-------- (BLANK 35) - -------- (BLANK 60) =	______	______
	-------- (BLANK 39) - -------- (BLANK 60) =	______	______
	-------- (BLANK 43) - -------- (BLANK 60) =	______	______

$\Sigma\Delta_M$ = ______ $\Sigma\Delta_M^2$ = ______

ITEM NO.	HIGH-RANGE DIFFERENCE	Δ_H	Δ_H^2
	-------- (BLANK 28) - -------- (BLANK 61) =	______	______
	-------- (BLANK 32) - -------- (BLANK 61) =	______	______
	-------- (BLANK 36) - -------- (BLANK 61) =	______	______
	-------- (BLANK 40) - -------- (BLANK 61) =	______	______
	-------- (BLANK 44) - -------- (BLANK 61) =	______	______

$\Sigma\Delta_H$ = ______ $\Sigma\Delta_H^2$ = ______

MEAN ERROR = $\overline{ME}_L$

$\overline{ME}_L = \frac{\Sigma\Delta_L}{n} = \frac{(\text{--------})}{(\text{--------})}$

62 $\overline{ME}_L$ = ______

CONFIDENCE INTERVAL = CI_L

$CI_L = ((n \times \Sigma\Delta_L^2) - (\Sigma\Delta_L)^2)^{0.5} \times 0.2776$

CI_L = ((______ x ______) - (______)^2)$^{0.5}$ x 0.2776

65 CI_L = ______

CALIBRATION ERROR = CE_L

$CE_L = |\overline{ME}_L| + CI_L$

CE_L = |______| + (______)

68 CE_L = ______

MEAN ERROR = $\overline{ME}_M$

$\overline{ME}_M = \frac{\Sigma\Delta_M}{n} = \frac{(\text{--------})}{(\text{--------})}$

63 $\overline{ME}_M$ = ______

CONFIDENCE INTERVAL = CI_M

$CI_M = ((n \times \Sigma\Delta_M^2) - (\Sigma\Delta_M)^2)^{0.5} \times 0.2776$

CI_M = ((______ x ______) - (______)^2)$^{0.5}$ x 0.2776

66 CI_M = ______

CALIBRATION ERROR = CE_M

$CE_M = |\overline{ME}_M| + CI_M$

CE_M = |______| + (______)

69 CE_M = ______

MEAN ERROR = $\overline{ME}_H$

$\overline{ME}_H = \frac{\Sigma\Delta_H}{n} = \frac{(\text{--------})}{(\text{--------})}$

64 $\overline{ME}_H$ = ______

CONFIDENCE INTERVAL = CI_H

$CI_H = ((n \times \Sigma\Delta_H^2) - (\Sigma\Delta_H)^2)^{0.5} \times 0.2776$

CI_H = ((______ x ______) - (______)^2)$^{0.5}$ x 0.2776

67 CI_H = ______

CALIBRATION ERROR = CE_H

$CE_H = |\overline{ME}_H| + CI_H$

CE_H = |______| + (______)

70 CE_H = ______

SIX-MINUTE AVERAGED ERROR

$E(6)_L$ = -------- (BLANK 47) - -------- (BLANK 59)

71 $E(6)_L$ = ______

$E(6)_M$ = -------- (BLANK 48) - -------- (BLANK 60)

72 $E(6)_M$ = ______

$E(6)_H$ = -------- (BLANK 49) - -------- (BLANK 61)

73 $E(6)_H$ = ______

DYNATRON MODEL 1100 TRANSMISSOMETER
OPACITY CEMS PERFORMANCE AUDIT REPORT
DATA SUMMARY
(JIG PROCEDURE)

AUDITOR ______________________ DATE ______________________

SOURCE ______________________ UNIT ______________________

RESULTS CHECKED BY ______________________ DATE ______________________

PARAMETER		BLANK NO.	AUDIT RESULT	SPECIFICATION
FAULT LAMPS				
LAMP		7		OFF
WINDOW		8		OFF
AIR PURGE		9		OFF
STACK EXIT CORRELATION ERROR		51		± 2%
INTERNAL ZERO ERROR	PANEL METER	52		± 4% Op
	DATA RECORDER	53		± 4% Op
INTERNAL SPAN ERROR	PANEL METER	54		± 4% Op
	DATA RECORDER	55		± 4% Op
MONITOR ALIGNMENT ANALYSIS		20		CENTERED
OPTICAL SURFACE DUST ACCUMULATION				
RETROREFLECTOR		56		≤ 2% Op
TRANSCEIVER		57		≤ 2% Op
TOTAL		58		≤ 4% Op
CALIBRATION ERROR ANALYSIS				
MEAN ERROR				
LOW		62		
		71 [a]		
MID		63		
		72 [a]		
HIGH		64		
		73 [a]		
CONFIDENCE INTERVAL				
LOW		65		
MID		66		
HIGH		67		
CALIBRATION ERROR				
LOW		68		≤ 3% Op
MID		69		≤ 3% Op
HIGH		70		≤ 3% Op

[a] ERROR BASED ON SIX-MINUTE AVERAGED DATA FROM A SINGLE FILTER INSERTION.

AUDIT DATA SHEET
DYNATRON MODEL 1100 TRANSMISSOMETER
(Continued)
INCREMENTAL CAL ERROR

CALIBRATION ERROR CHECK [INCREMENTAL PROCEDURE]

[THE INCREMENTAL CALIBRATION ERROR PROCEDURE SHOULD BE USED ONLY WHEN THE JIG PROCEDURE CANNOT BE USED, SUCH AS DURING AUDITS OF OLDER MODEL 1100 MONITORS WHICH DO NOT HAVE DIRTY WINDOW INDICATORS.]

[IF THE EFFLUENT OPACITY IS FLUCTUATING BY 2% OPACITY OR MORE, THE INCREMENTAL PROCEDURE CANNOT BE USED.]

[THE RATED OPACITY VALUES OF THE AUDIT FILTERS MUST INCLUDE AN ASSUMED NOMINAL OPACITY VALUE FOR THE TRANSCEIVER PROTECTIVE WINDOW.]

[RECORD AUDIT FILTER DATA.]

	FILTER	SERIAL NO.	% OPACITY
I-21	LOW	______	______
I-22	MID	______	______
I-23	HIGH	______	______

[REMOVE AUDIT FILTERS FROM PROTECTIVE COVERS, INSPECT, AND CLEAN.]
[RECORD THE EFFLUENT OPACITY VALUE FROM THE OPACITY DATA RECORDER.]
[REMOVE THE TRANSCEIVER PROTECTIVE WINDOW, INSERT A FILTER,WAIT APPROXIMATELY TWO MINUTES, AND RECORD THE OPACITY VALUE REPORTED FROM THE OPACITY DATA RECORDER.]
[REMOVE THE FILTER, REPLACE THE TRANSCEIVER PROTECTIVE WINDOW AND RECORD THE EFFLUENT OPACITY.]

[REPEAT THIS PROCESS FOR FIVE RUNS OF THREE FILTERS EACH.]

EFFLUENT	LOW	EFFLUENT	MID	EFFLUENT	HIGH
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______					

[IF SIX-MINUTE INTEGRATED DATA ARE ALSO AVAILABLE, THEN ALLOW 13 MINUTES EACH FOR AN ADDITIONAL RUN OF THE EFFLUENT LOW, MID, AND HIGH READINGS.]

EFFLUENT	LOW	EFFLUENT	MID	EFFLUENT	HIGH	EFFLUENT
______	______	______	______	______	______	______

[CLOSE THE TRANSCEIVER HOUSING.]
[RETURN TO CONTROL UNIT LOCATION.]

AUDIT DATA SHEET
DYNATRON MODEL 1100 TRANSMISSOMETER
(Continued)
INCREMENTAL CAL ERROR

CONTROL UNIT ADJUSTMENT RESET

[IF NECESSARY, RESET THE CONTROL UNIT CALIBRATION TIMER AND METER DISPLAY KNOBS TO THE POSITIONS INDICATED IN THE CORRESPONDING BLANKS.]

KNOB	BLANK NO.
Automatic Calibration Timer	10
Meter Display	11

[MARK THE DATA RECORD FOR THE END OF THE AUDIT, GET A COPY OF THE AUDIT DATA FROM THE OPACITY DATA RECORDER, AND ENSURE THAT THE DATA CAN BE CLEARLY READ AND INTERPRETED.]

[READ AND TRANSCRIBE FINAL CALIBRATION ERROR DATA.]

EFFLUENT	LOW	EFFLUENT	MID	EFFLUENT	HIGH
______ I-24	______ I-25	______ I-26	______ I-27	______ I-28	______ I-29
______ I-30	______ I-31	______ I-32	______ I-33	______ I-34	______ I-35
______ I-36	______ I-37	______ I-38	______ I-39	______ I-40	______ I-41
______ I-42	______ I-43	______ I-44	______ I-45	______ I-46	______ I-47
______ I-48	______ I-49	______ I-50	______ I-51	______ I-52	______ I-53
______ I-54					

SIX-MINUTE AVERAGE DATA (IF APPLICABLE)

______ I-55	______ I-56	______ I-57	______ I-58	______ I-59	______ I-60
______ I-61					

"M" FACTOR CORRECTION OF AUDIT FILTER (TRANSMITTANCE):

I-62 Low: $$\left[1 - \frac{\text{------ (BLANK I-21)}}{100}\right]^{2 \times \text{------- (BLANK 4)}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

I-63 Mid: $$\left[1 - \frac{\text{------ (BLANK I-22)}}{100}\right]^{2 \times \text{------- (BLANK 4)}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

I-64 High: $$\left[1 - \frac{\text{------ (BLANK I-23)}}{100}\right]^{2 \times \text{------- (BLANK 4)}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

EFFLUENT OPACITY CORRECTION OF AUDIT FILTERS

REPRESENTATIVE EQUATION

$$\left[1-\left[\left[1-\frac{A+B}{200}\right]\times C\right]\right]\times 100 = D$$

LOW				MID				HIGH			
A	B	C	D	A	B	C	D	A	B	C	D
------ 1-24	------ 1-26	------ 1-62	------ 1-65	------ 1-26	------ 1-28	------ 1-63	------ 1-66	------ 1-28	------ 1-30	------ 1-64	------ 1-67
------ 1-30	------ 1-32	------ 1-62	------ 1-68	------ 1-32	------ 1-34	------ 1-63	------ 1-69	------ 1-34	------ 1-36	------ 1-64	------ 1-70
------ 1-36	------ 1-38	------ 1-62	------ 1-71	------ 1-38	------ 1-40	------ 1-63	------ 1-72	------ 1-40	------ 1-42	------ 1-64	------ 1-73
------ 1-42	------ 1-44	------ 1-62	------ 1-74	------ 1-44	------ 1-46	------ 1-63	------ 1-75	------ 1-46	------ 1-48	------ 1-64	------ 1-76
------ 1-48	------ 1-50	------ 1-62	------ 1-77	------ 1-50	------ 1-52	------ 1-63	------ 1-78	------ 1-52	------ 1-54	------ 1-64	------ 1-79
------ 1-55	------ 1-57	------ 1-62	------ 1-80	------ 1-57	------ 1-59	------ 1-63	------ 1-81	------ 1-59	------ 1-61	------ 1-64	------ 1-82

CALIBRATION ERROR CALCULATIONS (INCREMENTAL PROCEDURE)

ITEM NO. n	LOW RANGE DIFFERENCE	Δ_L	Δ_L^2	ITEM NO.	MID-RANGE DIFFERENCE	Δ_M	Δ_M^2	ITEM NO.	HIGH RANGE DIFFERENCE	Δ_H	Δ_H^2
1	______ - ______ = (BLANK I-25) (BLANK I-65)	____	____		______ - ______ = (BLANK I-27) (BLANK I-66)	____	____		______ - ______ = (BLANK I-29) (BLANK I-67)	____	____
2	______ - ______ = (BLANK I-31) (BLANK I-68)	____	____		______ - ______ = (BLANK I-33) (BLANK I-69)	____	____		______ - ______ = (BLANK I-35) (BLANK I-70)	____	____
3	______ - ______ = (BLANK I-37) (BLANK I-71)	____	____		______ - ______ = (BLANK I-39) (BLANK I-72)	____	____		______ - ______ = (BLANK I-41) (BLANK I-73)	____	____
4	______ - ______ = (BLANK I-43) (BLANK I-74)	____	____		______ - ______ = (BLANK I-45) (BLANK I-75)	____	____		______ - ______ = (BLANK I-47) (BLANK I-76)	____	____
5	______ - ______ = (BLANK I-49) (BLANK I-77)	____	____		______ - ______ = (BLANK I-51) (BLANK I-78)	____	____		______ - ______ = (BLANK I-53) (BLANK I-79)	____	____
	$\Sigma\Delta_L$ =	____	$\Sigma\Delta_L^2$ = ____		$\Sigma\Delta_M$ =	____	$\Sigma\Delta_M^2$ = ____		$\Sigma\Delta_H$ =	____	$\Sigma\Delta_H^2$ = ____

MEAN ERROR = $\overline{ME}_L$

$$\overline{ME}_L = \frac{\Sigma\Delta_L}{n} = \frac{(------)}{(------)}$$

I-83 $\overline{ME}_L$ = ________

CONFIDENCE INTERVAL = CI_L

$CI_L = ((n \times \Sigma\Delta_L^2) - (\Sigma\Delta_L)^2)^{0.5} \times 0.2776$

$CI_L = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

I-86 CI_L = ________

CALIBRATION ERROR = CE_L

$CE_L = |\overline{ME}_L| + CI_L$

$CE_L = |\_\_\_\_| + (\_\_\_\_)$

I-89 CE_L = ________

MEAN ERROR = $\overline{ME}_M$

$$\overline{ME}_M = \frac{\Sigma\Delta_M}{n} = \frac{(------)}{(------)}$$

I-84 $\overline{ME}_M$ = ________

CONFIDENCE INTERVAL = CI_M

$CI_M = ((n \times \Sigma\Delta_M^2) - (\Sigma\Delta_M)^2)^{0.5} \times 0.2776$

$CI_M = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

I-87 CI_M = ________

CALIBRATION ERROR = CE_M

$CE_M = |\overline{ME}_M| + CI_M$

$CE_M = |\_\_\_\_| + (\_\_\_\_)$

I-90 CE_M = ________

MEAN ERROR = $\overline{ME}_H$

$$\overline{ME}_H = \frac{\Sigma\Delta_H}{n} = \frac{(------)}{(------)}$$

I-85 $\overline{ME}_H$ = ________

CONFIDENCE INTERVAL = CI_H

$CI_H = ((n \times \Sigma\Delta_H^2) - (\Sigma\Delta_H)^2)^{0.5} \times 0.2776$

$CI_H = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

I-88 CI_H = ________

CALIBRATION ERROR = CE_H

$CE_H = |\overline{ME}_H| + CI_H$

$CE_H = |\_\_\_\_| + (\_\_\_\_)$

I-91 CE_H = ________

SIX-MINUTE AVERAGED ERROR

$E(6)_L$ = -------- - -------- (BLANK I-56) (BLANK I-80)

I-92 $E(6)_L$ = ________

$E(6)_M$ = -------- - -------- (BLANK I-58) (BLANK I-81)

I-93 $E(6)_M$ = ________

$E(6)_H$ = -------- - -------- (BLANK I-60) (BLANK I-82)

I-94 $E(6)_H$ = ________

DYNATRON MODEL 1100 TRANSMISSOMETER
OPACITY CEMS PERFORMANCE AUDIT REPORT
DATA SUMMARY
(INCREMENTAL CAL ERROR PROCEDURE)

AUDITOR ______________________ DATE ______________________

SOURCE ______________________ UNIT ______________________

RESULTS CHECKED BY ______________________ DATE ______________________

PARAMETER		BLANK NO.	AUDIT RESULT	SPECIFICATION
FAULT LAMPS				
LAMP		7		OFF
WINDOW		8		OFF
AIR PURGE		9		OFF
STACK EXIT CORRELATION ERROR		51		± 2%
INTERNAL ZERO ERROR	PANEL METER	52		± 4%Op
	DATA RECORDER	53		± 4% Op
INTERNAL SPAN ERROR	PANEL METER	54		± 4% Op
	DATA RECORDER	55		± 4%Op
MONITOR ALIGNMENT ANALYSIS		20		CENTERED
OPTICAL SURFACE DUST ACCUMULATION				
RETROREFLECTOR		56		≤ 2% Op
TRANSCEIVER		57		≤ 2% Op
TOTAL		58		≤ 4% Op
CALIBRATION ERROR ANALYSIS				
MEAN ERROR				
LOW		I-83		
		I-92 [a]		
MID		I-84		
		I-93 [a]		
HIGH		I-85		
		I-94 [a]		
CONFIDENCE INTERVAL				
LOW		I-86		
MID		I-87		
HIGH		I-88		
CALIBRATION ERROR				
LOW		I-89		≤ 3% Op
MID		I-90		≤ 3% Op
HIGH		I-91		≤ 3% Op

[a] ERROR BASED ON SIX-MINUTE AVERAGED DATA FROM A SINGLE FILTER INSERTION.

APPENDIX D.

THERMO ELECTRON (CONTRAVES GOERZ) MODEL 400 AUDIT DATA FORMS

AUDIT DATA SHEET
THERMO ELECTRON (CONTRAVES GOERZ) MODEL 400 TRANSMISSOMETER AND MODEL 500 CONTROL UNIT

SOURCE IDENTIFICATION: ____________ CORPORATION: ____________

PROCESS UNIT/STACK IDENTIFICATION: ____________ PLANT/SITE: ____________

AUDITOR: ____________ REPRESENTING: ____________

ATTENDEES: ____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

____________ REPRESENTING: ____________

DATE: ____________

PRELIMINARY DATA

1 Stack exit inside diameter (FT) = L_x ____________

2 Stack (or duct) inside diameter (or width) at transmissometer location (FT) = L_t ____________

3 Calculated STR = L_x / L_t ____________

4 Source-cited STR value ____________

5 Source-cited zero automatic calibration values (% opacity) ____________

6 Source-cited span automatic calibration value (% opacity) ____________

[GO TO DATA RECORDER LOCATION]

[INSPECT DATA RECORDING SYSTEM AND MARK WITH "OPACITY AUDIT," AUDITOR'S NAME, DATE, SOURCE, PROCESS UNIT/STACK IDENTIFICATION, AND THE TIME OF DAY.]

[GO TO CONTROL UNIT LOCATION]

FAULT LAMP INSPECTION

	ON	OFF
7 CAL FAULT [excessive zero and/or span error]		
8 DIRTY WINDOW [excessive dirt on transceiver optics]		
9 PURGE AIR [insufficient purge air flow]		
10 STACK POWER [no power to transmissometer]		
11 LAMP FAILURE [insufficient measurement lamp intensity]		
12 ALARM [effluent opacity exceeds source-selected limit]		

ZERO CHECK

[PRESS THE "ZERO/CAL" SWITCH]

[READ THE ZERO CALIBRATION VALUE FROM THE PANEL METER AND THE DATA RECORDER]

13 Panel Meter zero calibration value (%Op) ____________

14 Opacity data recorder zero calibration value (%Op) ____________

SPAN CHECK

[PRESS THE "SPAN/CAL" SWITCH]

[READ THE SPAN CALIBRATION VALUE FROM THE PANEL METER AND THE DATA RECORDER]

15 Panel Meter span calibration value (%Op) ____________

16 Opacity data recorder span calibration value (%Op) ____________

[GO TO TRANSMISSOMETER LOCATION]

AUDIT DATA SHEET
THERMO ELECTRON (CONTRAVES GOERZ) MODEL 400 TRANSMISSOMETER AND MODEL 500 CONTROL UNIT
(Continued)

RETROREFLECTOR DUST ACCUMULATION CHECK

[GET EFFLUENT OPACITY READING FROM THE OPACITY DATA RECORDER.]

17 Pre-cleaning effluent opacity (%Op) ____________________
[Open retroreflector, inspect and clean retroreflector optical surface, and close retroreflector.]

18 Post-cleaning effluent opacity (%Op) ____________________

[GO TO TRANSCEIVER LOCATION]

TRANSCEIVER DUST ACCUMULATION CHECK

[GET EFFLUENT OPACITY READINGS]
[TURN OFF CHOPPER MOTOR SWITCH ON TRANSCEIVER CONTROL PANEL]

19 Pre-cleaning effluent opacity (% Op) ____________________
[Open transceiver, clean primary lens, close transceiver, and turn chopper motor switch on.]

20 Post-cleaning effluent opacity (% Op) ____________________

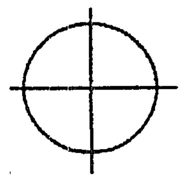
OPTICAL ALIGNMENT CHECK

[LOOK INTO VIEWING PORT ON BACK OF TRANSCEIVER AND OBSERVE POSITION OF BEAM IMAGE WITH RESPECT TO CROSS HAIRS]

21 Image centered?

YES	NO

[DRAW LOCATION OF BEAM IMAGE.]



CALIBRATION ERROR CHECK

[TURN OFF THE CHOPPER MOTOR SWITCH AND OPEN THE TRANSCEIVER]

[GET THE SOURCE'S CALIBRATION JIG AND INSTALL ON THE TRANSCEIVER]

[NOTE: MOST SOURCES HAVE A CALIBRATION DEVICE SUPPLIED BY THE MONITOR MANUFACTURER THAT IS ADJUSTED FOR THE MONITOR'S OPTICAL PATH-LENGTH. IF THIS DEVICE IS NOT AVAILABLE, THE AUDITOR MUST SUPPLY A SIMILAR DEVICE THAT CAN BE ADJUSTED TO COMPENSATE FOR THE MONITOR'S OPTICAL PATH LENGTH.]

[INSTALL THE AUDIT JIG ON THE TRANSCEIVER FACE IN FRONT OF THE PROJECTION LENS]

[RESTART THE CHOPPER MOTOR]

[RECORD AUDIT FILTER DATA.]

	FILTER	SERIAL NO.	% OPACITY
22	LOW	____________	____________
23	MID	____________	____________
24	HIGH	____________	____________

AUDIT DATA SHEET
THERMO ELECTRON (CONTRAVES GOERZ) MODEL 400 TRANSMISSOMETER AND MODEL 500 CONTROL UNIT
(Continued)

[REMOVE AUDIT FILTERS FROM PROTECTIVE COVERS, INSPECT, AND CLEAN.]

[INSERT EACH FILTER IN JIG,THEN WAIT APPROXIMATELY TWO MINUTES AND RECORD OPACITY VALUES REPORTED FROM OPACITY DATA RECORDER.]

ZERO	LOW	MID	HIGH	ZERO
______	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______

[IF SIX-MINUTE INTEGRATED DATA ARE ALSO AVAILABLE, THEN ALLOW 13 MINUTES EACH FOR AN ADDITIONAL RUN OF THE ZERO, LOW, MID, HIGH, AND ZERO READINGS.]

ZERO	LOW	MID	HIGH	ZERO
______	______	______	______	______

[TURN CHOPPER OFF, REMOVE AUDIT JIG, RESTART CHOPPER , AND CLOSE TRANSCEIVER.]

[RETURN TO CONTROL UNIT LOCATION.]

[GET A COPY OF THE AUDIT DATA FROM THE OPACITY DATA RECORDER AND ENSURE THAT THE DATA CAN BE CLEARLY READ AND INTERPRETED.]

[READ AND TRANSCRIBE FINAL CALIBRATION ERROR DATA.]

ZERO	LOW	MID	HIGH	ZERO
----- 25	----- 26	----- 27	----- 28	----- 29
	----- 30	----- 31	----- 32	----- 33
	----- 34	----- 35	----- 36	----- 37
	----- 38	----- 39	----- 40	----- 41
	----- 42	----- 43	----- 44	----- 45

[SIX-MINUTE AVERAGE DATA. IF APPLICABLE.]

----- 46	----- 47	----- 48	----- 49	----- 50

AUDIT DATA SHEET
THERMO ELECTRON (CONTRAVES GOERZ) MODEL 400 TRANSMISSOMETER
AND MODEL 500 CONTROL UNIT
(Continued)

CALCULATION OF AUDIT RESULTS

STACK EXIT CORRELATION ERROR (%):

51 $\left[\dfrac{\text{------ (BLANK 4)} - \text{------ (BLANK3)}}{\text{------ (BLANK 3)}}\right] \times 100 =$ ______________

ZERO ERROR (% Op):

52 Panel meter ______ (BLANK 13) - ______ (BLANK 5) = ______________

53 Opacity data recorder ______ (BLANK 14) - ______ (BLANK 5) = ______________

SPAN ERROR (% Op):

54 Panel Meter ______ (BLANK 15) - ______ (BLANK 6) = ______________

55 Opacity data recorder ______ (BLANK 16) - ______ (BLANK 6) = ______________

OPTICAL SURFACE DUST ACCUMULATION (% Op):

56 Retroreflector: ------- (BLANK 17) - ------ (BLANK 18) = ______________

57 Transceiver: ------- (BLANK 19) - ------- (BLANK 20) = ______________

58 Total: ------- (BLANK 56) + ------- (BLANK 57) = ______________

PATH LENGTH AND ZERO OFFSET CORRECTION OF AUDIT FILTERS:

59 Low: $\left[1 - \left[\left[1 - \dfrac{\text{------ (BLANK 22)}}{100}\right]^{\text{------- (BLANK 4)}} \times \left[1 - \dfrac{\text{------ (BLANK 45)}}{100}\right]\right]\right] \times 100 =$ ______________

60 Mid: $\left[1 - \left[\left[1 - \dfrac{\text{------ (BLANK 23)}}{100}\right]^{\text{------- (BLANK 4)}} \times \left[1 - \dfrac{\text{------ (BLANK 45)}}{100}\right]\right]\right] \times 100 =$ ______________

61 High: $\left[1 - \left[\left[1 - \dfrac{\text{------ (BLANK 24)}}{100}\right]^{\text{------- (BLANK 4)}} \times \left[1 - \dfrac{\text{------ (BLANK 45)}}{100}\right]\right]\right] \times 100 =$ ______________

CALIBRATION ERROR CALCULATIONS

n	LOW-RANGE DIFFERENCE	Δ_L	Δ_L^2	ITEM NO.	MID-RANGE DIFFERENCE	Δ_M	Δ_M^2	ITEM NO.	HIGH RANGE DIFFERENCE	Δ_H	Δ_H^2
1	------- - ------- = (BLANK 26) (BLANK 59)	______	______		------- - ------- = (BLANK27) (BLANK 60)	______	______		------- - ------- = (BLANK 28) (BLANK 61)	______	______
2	------- - ------- = (BLANK 30) (BLANK 59)	______	______		------- - ------- = (BLANK 31) (BLANK 60)	______	______		------- - ------- = (BLANK 32) (BLANK 61)	______	______
3	------- - ------- = (BLANK 34) (BLANK 59)	______	______		------- - ------- = (BLANK 35) (BLANK 60)	______	______		------- - ------- = (BLANK 36) (BLANK 61)	______	______
4	------- - ------- = (BLANK 38) (BLANK59)	______	______		------- - ------- = (BLANK 39) (BLANK 60)	______	______		------- - ------- = (BLANK 40) (BLANK 61)	______	______
5	------- - ------- = (BLANK 42) (BLANK 59)	______	______		------- - ------- = (BLANK 43) (BLANK 60)	______	______		------- - ------- = (BLANK 44) (BLANK 61)	______	______
	$\Sigma\Delta_L$ =	______	$\Sigma\Delta_L^2$ = ______		$\Sigma\Delta_M$ =	______	$\Sigma\Delta_M^2$ = ______		$\Sigma\Delta_H$ =	______	$\Sigma\Delta_H^2$ = ______

MEAN ERROR = $\overline{ME}_L$

$\overline{ME}_L = \frac{\Sigma\Delta_L}{n} = \frac{(------)}{(------)}$

62 $\overline{ME}_L$ = ______

CONFIDENCE INTERVAL = CI_L

$CI_L = ((n \times \Sigma\Delta_L^2) - (\Sigma\Delta_L)^2)^{0.5} \times 0.2776$

$CI_L = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

65 CI_L = ______

CALIBRATION ERROR = CE_L

$CE_L = |\overline{ME}_L| + CI_L$

$CE_L = |\_\_\_\_| + (\_\_\_\_)$

68 CE_L = ______

MID-RANGE MEAN ERROR = $\overline{ME}_M$

$\overline{ME}_M = \frac{\Sigma\Delta_M}{n} = \frac{(------)}{(------)}$

63 $\overline{ME}_M$ = ______

CONFIDENCE INTERVAL = CI_M

$CI_M = ((n \times \Sigma\Delta_M^2) - (\Sigma\Delta_M)^2)^{0.5} \times 0.2776$

$CI_M = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

66 CI_M = ______

CALIBRATION ERROR = CE_M

$CE_M = |\overline{ME}_M| + CI_M$

$CE_M = |\_\_\_\_| + (\_\_\_\_)$

69 CE_M = ______

HIGH-RANGE MEAN ERROR = $\overline{ME}_H$

$\overline{ME}_H = \frac{\Sigma\Delta_H}{n} = \frac{(------)}{(------)}$

64 $\overline{ME}_H$ = ______

CONFIDENCE INTERVAL = CI_H

$CI_H = ((n \times \Sigma\Delta_H^2) - (\Sigma\Delta_H)^2)^{0.5} \times 0.2776$

$CI_H = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$

67 CI_H = ______

CALIBRATION ERROR = CE_H

$CE_H = |\overline{ME}_H| + CI_H$

$CE_H = |\_\_\_\_| + (\_\_\_\_)$

70 CE_H = ______

SIX-MINUTE AVERAGED ERROR

$E(6)_L$ = ------- - ------- (BLANK 47) (BLANK 59)

71 $E(6)_L$ = ______

$E(6)_M$ = ------- - ------- (BLANK 48) (BLANK 60)

72 $E(6)_M$ = ______

$E(6)_H$ = ------- - ------- (BLANK 49) (BLANK 61)

73 $E(6)_H$ = ______

THERMO ELECTRON (CONTRAVES GOERZ) MODEL 400 TRANSMISSOMETER AND MODEL 500 CONTROL UNIT OPACITY CEMS PERFORMANCE AUDIT REPORT DATA SUMMARY

AUDITOR ______________________ DATE ______________

SOURCE ______________________ UNIT ______________

RESULTS CHECKED BY ______________________ DATE ______________

PARAMETER		BLANK NO.	AUDIT RESULT	SPECIFICATION
FAULT LAMPS				
CAL FAULT		7		OFF
DIRTY WINDOW		8		OFF
PURGE AIR		9		OFF
STACK POWER		10		OFF
LAMP FAILURE		11		OFF
ALARM		12		OFF
STACK EXIT CORRELATION ERROR		51		± 2%
INTERNAL ZERO ERROR	PANEL METER	52		± 4%Op
	DATA RECORDER	53		± 4% Op
INTERNAL SPAN ERROR	PANEL METER	54		± 4% Op
	DATA RECORDER	55		± 4%Op
MONITOR ALIGNMENT ANALYSIS		21		CENTERED
OPTICAL SURFACE DUST ACCUMULATION				
RETROREFLECTOR		56		≤ 2% Op
TRANSCEIVER		57		≤ 2% Op
TOTAL		58		≤ 4% Op
CALIBRATION ERROR ANALYSIS				
MEAN ERROR				
LOW		62		
		71 [a]		
MID		63		
		72 [a]		
HIGH		64		
		73 [a]		
CONFIDENCE INTERVAL				
LOW		65		
MID		66		
HIGH		67		
CALIBRATION ERROR				
LOW		68		≤ 3% Op
MID		69		≤ 3% Op
HIGH		70		≤ 3% Op

[a] ERROR BASED ON SIX-MINUTE AVERAGED DATA FROM A SINGLE FILTER INSERTION.

APPENDIX E.

THERMO ELECTRON (EDC) MODEL 1000A AUDIT DATA FORMS

AUDIT DATA SHEET
THERMO ELECTRON (ENVIRONMENTAL DATA CORPORATION)
MODEL 1000A TRANSMISSOMETER

SOURCE IDENTIFICATION: ________________ CORPORATION ________________

PROCESS UNIT/STACK IDENTIFICATION: ________________ PLANT/SITE ________________

AUDITOR: ________________ REPRESENTING: ________________

ATTENDEES: ________________ REPRESENTING: ________________

________________ REPRESENTING: ________________

________________ REPRESENTING: ________________

________________ REPRESENTING: ________________

DATE: ________________

PRELIMINARY DATA

1 Stack exit inside diameter (FT) = L_x ________________

2 [Stack (or duct) inside diameter (or width) at transmissometer location (FT) x 2] = L_t ________________

3 Calculated optical pathlength correction factor = L_x / L_t ________________

4 Source-cited optical pathlength correction factor ________________

5 Source-cited zero automatic calibration values (% opacity) ________________

6 Source-cited span automatic calibration value (% opacity) ________________

[GO TO DATA RECORDER LOCATION]

[INSPECT DATA RECORDING SYSTEM AND MARK WITH "OPACITY AUDIT," AUDITOR'S NAME, DATE, SOURCE, PROCESS UNIT/STACK IDENTIFICATION, AND THE TIME OF DAY.]

ZERO CHECK

[IF THE SOURCE HAS INSTALLED A "CAL-INITIATE" BUTTON NEAR THE DATA RECORDER, PRESS THIS BUTTON TO INITIATE THE ZERO/SPAN CHECK AND RECORD THE VALUES BELOW.]

[IF THE SOURCE HAS NOT INSTALLED A "CAL-INITIATE" BUTTON, TURN THE TRANSCEIVER "MODE SWITCH" TO THE "ZERO" POSITION AND WAIT THREE MINUTES.]

7 Opacity data recorder zero calibration value (%Op) ________________
[FROM "CAL-INITIATE" CHECK]

7a Opacity data recorder zero calibration value (%Op) ________________
[FROM TRANSCEIVER MODE SWITCH CHECK]

AUDIT DATA SHEET
THERMO ELECTON (ENVIROMENTAL DATA CORPORATION)
MODEL 1000A TRANSMISSOMETER
(Continued)

SPAN CHECK

[IF THERE IS NO "CAL-INITIATE" BUTTON, TURN THE TRANSCEIVER "MODE SWITCH"

TO THE "SPAN" POSITION, WAIT THREE MINUTES, OBTAIN A SPAN VALUE, AND

RETURN THE "MODE SWITCH" TO THE NORMAL OPERATING POSITION.

8 Opacity data recorder span calibration value (%Op) ____________
[FROM "CAL-INITIATE" CHECK]

9 Opacity data recorder span calibration value (% Op) ____________
[FROM TRANSCEIVER "MODE SWITCH" CHECK]

[GO TO TRANSMISSOMETER LOCATION.]

RETROREFLECTOR DUST ACCUMULATION CHECK

[GET EFFLUENT OPACITY READINGS FROM THE OPACITY DATA RECORDER.]

10 Pre-cleaning effluent opacity (% Op) ____________
[Inspect and clean optical window.]

11 Post-cleaning effluent opacity (% Op) ____________
[Go to transceiver location.]

TRANSCEIVER DUST ACCUMULATION CHECK

12 Pre-cleaning effluent opacity (% Op) ____________
[Inspect and clean optical window.]

13 Post-cleaning effluent opacity (% Op) ____________

CALIBRATION ERROR CHECK

[INSTALL THE FILTER HOLDER ASSEMBLY ON THE RETROREFLECTOR.]

[RECORD AUDIT FILTER DATA.]

	FILTER	SERIAL NO.	% OPACITY
14	LOW	____________	____________
15	MID	____________	____________
16	HIGH	____________	____________

AUDIT DATA SHEET
THERMO ELECTRON (EDC) MODEL 1000A TRANSMISSOMETER
(Continued)

[REMOVE AUDIT FILTERS FROM PROTECTIVE COVERS, INSPECT, AND CLEAN.]

[RECORD THE EFFLUENT OPACITY VALUE FROM THE OPACITY DATA RECORDER.]

[INSERT A FILTER,WAIT APPROXIMATELY TWO MINUTES, AND RECORD THE OPACITY VALUE REPORTED FROM THE OPACITY DATA RECORDER.]

[REMOVE THE FILTER AND RECORD THE EFFLUENT OPACITY.]

[REPEAT THIS PROCESS FOR FIVE RUNS OF THREE FILTERS EACH.]

EFFLUENT	LOW	EFFLUENT	MID	EFFLUENT	HIGH

[IF SIX-MINUTE INTEGRATED DATA ARE ALSO AVAILABLE, THEN ALLOW 13 MINUTES EACH FOR AN ADDITIONAL RUN OF THE EFFLUENT LOW, MID, AND HIGH READINGS.]

EFFLUENT	LOW	EFFLUENT	MID	EFFLUENT	HIGH

[CLOSE THE RETROREFLECTOR HOUSING.]

[RETURN TO CONTROL UNIT LOCATION.]

AUDIT DATA SHEET
THERMO ELECTRON (EDC) MODEL 1000A TRANSMISSOMETER
(Continued)

[READ AND TRANSCRIBE FINAL CALIBRATION ERROR DATA.]

EFFLUENT	LOW	EFFLUENT	MID	EFFLUENT	HIGH
______ 17	______ 18	______ 19	______ 20	______ 21	______ 22
______ 23	______ 24	______ 25	______ 26	______ 27	______ 28
______ 29	______ 30	______ 31	______ 32	______ 33	______ 34
______ 35	______ 36	______ 37	______ 38	______ 39	______ 40
______ 41	______ 42	______ 43	______ 44	______ 45	______ 46
______ 47					

SIX-MINUTE AVERAGE DATA (IF APPLICABLE)

______ 48	______ 49	______ 50	______ 51	______ 52	______ 53
______ 54					

CORRECTION OF AUDIT FILTER (TRANSMITTANCE):

55 Low: $\left[1 - \frac{\text{------ (BLANK 14)}}{100}\right]^{2 \times \text{------- (BLANK)}}$ = ______________

56 Mid: $\left[1 - \frac{\text{------ (BLANK 15)}}{100}\right]^{2 \times \text{------- (BLANK)}}$ = ______________

57 High: $\left[1 - \frac{\text{------ (BLANK 16)}}{100}\right]^{2 \times \text{------- (BLANK)}}$ = ______________

EFFLUENT OPACITY CORRECTION OF AUDIT FILTERS

REPRESENTATIVE EQUATION

$$\left[1-\left[\left[1-\frac{A+B}{200}\right]\times C\right]\right]\times 100 = D$$

LOW				MID				HIGH			
A	B	C	D	A	B	C	D	A	B	C	D
17	19	55	58	19	21	56	59	21	23	57	60
23	25	55	61	25	27	56	62	27	29	57	63
29	31	55	64	31	33	56	65	33	35	57	66
35	37	55	67	37	39	56	68	39	41	57	69
41	43	55	70	43	45	56	71	45	47	57	72
48	50	55	73	50	52	56	74	52	54	57	75

CALIBRATION ERROR CALCULATIONS

ITEM NO. n	LOW RANGE DIFFERENCE	Δ_L	Δ_L^2	ITEM NO.	MID-RANGE DIFFERENCE	Δ_M	Δ_M^2	ITEM NO.	HIGH RANGE DIFFERENCE	Δ_H	Δ_H^2
1	------- - ------- = (BLANK 18) (BLANK 58)	____	____		------- - ------- = (BLANK 20) (BLANK 59)	____	____		------- - ------- = (BLANK 22) (BLANK 60)	____	____
2	------- - ------- = (BLANK 24) (BLANK 61)	____	____		------- - ------- = (BLANK 26) (BLANK 62)	____	____		------- - ------- = (BLANK 28) (BLANK 63)	____	____
3	------- - ------- = (BLANK 30) (BLANK 64)	____	____		------- - ------- = (BLANK 32) (BLANK 65)	____	____		------- - ------- = (BLANK 34) (BLANK 66)	____	____
4	------- - ------- = (BLANK 36) (BLANK 67)	____	____		------- - ------- = (BLANK 38) (BLANK 68)	____	____		------- - ------- = (BLANK 40) (BLANK 69)	____	____
5	------- - ------- = (BLANK 42) (BLANK 70)	____	____		------- - ------- = (BLANK 44) (BLANK 71)	____	____		------- - ------- = (BLANK 46) (BLANK 72)	____	____

$\Sigma\Delta_L$ = ______ $\Sigma\Delta_L^2$ = ______

$\Sigma\Delta_M$ = ______ $\Sigma\Delta_M^2$ = ______

$\Sigma\Delta_H$ = ______ $\Sigma\Delta_H^2$ = ______

MEAN ERROR = $\overline{ME}_L$

$$\overline{ME}_L = \frac{\Sigma\Delta_L}{n} = \frac{(------)}{(------)}$$

76 $\overline{ME}_L$ = ______

CONFIDENCE INTERVAL = CI_L

$$CI_L = ((n \times \Sigma\Delta_L^2) - (\Sigma\Delta_L)^2)^{0.5} \times 0.2776$$

$$CI_L = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$$

79 CI_L = ______

CALIBRATION ERROR = CE_L

$$CE_L = |\overline{ME}_L| + CI_L$$

CE_L = |______| + (______)

82 CE_L = ______

MEAN ERROR = $\overline{ME}_M$

$$\overline{ME}_M = \frac{\Sigma\Delta_M}{n} = \frac{(------)}{(------)}$$

77 $\overline{ME}_M$ = ______

CONFIDENCE INTERVAL = CI_M

$$CI_M = ((n \times \Sigma\Delta_M^2) - (\Sigma\Delta_M)^2)^{0.5} \times 0.2776$$

$$CI_M = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$$

80 CI_M = ______

CALIBRATION ERROR = CE_M

$$CE_M = |\overline{ME}_M| + CI_M$$

CE_M = |______| + (______)

83 CE_M = ______

MEAN ERROR = $\overline{ME}_H$

$$\overline{ME}_H = \frac{\Sigma\Delta_H}{n} = \frac{(------)}{(------)}$$

78 $\overline{ME}_H$ = ______

CONFIDENCE INTERVAL = CI_H

$$CI_H = ((n \times \Sigma\Delta_H^2) - (\Sigma\Delta_H)^2)^{0.5} \times 0.2776$$

$$CI_H = ((\_\_\_\_ \times \_\_\_\_) - (\_\_\_\_)^2)^{0.5} \times 0.2776$$

81 CI_H = ______

CALIBRATION ERROR = CE_H

$$CE_H = |\overline{ME}_H| + CI_H$$

CE_H = |______| + (______)

84 CE_H = ______

SIX-MINUTE AVERAGED ERROR

$E(6)_L$ = -------- - -------- (BLANK 49) (BLANK 73)

85 $E(6)_L$ = ______

$E(6)_M$ = -------- - -------- (BLANK 51) (BLANK 74)

86 $E(6)_M$ = ______

$E(6)_H$ = -------- - -------- (BLANK 53) (BLANK 75)

87 $E(6)_H$ = ______

AUDIT DATA SHEET
THERMO ELECTRON (EDC) MODEL 1000A TRANSMISSOMETER
(Continued)

STACK EXIT CORRELATION ERROR (%):

88 ($\frac{\text{------ (BLANK 4)} - \text{------ (BLANK 3)}}{\text{-------- (BLANK 3)}}$) x 100 = ____________

ZERO ERROR (% Op):

89 Opacity data recorder -------- (BLANK 7 or 7a) - ------- (BLANK 5) = ____________

SPAN ERROR (% Op):

____

90 Opacity Data Recorder ------- (BLANK 8 or 9) - ------- (BLANK 6) = ____________

OPTICAL SURFACE DUST ACCUMULATION (% Op):

91 Retroreflector: ---------- (BLANK 10) - ---------- (BLANK 11) = ____________

92 Transceiver: ----------- (BLANK 12) - ---------- (BLANK 13) = ____________

93 Total: ----------- (BLANK 91) + ---------- (BLANK 92) = ____________

THERMO ELECTRON (EDC) MODEL 1000A TRANSMISSOMETER
OPACITY CEMS PERFORMANCE AUDIT REPORT
DATA SUMMARY

AUDITOR ______________________________ DATE ____________________

SOURCE ______________________________ UNIT ____________________

RESULTS CHECKED BY ______________________ DATE ____________________

PARAMETER	BLANK NO.	AUDIT RESULT	SPECIFICATION
STACK EXIT CORRELATION ERROR	88		± 2%
INTERNAL ZERO ERROR	89		± 4% Op
INTERNAL SPAN ERROR	90		± 4% Op
OPTICAL SURFACE DUST ACCUMULATION			
RETROREFLECTOR	91		≤ 2% Op
TRANSCEIVER	92		≤ 2% Op
TOTAL	93		≤ 2% Op
CALIBRATION ERROR ANALYSIS			
MEAN ERROR			
LOW	76		
	85 [a]		
MID	77		
	86 [a]		
HIGH	78		
	87 [a]		
CONFIDENCE INTERVAL			
LOW	79		
MID	80		
HIGH	81		
CALIBRATION ERROR			
LOW	82		≤ 3% Op
MID	83		≤ 3% Op
HIGH	84		≤ 3% Op

[a] ERROR BASED ON SIX-MINUTE AVERAGED DATA FROM A SINGLE FILTER INSERTION.

APPENDIX F.

ENVIROPLAN MODEL D-R280 AV "DURAG" AUDIT DATA FORMS

AUDIT DATA SHEET
ENVIROPLAN (THERMO ELECTRON) MODEL D-R280AV
(DURAG) TRANSMISSOMETER

SOURCE IDENTIFICATION: ______________ CORPORATION ______________
PROCESS UNIT/STACK IDENTIFICATION: ______________ PLANT/SITE ______________
AUDITOR: ______________ REPRESENTING: ______________
ATTENDEES: ______________ REPRESENTING: ______________
______________ REPRESENTING: ______________
______________ REPRESENTING: ______________
______________ REPRESENTING: ______________
DATE: ______________

PRELIMINARY DATA

1 Stack exit inside diameter (FT) = L_x ______________
2 Stack (or duct) inside diameter (or width) at transmissometer location (FT) = L_t ______________
3 Calculated optical pathlength correction factor = L_x / L_t ______________
4 Source-cited optical pathlength correction factor ______________
5 Source-cited zero automatic calibration values (% opacity/milliamps) ______________
6 Source-cited span automatic calibration value (% opacity/milliamps) ______________

[GO TO CONTROL UNIT DATA RECORDER LOCATION]

[INSPECT DATA RECORDING SYSTEM AND MARK WITH "OPACITY AUDIT," AUDITOR'S NAME, DATE, SOURCE, PROCESS UNIT/STACK IDENTIFICATION, AND THE TIME OF DAY.]

FAULT LAMP CHECKS

	ON	OFF
7 BLOWER FAILURE [loss of purge air blower power]		
8 FILTER BLOCK [inadequate purge air flow]		
9 WINDOW [excessive dirt on transceiver window]		

CONTROL UNIT CHECKS

10 Opacity range switch position
[Turn RANGE SWITCH to "4" position.] ______________

ZERO CHECK

(PRESS CALIBRATION BUTTON ON CONTROL PANEL)

11 Internal zero value (milliamps) ______________
(WAIT TWO MINUTES FOR AUTOMATIC CHANGE TO EXTERNAL ZERO MODE.)

12a Panel meter zero calibration value (milliamps) ______________

AUDIT DATA SHEET
ENVIROPLAN (THERMO ELECTRON) D-R280AV TRANSMISSOMETER
(Continued)

SPAN CHECK

13 Internal span calibration value (milliamps) ____________

14 Opacity data recorder span calibration value (% Op) ____________

[GO TO TRANSMISSOMETER LOCATION.]

RETROREFLECTOR DUST ACCUMULATION CHECK

[GET EFFLUENT OPACITY READINGS FROM THE OPACITY DATA RECORDER.]

15 Pre-cleaning effluent opacity (% Op) ____________
[Inspect and clean optical surface.]

16 Post-cleaning effluent opacity (% Op) ____________
[Go to transceiver location.]

TRANSCEIVER DUST ACCUMULATION CHECK

17 Pre-cleaning effluent opacity (% Op) ____________
[Inspect and clean optical surface.]

18 Post-cleaning effluent opacity (% Op) ____________

OPTICAL ALIGNMENT CHECK (OPTIONAL)

[LOOK THROUGH ALIGNMENT SIGHT AND DETERMINE IF BEAM IMAGES ARE CENTERED.]

19 Images centered?

YES	NO

[DRAW LOCATION OF IMAGES IN SIGHT.]

20 Span filter value (milliamps) ____________

21 Span filter value (%Op) ____________

CALIBRATION ERROR CHECK [JIG PROCEDURE]

[INSTALL THE AUDIT JIG ON THE PRIMARY LENS AND ADJUST THE JIG ZERO UNTIL A VALUE OF 4 mA IS READ ON THE REMOTE PANEL METER.]

[MAKE FINAL JIG ZERO ADJUSTMENTS BASED ON OPACITY DATA FROM DATA RECORDER.]

21a Jig zero value from data recorder (%Op) ____________

[RECORD AUDIT FILTER DATA.]

	FILTER	SERIAL NO.	% OPACITY
22	LOW	____________	____________
23	MID	____________	____________
24	HIGH	____________	____________

AUDIT DATA SHEET
ENVIROPLAN (THERMO ELECTRON) D-R280AV TRANSMISSOMETER
(Continued)

[REMOVE AUDIT FILTERS FROM PROTECTIVE COVERS, INSPECT, AND CLEAN.]
[INSERT EACH FILTER, WAIT APPROXIMATELY TWO MINUTES,AND RECORD OPACITY VALUES REPORTED FROM OPACITY DATA RECORDER.]
[IF JIG ZERO VALUES CHANGE BY MORE THAN 1.0% OPACITY BETWEEN THREE (3) FILTER RUNS, READJUST JIG ZERO TO ORIGINAL VALUE AND REPEAT RUN.]

ZERO	LOW	MID	HIGH	ZERO
______	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______
	______	______	______	______

[IF SIX-MINUTE INTEGRATED DATA ARE ALSO AVAILABLE, THEN ALLOW 13 MINUTES EACH FOR AN ADDITIONAL RUN OF THE ZERO, LOW, MID, HIGH, AND ZERO READINGS.]

ZERO	LOW	MID	HIGH	ZERO
______	______	______	______	______

[REMOVE AUDIT JIG, CLOSE THE TRANSCEIVER HEAD AND THE WEATHER COVER.]

[RETURN TO CONTROL UNIT LOCATION.]

CONTROL UNIT ADJUSTMENT RESET

[IF NECESSARY, RESET THE OPACITY RANGE SWITCH TO THE POSITION INDICATED IN BLANK 10.]

[MARK THE DATA RECORD FOR THE END OF THE AUDIT, GET A COPY OF THE AUDIT DATA FROM THE OPACITY DATA RECORDER, AND ENSURE THAT THE DATA CAN BE CLEARLY READ AND INTERPRETED.]

[READ AND TRANSCRIBE FINAL CALIBRATION ERROR DATA.]

ZERO	LOW	MID	HIGH	ZERO
----- 25	----- 26	----- 27	----- 28	----- 29
	----- 30	----- 31	----- 32	----- 33
	----- 34	----- 35	----- 36	----- 37
	----- 38	----- 39	----- 40	----- 41
	----- 42	----- 43	----- 44	----- 45

[SIX-MINUTE AVERAGE DATA, IF APPLICABLE.]

----- 46	----- 47	----- 48	----- 49	----- 50

AUDIT DATA SHEET
ENVIROPLAN (THERMO ELECTRON) D-R280AV TRANSMISSOMETER
(Continued)

CALCULATION OF AUDIT RESULTS

STACK EXIT CORRELATION ERROR (%):

51 $$\frac{\text{------ (BLANK 4)} - \text{------ (BLANK 3)}}{\text{-------- (BLANK 3)}} \times 100 = \_\_\_\_\_\_\_\_\_\_$$

ZERO ERROR (% Op):

52 Panel meter $$\text{-------- (BLANK 12a)} - \text{------- (BLANK 5)} = \_\_\_\_\_\_\_\_\_\_$$

53 Opacity data recorder $$\text{-------- (BLANK 12b)} - \text{------- (BLANK 5)} = \_\_\_\_\_\_\_\_\_\_$$

SPAN ERROR (% Op):

54 Panel Meter $$\text{------- (BLANK 13)} - \text{------- (BLANK 6)} = \_\_\_\_\_\_\_\_\_\_$$

55 Opacity Data Recorder $$\text{------- (BLANK 14)} - \text{------- (BLANK 6)} = \_\_\_\_\_\_\_\_\_\_$$

OPTICAL SURFACE DUST ACCUMULATION (% Op):

56 Retroreflector: $$\text{---------- (BLANK 15)} - \text{---------- (BLANK 16)} = \_\_\_\_\_\_\_\_\_\_$$

57 Transceiver: $$\text{----------- (BLANK 17)} - \text{---------- (BLANK 18)} = \_\_\_\_\_\_\_\_\_\_$$

58 Total: $$\text{----------- (BLANK 56)} + \text{---------- (BLANK 57)} = \_\_\_\_\_\_\_\_\_\_$$

OPTICAL PATHLENGTH CORRECTION FACTOR AND ZERO OFFSET CORRECTION OF AUDIT FILTERS:

59 Low: $$\left[1 - \left[\left[1 - \frac{\text{------ (BLANK 22)}}{100}\right]^{\text{------- (BLANK 4)}} \times \left[1 - \frac{\text{------ (BLANK 45)}}{100}\right]\right]\right] \times 100 = \_\_\_\_\_\_\_\_\_\_$$

60 Mid: $$\left[1 - \left[\left[1 - \frac{\text{------ (BLANK 23)}}{100}\right]^{\text{------- (BLANK 4)}} \times \left[1 - \frac{\text{------ (BLANK 45)}}{100}\right]\right]\right] \times 100 = \_\_\_\_\_\_\_\_\_\_$$

61 High: $$\left[1 - \left[\left[1 - \frac{\text{------ (BLANK24)}}{100}\right]^{\text{------- (BLANK 4)}} \times \left[1 - \frac{\text{------ (BLANK 45)}}{100}\right]\right]\right] \times 100 = \_\_\_\_\_\_\_\_\_\_$$

CALIBRATION ERROR CALCULATIONS (JIG PROCEDURE)

Low Range

ITEM NO. n	LOW RANGE DIFFERENCE		Δ_L	Δ_L^2
1	-------- (BLANK 26)	- -------- (BLANK 59) =	______	______
2	-------- (BLANK 30)	- -------- (BLANK 59) =	______	______
3	-------- (BLANK 34)	- -------- (BLANK 59) =	______	______
4	-------- (BLANK 38)	- -------- (BLANK 59) =	______	______
5	-------- (BLANK 42)	- -------- (BLANK 59) =	______	______

$\Sigma\Delta_L$ = ______ $\Sigma\Delta_L^2$ = ______

MEAN ERROR = $\overline{ME}_L$

$\overline{ME}_L = \frac{\Sigma\Delta_L}{n} = \frac{(------)}{(------)}$

62 $\overline{ME}_L$ = ______

CONFIDENCE INTERVAL = CI_L

$CI_L = ((n \times \Sigma\Delta_L^2) - (\Sigma\Delta_L)^2)^{0.5} \times 0.2776$

$CI_L = ((\_\_\_ \times \_\_\_) - (\_\_\_)^2)^{0.5} \times 0.2776$

65 CI_L = ______

CALIBRATION ERROR = CE_L

$CE_L = |\overline{ME}_L| + CI_L$

$CE_L = |\_\_\_| + (\_\_\_)$

68 CE_L = ______

Mid Range

ITEM NO.	MID-RANGE DIFFERENCE		Δ_M	Δ_M^2
	-------- (BLANK 27)	- -------- (BLANK 60) =	______	______
	-------- (BLANK 31)	- -------- (BLANK 60) =	______	______
	-------- (BLANK 35)	- -------- (BLANK 60) =	______	______
	-------- (BLANK 39)	- -------- (BLANK 60) =	______	______
	-------- (BLANK 43)	- -------- (BLANK 60) =	______	______

$\Sigma\Delta_M$ = ______ $\Sigma\Delta_M^2$ = ______

MEAN ERROR = $\overline{ME}_M$

$\overline{ME}_M = \frac{\Sigma\Delta_M}{n} = \frac{(------)}{(------)}$

63 $\overline{ME}_M$ = ______

CONFIDENCE INTERVAL = CI_M

$CI_M = ((n \times \Sigma\Delta_M^2) - (\Sigma\Delta_M)^2)^{0.5} \times 0.2776$

$CI_M = ((\_\_\_ \times \_\_\_) - (\_\_\_)^2)^{0.5} \times 0.2776$

66 CI_M = ______

CALIBRATION ERROR = CE_M

$CE_M = |\overline{ME}_M| + CI_M$

$CE_M = |\_\_\_| + (\_\_\_)$

69 CE_M = ______

High Range

ITEM NO.	HIGH-RANGE DIFFERENCE		Δ_H	Δ_H^2
	-------- (BLANK 28)	- -------- (BLANK 61) =	______	______
	-------- (BLANK 32)	- -------- (BLANK 61) =	______	______
	-------- (BLANK 36)	- -------- (BLANK 61) =	______	______
	-------- (BLANK 40)	- -------- (BLANK 61) =	______	______
	-------- (BLANK 44)	- -------- (BLANK 61) =	______	______

$\Sigma\Delta_H$ = ______ $\Sigma\Delta_H^2$ = ______

MEAN ERROR = $\overline{ME}_H$

$\overline{ME}_H = \frac{\Sigma\Delta_H}{n} = \frac{(------)}{(------)}$

64 $\overline{ME}_H$ = ______

CONFIDENCE INTERVAL = CI_H

$CI_H = ((n \times \Sigma\Delta_H^2) - (\Sigma\Delta_H)^2)^{0.5} \times 0.2776$

$CI_H = ((\_\_\_ \times \_\_\_) - (\_\_\_)^2)^{0.5} \times 0.2776$

67 CI_H = ______

CALIBRATION ERROR = CE_H

$CE_H = |\overline{ME}_H| + CI_H$

$CE_H = |\_\_\_| + (\_\_\_)$

70 CE_H = ______

SIX-MINUTE AVERAGED ERROR

$E(6)_L$ = -------- (BLANK 47) - -------- (BLANK 59)

71 $E(6)_L$ = ______

$E(6)_M$ = -------- (BLANK 48) - -------- (BLANK 60)

72 $E(6)_M$ = ______

$E(6)_H$ = -------- (BLANK 49) - -------- (BLANK 61)

73 $E(6)_H$ = ______

ENVIROPLAN (THERMO ELECTRON) D-R280AV TRANSMISSOMETER
OPACITY CEMS PERFORMANCE AUDIT REPORT
AUDIT SUMMARY

AUDITOR ______________________ DATE ______________________

SOURCE ______________________ UNIT ______________________

RESULTS CHECKED BY ______________________ DATE ______________________

PARAMETER		BLANK NO.	AUDIT RESULT	SPECIFICATION
FAULT LAMPS				
BLOWER FAILURE		7		OFF
FILTER BLOCK		8		OFF
WINDOW		9		OFF
STACK EXIT CORRELATION ERROR		51		± 2%
INTERNAL ZERO ERROR	PANEL METER	52		± 4%Op
	DATA RECORDER	53		± 4% Op
INTERNAL SPAN ERROR	PANEL METER	54		± 4% Op
	DATA RECORDER	55		± 4%Op
OPTICAL ALIGNMENT ANALYSIS		19		CENTERED
OPTICAL SURFACE DUST ACCUMULATION				
RETROREFLECTOR		56		≤ 2% Op
TRANSCEIVER		57		≤ 2% Op
TOTAL		58		≤ 4% Op
CALIBRATION ERROR ANALYSIS				
MEAN ERROR				
LOW		62		
		71[a]		
MID		63		
		72[a]		
HIGH		64		
		73[a]		
CONFIDENCE INTERVAL				
LOW		65		
MID		66		
HIGH		67		
CALIBRATION ERROR				
LOW		68		≤ 3% Op
MID		69		≤ 3% Op
HIGH		70		≤ 3% Op

[a] ERROR BASED ON SIX-MINUTE AVERAGED DATA FROM A SINGLE FILTER INSERTION.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE PERFORMANCE AUDIT PROCEDURES FOR OPACITY MONITORS		5. REPORT DATE
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Steven J. Plaisance, James W. Peeler		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Entropy Environmentalists, Inc. P. O. Box 12291 Research Triangle Park, NC 27709		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-02-4125; Tasks 140A & 182A 68-02-4442; Task 11
12. SPONSORING AGENCY NAME AND ADDRESS U. S. Environmental Protection Agency Office of Research and Development Environmental Monitoring Systems Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This manual contains monitor-specific performance audit procedures and data forms for use in conducting audits of installed opacity continuous emission monitoring systems (CEMS). General auditing procedures and acceptance limits for various audit criteria are discussed. Practical considerations and common problems encountered in conducting audits are delineated, and recommendations are included to optimize the successful completion of performance audits.

Performance audit procedures and field data forms were developed for six common opacity CEMS: (1) Lear Siegler, Inc. Model RM-41; (2) Lear Siegler, Inc. Model RM-4; (3) Dynatron Model 1100; (4) Thermo Electron, Inc. Model 400; (5) Thermo Electron, Inc. Model 1000A; and (6) Enviroplan Model D-R280 AV.

Generic audit procedures have been included for use in evaluating opacity CEMS with multiple transmissometers and combiner devices. In addition, several approaches for evaluating the zero alignment or "clear-path" zero response have been described. The zero alignment procedures have been included since this factor is fundamental to the accuracy of opacity monitoring data, even though the zero alignment checks cannot usually be conducted during a performance audit.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Opacity Monitors Quality Assurance Transmissometers Continuous Emission Monitoring		

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