Appendix A

QUALITY ASSURANCE PROJECT PLAN

for the National Air Emissions Monitoring Study (Barns Component) QAPP Category #1

Revision 2.0

January 24, 2008

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National Air Emissions Monitoring Study
(Barns Component)

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Agriculture Air Research Council (AARC)
Purdue University Department of Agricultural and Biological Engineering

Prepared by
Purdue Agricultural Air Quality Laboratory (PAAQL)
West Lafayette, IN 47907

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QAPP Distribution List

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Copies of the EPA-Approved Quality Assurance Project Plan will be made available to any organization upon request.

Definitions of Abbreviations, Acronyms and Chemical Names

Abbreviations and Acronyms

AARC	Agricultural Air Research Council
ABE	Agricultural & Biological Engineering Department, Purdue University
AirDAC	Air Data Acquisition and Control software (SOP B2)
AMCA	Air Movement & Control Association International, Inc.
ANSI	American National Standards Institute
APECAB	Aerial Pollutant Emissions from Confined Animal Buildings
ASME	American Society of Mechanical Engineers
BACT	Best Available Control Technology
BESS	Bioenvironmental Systems and Simulations Lab at the University of Illinois
CAA	Clean Air Act
CAB	Confined animal buildings
CAFO	Confined animal feeding operation
CCB	Center-ceiling baffled inlet
CEM	Continuous emission monitoring
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Chain of custody
CSRS	Cation self-regenerating suppressor
CTC	Cation trap column
CTM	Conditional Test Method
CV	Coefficient of variation
DA	Data Analyst
DAC	Data acquisition and control
DAQ	Data acquisition
dP	Differential pressure
DQA	Data quality assessment
DQI	Data quality indicator
DQO	Data quality objective
DSC	Datalogging and supervisory control
EP	Evaporative pad
EPCRA	Emergency Planning and Community Right-to-Know Act
FANS	Fan Assessment Numeration System
FRM	Federal Reference Method
FTIR	Fourier transform infrared
GC/MS	Gas chromatography/mass spectrometry
GSLG	Gas sampling location group
GSS	Gas sampling system
HVAC	Heating, ventilation and air conditioning
IC	Ion chromatography
IEC	International Electrotechnical Commission
IFAFS	Initiative for Future Agricultural and Food Systems

IMC	Independent Monitoring Contractor
ISO	International Organization for Standardization
JAWMA	Journal of the Air and Waste Management Association
LSAS	Location-shared analyzers and sensors
MC	Moisture content
MFC	Mass flow controller
MQO	Measurement quality objective
MSA	Methanesulfonic acid **OR** Mine Safety Appliances, Inc.
MSS	Major Stationary Source
MV	Mechanically ventilated
NAEMS	National Air Emissions Monitoring Study
NAS	National Academy of Sciences
NCC	National Chicken Council
NCSL	National Council of Standard Laboratories
NELAP	National Environmental Laboratory Accreditation Program
NMPF	National Milk Producers Federation
NPPC	National Pork Producers Council
NRCS	Natural Resources Conservation Service
NV	Naturally ventilated
OFIS	On-farm instrument shelter
PAAQL	Purdue Agricultural Air Quality Laboratory
PFA	Grade of Teflon
PI	Principal Investigator
PIR	Passive infrared
PM	Particulate matter
PM_{10}	Particulate matter less than 10 μm diameter
$PM_{2.5}$	Particulate matter less than 2.5 μm diameter
PP	Pull-plug manure pit
PPR	Pull-plug manure pit with recharge
PREF	Primary representative exhaust fan
PTE	Potential to Emit
QA	Quality assurance
QC	Quality control
QAPP	Quality Assurance Project Plan
RQ	Reportable quantity
RSD	Relative standard deviation
SA	Science Advisor
SLG	Sampling location group
SMP	Site Monitoring Plan
SOP	Standard Operating Procedure
RH	Relative humidity
TDS	Thermodesorption System
TEC	Thermo Electron Corporation
TEOM	Tapered element oscillating microbalance
TFC	Thin-film capacitor

TFS	Thermo Fisher Scientific
TPY	Tons per year
TSP	Total suspended particulate
UEP	United Egg Producers
UIUC	University of Illinois at Urbana-Champaign
UPS	Uninterruptible power supply
USDA	United State Department of Agriculture
USEPA	United States Environmental Protection Agency
VDC	Volts direct current
VFA	Volatile fatty acid
VOC	Volatile organic compound
VSCC	Very sharp cut cyclone
Z/S	Zero/span

Chemical Names

CO_2	Carbon dioxide
H_2S	Hydrogen sulfide
H_2SO_4	Sulfuric acid
Hg	Mercury
KBr	Potassium bromide
KCl	Potassium chloride
N_2	Nitrogen gas
NH_3	Ammonia
NO	Nitric oxide
NO_2	Nitrogen dioxide
S	Sulfur
SO_2	Sulfur dioxide

1. Project Management

1.1 Project/Task Organization

Figure 1.1.1 provides an overview of the personnel involved in the NAEMS, with lines of authority, and responsibilities and job titles for each individual. Dr. Albert Heber (Purdue University) is responsible for overall project management and for coordinating administrative logistics, including selecting University PIs and implementing sub-contracts, filing of project reports, and management of financial resources. As Science Advisor (SA), Dr. Heber is also responsible for directing the technical aspects of the project, including drafting the comprehensive study design, selecting test sites, creating, updating, distributing and implementing the quality assurance project plan, specifying instrumentation and equipment, designing, constructing and delivering the gas sampling systems, developing and distributing the data acquisition program, and analyzing the data. Dr. Heber's staff at the Purdue Agricultural Air Quality Laboratory (PAAQL) will be responsible for the initial acceptance of all test instruments, and for ensuring that all University PIs (and their staffs as appropriate) are adequately trained in the setup of the equipment and the methodology of the study. Dr. Richard Grant (Purdue University) will, as co-PI, be responsible for conducting all open-source and micrometeorological measurements, as described in the QAPP for the NAEMS Open-Source Component (submitted separately).

Members of Dr. Heber's PAAQL staff (one or two for each site) will also spend approximately one week assisting the University PIs with the setup of each individual site, including setting up the gas sampling system and other analytical instrumentation, setting up the on-farm instrument shelter (OFIS), establishing communications (including high-speed internet/data transmission), fixing sensor locations, and initiating installation and configuration of data-collection hardware and software. University PIs will then complete the setup at the individual sites, which is expected to take 1-2 mos. Dr. Heber or other PAAQL personnel will then return to the site for an initial audit of the completed and functioning setup. Once the project enters the data-collection phase (May 8, 2007 through approximately December 15, 2007, depending on the site), the university PIs and their designated staff member(s) (the site engineers in Fig. 1.1.1) will oversee the daily operation of all on-site equipment and instrumentation (e.g. gas analyzers, PM-monitoring equipment, environmental sensors). NAEMS-designated staff member(s) at each university are expected to visit their site, at minimum, once per week, and are expected to monitor the site remotely (via internet connection using the AirDAC program) at least once per day. Site PIs and their staff will also be responsible for all routine sample collection, including manure (and feed, bedding, milk, and eggs) sampling, assessing animal inventories, collecting and shipping VOC samples (described in Section 2.1.8), and conducting fan tests. In most cases, the samples (manure and other materials, VOCs) will be sent, as described in detail in Section 2.2, either to PAAQL, or to a designated commercial laboratory (Midwest Laboratories) for analysis.

Individuals who will serve as Principal Investigators for one or more sites are as follows:

- Dr. Jacek Koziel, Iowa State University
- Dr. Wayne Robarge, North Carolina State University
- Dr. Lingjuan Wang, North Carolina State University
- Dr. Larry Jacobson, University of Minnesota
- Mr. Curt Gooch, Cornell University
- Dr. Frank Mitloehner, University of California-Davis
- Dr. Ruihong Zhang, University of California-Davis
- Dr. Ken Casey, Texas A&M University
- Dr. Pius Ndegwa, Washington State University-Pullman
- Dr. Teng Lim, Purdue University
- Dr. Jiqin Ni, Purdue University

Purdue University will have specific fiduciary, communications and technical responsibilities. Purdue University will oversee the process to ensure the study funds and equipment are properly accounted for under the approved budget and federal check-off funding requirements and any applicable tax laws. Purdue University will report on the conduct of the study to EPA and the nonprofit entity. In addition, Purdue University will build a web site specific for this study and regularly post updates for the public to follow the progress of the study. Purdue University will oversee certain technical aspects of the study, will help interpret the progress of the study, and provide periodic reports to EPA and AARC.

Purdue University will directly administer: (a) all subcontracts with the principal investigators (PIs) doing the data collection; (b) purchasing and inventory control of all equipment throughout the study, (c) construction and distribution of mobile laboratories, (d) direct supervision of the teams of PIs in the course of the study, (e) direct supervision of data acquisition, data management, data processing, data and equipment QA/QC, etc., and (f) other activities as described below. Purdue University will interact with the business offices of the universities to administer their respective PI’s budgets. These budgets will vary depending on the location of the farm(s), the number of barns monitored, and local characteristics (e.g., distance PIs and technicians have to travel to visit the site(s), climate extremes, etc.). Individual PIs will likely employ their existing technicians and their own university business offices will handle their team’s payroll, travel reimbursements etc. as they would any other external contract or grant. Purdue University will monitor expenditures of each subcontracting university, approve transfer of funds to them according to approved budgets, review the financial statements of the business offices of the subcontracting universities, and report to EPA and AARC on a regular basis.

Purdue University will employ an in-house QA/QC Manager (Dr. Juan Carlos Ramirez), who will be responsible for conducting or directing audits of each site. Audits will be conducted during the first quarter of data collection for each site, and at the midpoint of the study. These audits are detailed in Section 3.1 of this QAPP. Data review for all sites will be conducted at Purdue by a team of data analysts. Drs. Teng Lim and JiQin Ni of Purdue will also be responsible, as PI on 2 sites and one site, respectively, for contributing to data review and processing of those sites. This arrangement will result in eight persons being the primary data analyst for 1-4 individual sites. The following is the current distribution of sites among data analysts, subject to change based on site requirements and personnel availability.

- Dr. Ruiqiang Liu – IN3B
- Dr. Jeong-Hyub Ha – IN5B
- Dr. Juan Carlos Ramirez – CA5B, WA5B
- Dr. Erin Cortus – CA1B, IA4B, OK4B, WI5B
- Dr. Kaiying Wang – NC2B, NC3B
- Dr. Bill Bogan – NY5B
- Dr. Teng Lim – CA2B
- Dr. Jiqin Ni – IN2B/IN2H
- Mr. Sam Hanni – NC4B

Data analysts will be responsible for daily on-line (remote) checking of their assigned sites, will receive warning emails whenever out-of-range data is encountered (SOP B2), and will conduct most data pre-processing (SOP B3) and all data processing (SOP B6) activities.

One contract analytical laboratory, Midwest Laboratories (Omaha, NE), will analyze all manure, feed, bedding, milk, and eggs samples generated in the NAEMS. Midwest Laboratories' QA/QC Director, Dr. Jerome King, will be responsible for overseeing the QA function of that portion of the project. Midwest Laboratories' QA/QC Program is based on the principles contained in ISO9000, ISO/IEC Guide 25, and ISO Guide 17025. The company is certified by the National Environmental Laboratory Accreditation Program (NELAP), and holds accreditation from USDA, the National Forage Testing Association, and several states (OK, NE, CO, IA, MN, and WI). Further details of Midwest Laboratories' Involvement, and their QA/QC program, are provided in the appropriate sections of this QAPP. PAAQL personnel led by Dr. Changhe Xiao, who will serve as NAEMS VOC Manager, will analyze all VOC samples collected in the study.

The Agricultural Air Research Council (AARC), a non-profit entity established by representatives of the dairy (NMPF), swine (NPPC), layer (UEP) and broiler (NCC) industries, will fund the study. The AARC Board of Directors will meet regularly, receive reports on the progress of the study, approve the budget, and review audits of expenditures. The AARC will be responsible for holding and disbursing to Purdue University the funds necessary to complete the study according to its approved schedule, protocol and budget. The AARC will also provide a communication mechanism to livestock and poultry producers, the media and other parties.

Specific USEPA personnel involved in NAEMS are as follows. OAQPS will designate one person as the overall Project Manager for EPA, while Joseph Elkins will serve as the QA Manager. Mr. Elkins will direct the external QA audits of the sites, which will be conducted by EPA and/or an EPA contractor (e.g., Battelle), as shown in Fig. 1.1.1.

Producers/farm managers involved in the study must be willing to: 1) attend a training session (Section 1.5), 2) make changes as needed to accommodate the project, and 3) maintain and share certain production records to facilitate data analysis and interpretation. A description of the type of data that each individual producer is expected to provide is given in SOP S1.

1.1.1 Personnel and Agencies Involved

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Bruce Ferguson	USEPA OECA	202-564-1261	fergusson.bruce@epa.gov
	Ariel Rios Building, 1200 Pennsylvania Ave., N.W. Washington, D.C. 20460		
Confidential	Producers at each site	Confidential	Confidential

1.1.2 Personnel Responsibilities/Project Organization

Science Advisor	Heber
Quality Assurance Project Plan (QAPP)	Heber
QAPP Review/Approval	USEPA, Battelle, RTI, USDA
Select Monitoring Sites and University PIs	Heber
Field Support	Producers
Obtain Access Agreements	Heber, PIs
Prepare Producer Contracts	Heber
Internal QA/QC Audits of Field Tests	Purdue University
External Field Oversight	PIs
Media Inquiries	Heber
Field Data Analysis	Heber, PIs
NH_3 Data Reporting	Heber
H_2S Data Reporting	Heber
CO_2 Data Reporting	Heber
VOCs Data Reporting	Heber
$PM_{2.5}$, PM_{10}, and TSP Data Reporting	Heber
Data Compilation/Final Report	Heber
Final Report Review & Approval	Heber, EPA

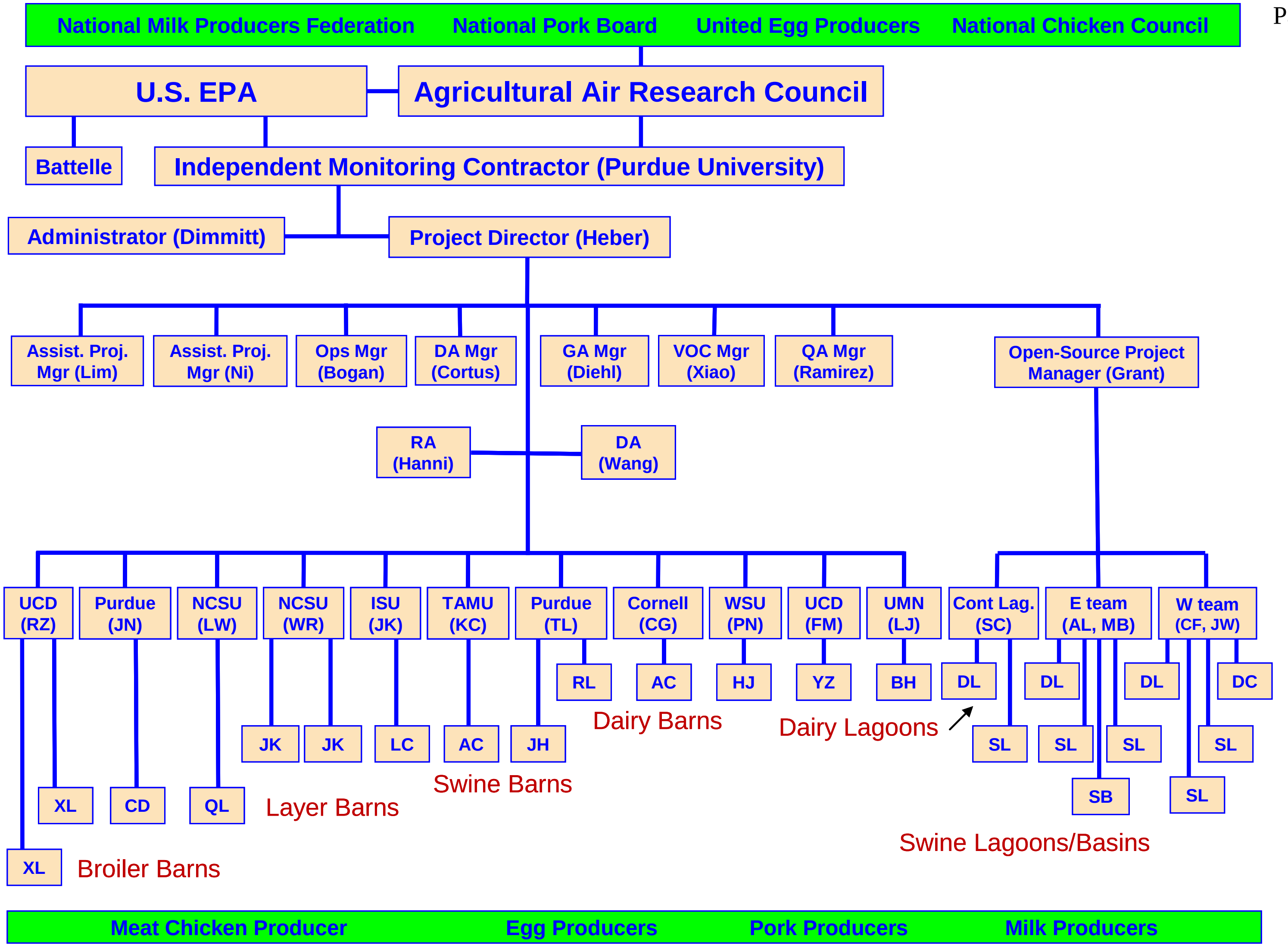


Figure 1.1.1. Responsibility & Authority Flow Chart for the NAEMS. Includes open-source measurements (see companion QAPP). GA = Gas Analyzer; RA = Research Assistant; DA = Data Analyst; DL = Dairy Lagoon; PL = Pork Lagoon; PB = Pork Basin; DC = Dairy Corral;

1.2 Problem Definition/Background

Air pollutants emitted from livestock buildings may represent a significant source of pollution to the wider environment. Aerial pollutants of particular interest in livestock buildings are ammonia (NH_3), hydrogen sulfide (H_2S), volatile organic compounds (VOCs), and particulate matter ($PM_{2.5}$, PM_{10} and TSP). It would be helpful to obtain more information about how much air pollution is emitted by livestock facilities, and how much emissions may be influenced by climate, animal species, and design and management of the facility, in a national study using consistent measurement protocols. The Environmental Protection Agency (EPA) expects Animal Feeding Operations (AFOs) to comply with air quality laws, but has found it difficult to determine if an AFO is in violation and if so, the extent of the violation. In 2000, EPA began applying federal air quality laws to AFOs (Schutz, et al., 2005).

Currently, air emissions from AFOs, such as PM, NH_3, H_2S, and VOCs, fall under the U.S. Clean Air Act of 1990 (CAA). In addition, there are notification requirements for NH_3 and H_2S under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA) (Schutz, et al., 2005).

1.2.1 Regulation under the CAA

A Major Stationary Source (MSS) is defined as any stationary source that emits, or has the potential to emit, 250 TPY of a regulated air pollutant. For livestock sources, that means 250 tons per year (TPY) of TSP or any particle size fraction thereof, 250 TPY of non-methane VOCs, or 250 TPY of H_2S. A MSS requires installation of Best Available Control Technology (BACT).

A facility must obtain a Title V permit if it emits more than 100 TPY of PM_{10} (but not TSP, which remains at 250 TPY) or VOCs. In most states, Minor New Source Review permits must be obtained and emissions fees must be paid if they emit more than 15 TPY of PM_{10}, 25 TPY of TSP, or 40 TPY of VOCs. These MNSR permits do not automatically require installation of controls, but controls can be required at the discretion of the state or local air pollution control agency (Secrest, 2004).

Potential to emit (PTE) refers to the maximum capacity of a stationary source to emit a pollutant under its physical and operational design (e.g., summer ventilation rate with full housing capacity times 12 would be the 12 month PTE rate). Any physical or operational limitation on the capacity of a source to emit (such as winter ventilation rate and its effect on total actual emissions) is treated as part of its "design" if the limitation or the effect it would have on the potential to emit is Federally enforceable (e.g., is contained in the source's CAA permit) (40 CFR 51.166). For example, if a livestock operation could emit over 250 TPY based solely on its high summer month rate times 12, and the source did not have a Federally enforceable MSS permit defining its PTE based on actual operational conditions (in this case, winter ventilation rate restrictions), then the source could be liable for violating the CAA. Whereas this practice has not been considered for livestock industries, the PTE definition was intended to apply to sources such as manufacturing facilities that, for example, could emit 250 TPY of VOCs except they only run two work shifts instead of three (Secrest, 2004).

For purposes of Title V (State Operating Permit Programs), a stationary source that emits, or has the potential to emit, 100 TPY of a regulated air pollutant must comply with 40 CFR Part 70 (Title V permit program). In practice, this means 100 TPY or more of PM_{10} (but not TSP), or 100 TPY of VOCs (Secrest, 2004).

Many state CAA implementation programs also include a requirement that a facility notify the state of its annual emissions if they exceed 40 TPY of VOCs, 25 TPY of TSP, or 15 TPY of PM_{10}. These "de minimis" sources may be subject to a letter notification process and must file emissions inventory reports and emissions fees as set forth in the State Implementation Plan (Secrest, 2004).

The primary authority for regulating sources under the CAA is the state or local air pollution control agency and specific requirements vary from state to state. The requirements are contained in the State Implementation Plan regulations. For example, California is divided into more than 20 county- and area-level air pollution control districts, and each defines "Major Source" at different levels of emissions, some of which are lower than the general Federal rule (e.g., 40 TPY of VOCs). Twenty states were notified by the EPA in 2004 that they did not meet ambient air quality standards for $PM_{2.5}$. States with non-attainment areas must submit plans by 2008 indicating how they plan to meet this standard, and meet the standard by 2010. Non-attainment areas are geographical regions that have failed to meet the air quality standards of specific pollutants based on state-operated networks of ambient monitors (Schutz, et al., 2005).

1.2.2 Regulation under CERCLA/EPCRA

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) or the “Superfund” Act addresses the physical and financial responsibilities associated with the release of airborne hazardous materials (Schutz et al., 2005). The quantity of material released is used to determine if the facility must report the release. Thus, each reportable substance has a reportable release quantity. The reportable release quantity for NH_3 or H_2S, for example, is 100 lb in any 24-h period.

The Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986 was passed to allow people to be aware of any hazardous materials that are stored in their community and to help citizens make better decisions about the risks associated with living or working nearby. EPCRA establishes a list of hazardous materials and a threshold planning and reportable release quantity for each hazardous chemical. Like CERCLA, the reportable release quantity is 100 lb/d for NH_3 or H_2S. In the case of AFOs, EPA is proposing that operations above a threshold size annually report the release of emissions from the operation unless mitigating practices can reduce the emission release (Schutz et al., 2005).

1.2.3 Emission Estimation Methodology

The EPA currently estimates air emissions based on the size and type of the AFO using emission factors, rather than on direct monitoring or process-based modeling. According to the NRC

(2003), these emission factors are based on inadequate data. New methodologies to estimate emissions from livestock or poultry operations are needed, but more up-to-date and comprehensive data is required to support the development of more reliable emission estimation the methodologies (EEMs).

A significant step towards obtaining the data needed to support new EEMs was taken through the Air Consent Agreement, under which livestock producers and commodity groups will sponsor the National Air Emissions Monitoring Study at a number of representative AFOs to obtain new emission data. The Environmental Protection Agency offered animal feeding operations (AFOs) in the swine, dairy, broiler chicken, and egg, industries a one-time opportunity to participate in a legal agreement that would provide protection from prosecution for past federal air law violations that may have occurred at those operations. In return, those industries would agree to participate in an extensive nationwide study that would generate data for determining emissions from major types of farms in geographic areas where they are located. NAEMS is the culmination of that agreement.

NAEMS was developed in response to a 2003 National Academy of Sciences (NAS) report that highlighted possible air pollution problems arising from animal feeding operations, and discussed the insufficiency of existing databases. NAEMS was designed by the Air Quality Group of the USDA’s Natural Resources Conservation Service (NRCS) to address the issues in the NAS report, and to determine whether AFOs were likely to have compliance issues regarding the CAA and/or CERCLA/EPCRA. Since the NAS assessment focused on the incompleteness of the existing emissions factors, it was determined from the beginning of this process that a multi-industry, comprehensive study (such as NAEMS) would be necessary to address the issue satisfactorily. Compared with previous studies of livestock air emissions, NAEMS was designed to have the following features:

1. A large number of pollutants measured simultaneously ($PM_{2.5}$, PM_{10}, TSP, NH_3, H_2S, VOCs)
2. A longer duration (24 months) at each site than previous studies, the longest of which was 15 months (Jacobson, et al., 2004)
3. Largest number of barn monitoring sites (14) that use the same protocol for good comparability. Jacobson et al. (2004) used six mobile labs in their study of PM_{10}, TSP, NH_3, H_2S and odor
4. Most careful selection of farms to enhance the representativeness of the sites for their respective industries
5. The highest level of quality assurance and quality control (Category 1 QAPP). As a result, this study will “set the bar” for future studies.

The technical approach to emissions measurements was addressed by a group of invited scientists and producers’ representatives, and officials from EPA and USDA, who spent 2.5 d in November, 2003 together at a meeting in Beltsville, MD, to decide on the measurement protocols for the study. It was decided at this meeting by consensus to utilize the “mobile lab approach” for barns (rather than portable monitoring units), and open-path micrometeorological techniques (rather than flux chambers) for open sources such as lagoons and manure basins.

Protocols were refined during ensuing conference calls among subcommittees during the next three months. The goals of the NAEMS are as follows:

1. Quantify aerial pollutant emissions from AFOs in the dairy, pork, egg, and broiler meat industries and provide reliable air emissions data from representative confined livestock farms in the continental U.S. for developing and validating EEMs for livestock production and to obtain nationally-representative emission rates.
2. Determine whether individual farms are likely to emit PM and VOCs in excess of applicable Clean Air Act (CAA) thresholds.
3. Determine whether individual farms are likely to emit ammonia (NH_3) and/or hydrogen sulfide (H_2S) in excess of applicable Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Emergency Planning and Community Right-to-Know Act (EPCRA) reporting requirements.
4. Promote a national consensus on methods and procedures for estimating emissions from livestock operations.
5. Produce a database with which additional studies of air emissions and effectiveness of control technologies can be compared and from which emission factors can be developed, including data from existing emissions studies that meet EPA's quality assurance criteria along with the new NAEMS-generated data.

In addition, it is expected that this project will result in a database with which additional studies of air emissions and effectiveness of control technologies can be compared, and from which emission factors can be developed. Data from existing emissions studies that meet USEPA's quality assurance criteria will be integrated into this database, along with the new NAEMS-generated data.

The primary users of this information will be the EPA and state regulatory agencies, in determining new emissions factors for use in modeling and in enforcement actions. Another will be the industries themselves, as they consider mitigation approaches to comply with the regulations. Using NAEMS data, the EPA will develop emissions-estimating methodologies. The NAEMS measurement protocol will be used by these groups (regulatory agencies if they require certain methods for measuring emissions, producers if they undertake such measurements themselves) and other scientists and consultants with an interest in agricultural air quality.

1.3 Project/Task Description

1.3.1 Monitoring Sites

The emissions measurements needed to complete this study and serve as the basis for the database described above will be conducted at a total of 14 different barn monitoring sites in the continental U.S. (Table 1.3.1). The sites were chosen based on their representativeness of one of four main industries, namely, swine, dairy, layers, and broilers. The regions from which sites for each industry were selected were defined in the National Air Emissions Monitoring Study Protocol (Appendix B of the Consent Agreement). Important factors that were considered in the evaluation of each site's industry representativeness included: a) management of buildings, manure, etc., b) farm design and layout, c) age and size of facilities, d) animal diet and genetics, and e) geographic distribution.

Table 1.3.1. Summary of sites selected for NAEMS. "Area sites" including corrals, basins and lagoons are described in the companion Open-Source QAPP.

Industry	**Barn sites**					**Area sites**			
	2-barns	**3-barns**	**4-barns**	**# Sites**	**# Barns**	**Corrals**	**Lagoons**	**Basins**	**Total**
Swine	0	4	1[**]	5	16	0	5	1	6
Dairy[*]	3	2	0	5	12	1	3	0	4
Layers	2	0	1	3	8	0	0	0	0
Broilers	1	0	0	1	2	0	0	0	0
Total	6	6	2	14	38	1	8	1	10

[*] In the case of dairy, "barn" can refer to a freestall barn or the milking center.
[**] Four independent rooms within one "quad" finisher barn

Other factors were considered in the site-selection process, including the degree to which each site is conducive to collecting reliable and accurate emissions data with a single mobile lab. Thus, site layout and topographical considerations were factors. It is preferable that the monitored room and/or buildings are adjacent to each other, so that they can be connected to a single mobile laboratory, and that the buildings be mechanically ventilated, with single-speed fans. The site must be operated by a supportive producer, who is willing to accommodate the measurements, willing to record extra information for the study, and able to provide accurate production and inventory records and feed-conversion data. The potential of each farm for testing emission-mitigation strategies after the conclusion of NAEMS was also factored into the decision-making process. Also important was the provision that each site be within a 2.5-h drive to a PI, with all-weather access, and have access available to phones, electric, internet, and nearby lodging. All sites selected were judged representative of the operations under study, and were visited by the SA and/or the selected PI for the site. The following sections describe in more specific detail the rationale that was used to choose sites in each of the four industries.

1.3.2. Site Selection for Swine

Swine production phases include sows (breeding, gestation, and farrowing), nursery pigs, and finishing pigs. The buildings are either naturally-ventilated (NV) or mechanically-ventilated (MV), but many buildings have a combination of the two ventilation types (depending, for example on the season). Manure treatment and/or storage generally consists of either basins (earthen, clay or synthetic lined earthen, concrete, glass lined steel) and deep underfloor pits that store manure collected from the barn, or clay/synthetic lined earthen anaerobic treatment lagoons that dilute (approx. 5:1), treat and store manure. Manure collection systems with external manure storage/treatment are generally scrape, flush or pull-plug.

Overall, the U.S. hog inventory is located in three general regions. The five top Midwest swine states (IA, MN, IL, MO, and IN) represent about 54% of the total inventory in the U.S. In the Southeast, NC, AR, VA, KY, and MS represent about 19% of the total, and in the West, OK, NE, KS, SD, and TX make up a combined 15% of the total.

Table 1.3.2 identifies the types of swine farms where measurements will be taken to provide the needed data to complete the objectives of this study. Barn monitoring sites were selected based on criteria such as facility age, size, design and management, swine diet and genetics. Also, every attempt was made to identify sites that would be suitable for both barn and area measurements. Descriptions of all of these parameters, including a discussion of the rationale for choosing each site, are found in the individual Site Monitoring Plans in Appendix A. Two farms in the Southeast, representing the sow and finishing phases of production with lagoon manure treatment, were selected, both in North Carolina. The NC sow site will also have its lagoon monitored; due to site layouts (the spatial relationship between the barns and lagoon, with respect to wind patterns), the lagoon and barns for the NC finishers will be measured at two different farms. Two farms in the Midwest, representing a finishing farm using a deep pit system (Indiana) and a deep pit sow farm (Iowa), were selected. Finally, one farm in the West (Oklahoma) was selected. This farm represents sow farms with lagoon treatment, and both components (barns and lagoon) will be measured.

On each of the farms, three barns will have measurements taken simultaneously. Sow farms will have emissions measured at one farrowing room and two gestation barns. On finishing farms, three barns will have emission measurements, except in the case of the Midwest finisher, in which four separate rooms of a “quad” barn will be treated individually.

Table 1.3.2. Swine industry barn sites.

SMP #	Production phase	Ventilation type	Number of units measured	Manure collection	Manure storage[2]	PI
Southeast						
NC4B[1]	Breeding/gestation	MV (tunnel)	2	PPR[3]	Lagoon	Robarge
	Farrowing	MV	1	PPR	Lagoon	
NC3B	Finisher	MV (tunnel)	3	PPR	Lagoon	Robarge
Midwest						
IA4B	Breeding/gestation	MV (tunnel)	2	Deep pit[4]		Koziel
	Farrowing	MV	1	PPR	Gestation pits	
IN3B	Finisher	MV (tunnel)	4	Deep pit[4]		Lim
West						
OK4B[1]	Breeding/gestation	MV (tunnel)	2	PPR	Lagoon	Casey
	Farrowing	MV	1	PPR	Lagoon	

[1] Barn sites that also have measured area sources, which are described in the open-source QAPP

[2] Characterizes type of farm, not necessarily a measurement location.

[3] PPR = pull plug with recharge

[4] Storage is inside the barn so separate measurement not needed for storage.

1.3.3. Site Selection for Laying Hens

Most U.S. layer housing types and manure management schemes fall under one of two categories: 1) high-rise houses in which manure is stored in the lower level and removed every 1 to 2 yrs; and 2) belt houses with quasi-continuous manure transfer to an external storage/ treatment facility. The locations for three sites with specific housing types were recommended for this study, with consideration of these housing categories, along with the potential impact of climatic differences and the geographical density of egg production (Table 1.3.3). Final site selections also depended on site-specific factors including: representativeness of facility age, size, design and management, and flock diet and genetics. A four-barn (two high-rise, two belt battery) site was chosen in Indiana, while a two-barn (high-rise only) site was selected in California. A two-barn site (high-rise only) was chosen in North Carolina. A detailed description of each site, including a summary of the rationale behind its selection for NAEMS, is given in the respective Site Monitoring Plans.

Table 1.3.3. Layer (egg) industry sites.

SMP #	Site Type	Ventilation type	Number of units measured	Manure Collection	Manure Storage	PI
East						
NC2B	High-rise	MV (tunnel)	2	CBC[1]	Inside	Wang
Midwest						
IN2B	High-rise Belt battery Manure shed	MV (sidewall) MV (sidewall) MV	2 2 1	CBC Belt Loader	First floor Shed -	Ni
West						
CA2B	High-rise	MV (sidewall)	3	DB[2]	Inside	Zhang

[1] CBC = curtain backed cages
[2] DB = dropping boards under cages

1.3.4. Site Selection for Broiler Chickens

Broilers are raised in confinement barns on dirt or concrete floors covered with litter. Broiler barns are typically mechanically ventilated (MV). The locations for two sites with specific housing types were recommended for this study with consideration of the potential impact of climatic differences and the geographical density of poultry meat production (Table 1.3.4). However, only one of these sites – a two-barn broiler ranch in California – will actually be included in the NAEMS. A second site is in Kentucky, and is being tested in another study that is not part of the NAEMS. EPA will decide at a later date whether the Kentucky site's data can be integrated into the database that will be developed through the NAEMS.

Table 1.3.4. Broiler industry site (location in western U.S.)

SMP#	Site type	Ventilation type	Number of units measured	Manure collection	Manure storage	PI
West						
CA1B	Litter on floor	MV (tunnel)	2	Scraper	None	Zhang

1.3.5. Site Selection for Dairy

Milk production facilities include cattle (dry and lactating cows, and replacement heifers) and calves, and consist of freestall barns or open corrals and manure-storage facilities. The barns are most typically naturally–ventilated, except for some mechanically-ventilated freestall and tie stall barns. Only a small percentage of freestall barns are mechanically–ventilated, but the number is growing as tunnel ventilation is used to relieve heat stress in hot weather. Natural ventilation is exclusively used in freestall barns in more temperate regions, such as California. The naturally-ventilated barns range from partially-open barns with windows and flaps to fully-open free stalls. Open corrals are exclusively used in other parts of the country, such as New Mexico and the Texas panhandle. External manure storages generally consist of earthen basins that store undiluted manure collected from the barn after it goes through a solid separation process. Manure-collection systems generally are either scrape or flush. The measurements of emissions from manure storage systems and corrals will be conducted using micrometeorological techniques that are described in the companion QAPP on Open Source Emissions Measurements. The site selection criteria for the dairy industry are shown in Table 1.3.5.

Table 1.3.5. Dairy industry sites.

SMP #	Site Type	Ventilation type	Number of units measured	Manure Collection	Manure Storage[4]	Bedding Type[5]	PI
Northeast							
NY5B	Freestall	MV	2[3]	Scrape	Digester/ SS/Basin	SDS	Gooch
Midwest							
IN5B	Freestall	MV	2[3]	Scrape	Digester/ SS/Basin	SDS	Lim
WI5B	Freestall	MV	3	Flush	SP/Basin	Mattress/ shavings	Jacobson
West							
CA5B	Open freestall[2]	NV	2	Flush	SP/Basin	Soil/MS/ Almond shells	Mitloehner
WA5B[1]	Open freestall[2]	NV	2	Flush	SP/SS/Basin	MS	Ndegwa

[1] Barn sites that also have measured area sources, which are described in the open-source QAPP
[2] Cattle are free to walk from open freestall barn into dry lots between the barns.
[3] Monitored units include the milking center.
[4] SP = Settling pond
[5] MS = Manure solids; SDS = Separated digested solids

1.3.6. Study Boundary

The target population for the NAEMS, for which inferences will be made from the data collected in this study, consists of all AFOs in the continental U.S. within the dairy, pork, egg, and broiler meat industries. The overall distribution of the fourteen selected NAEMS barn monitoring sites is shown in Figure 1.3.1. The site's sizes range from 100,000 to 7,000,000 ft^2, and the barn's sizes range from 6,000 to 60,000 ft^2. At each site selected for monitoring in the NAEMS, from one to five buildings will be selected for air sampling. The descriptions of the sites, and the monitoring plans for each site, are described in Appendix B of the QAPP. The overall distribution of the NAEMS sites throughout the U.S. is as shown in Fig. 1.3.1. The descriptions of the sites, and the monitoring plans for each site, are described in Appendix A of this QAPP.

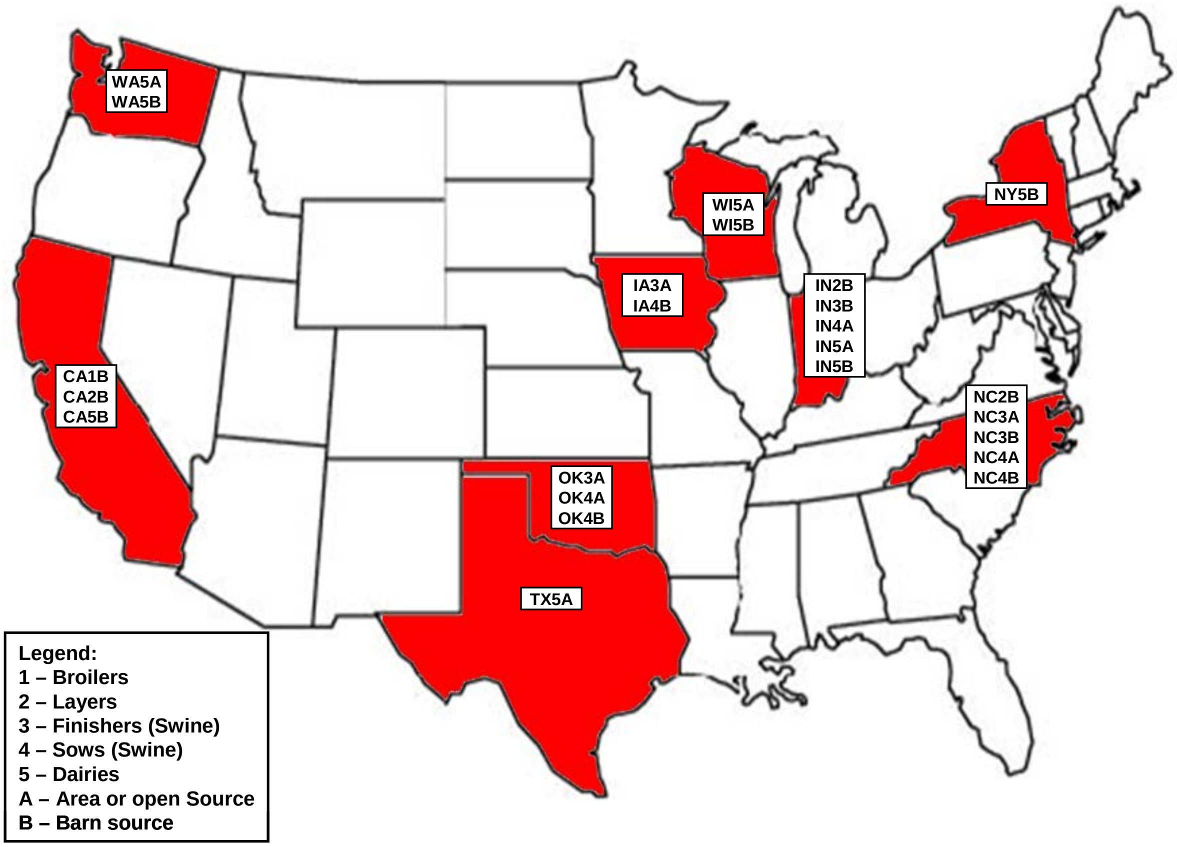


Figure 1.3.1. Locations of NAEMS sites (Barns and Open-Source).

The temporal boundary of this study is approximately three years after the first purchases of instruments and equipment. This time line includes 10 months for purchasing equipment and setting up the monitoring instrumentation at the farms (many of which will be set up well before 12 months), 24 months for collecting data from each site, and two months to decommission the last sites and prepare the final report. The 24-month duration of data collection assures that the project will meet the objectives of characterizing long-term emissions, and will adequately address the need for annual emission factors from animal facilities by regulatory agencies and others. Long-term measurements will also allow the recording of variations in emissions due to seasonal effects, animal growth cycles, and diurnal variations.

The spatial boundary for this study are the ventilation inlets and exhausts of the barns where the emissions will be measured. The emissions will be measured at representative exhaust points of the barn's ventilation systems. To obtain the building's net emission, the concentration of NH_3, H_2S, and VOCs will be measured at the barn inlet, and PM_{10}, $PM_{2.5}$ and TSP will be measured at a location close to the barn inlet where the instrument can be kept secure and accessible.

Some of the constraints to develop this study include:

- **Budget**: For example, more than one TEC TEOM (real-time PM monitor) per barn, and one gas sampling system and set of gas analyzers per site cannot be afforded.
- **Facility Size**: Large facilities tend to negatively affect data collection and data quality.
- **Ventilation Method**: Greater uncertainty and less data completeness occur with naturally-ventilated barns. Less uncertainty occurs with tunnel-ventilated barns.
- **Robustness**: Inability to measure each emission source at dairy sites (e.g. silage piles, digesters).
- **Participation**: Less than 100 percent participation in the Air Consent Agreement limited the available sites for selection, especially in some geographical regions.
- **Set-up Time:** Data collection is scheduled to begin four months after equipment can be purchased.
- **Location**: Distance between the principal investigators' offices and the sites.
- **Experience:** Expertise and experience of project directors, project managers, principal investigators, and their respective staff members.
- **Commitment**: Investigator's enthusiasm and dedication. They may have teaching loads and other research projects that may compete for their time and attention.
- **Producer Participation**: Effective producer collaboration and communication.
- **Vendors**: The willingness and ability of equipment and instrument manufacturers to prioritize the manufacture, delivery, pricing, and servicing of their products.

The inference limits for this study include the continental US. The validity of this inference was maximized by selecting representative sites in each region with major industries of interest, as described above.

1.3.7. On-Farm Measurements and Methods

An on-farm instrumentation shelter (OFIS) will house the equipment for measuring pollutant concentrations at representative air inlets and outlets (primarily by air extraction for gases), barn airflows, operational processes and environmental variables. Sampling will be conducted for 24 months, with averaged data logged every 15 s and 60 s (Section 2.1). Data will be retrieved with network-connected PCs, formatted, validated, and delivered to EPA for subsequent calculations of emission factors. A multipoint air sampling system in the shelter will draw air sequentially from representative locations (including outdoor air) at the barns and deliver selected streams to a manifold from which on-line gas monitors draw their sub samples. Sampling line lengths will vary from site to site, but the maximum will generally be on the order of 350 m. Previous experience (Heber et al., 2006) has shown that the residence time for gas in a 300-ft long, ¼″ inside diameter sampling line, flowing at 4 L/min, is approximately 45 s. Thus, the maximum residence time in a 350-m sample line would be approximately 3 min. Sample flow rates will be selected at each NAEMS site such that the maximum residence time in the longest line at the site is 2 min. This will be conducted by referencing Table 1.3.6, which presents residence time as a function of sampling line length and flow rate. Each point is sampled for a minimum of 10 min, allowing the gas analyzers to reach and maintain equilibrium. The distance from the analyzer manifold of the GSS to the analyzers themselves will never exceed 3 m (10 ft), which is compatible with the sample-drawing capabilities of each of the analyzers. Sample flow will also always exceed the total draw of the gas analyzers by at least 25%. A schematic representation of the equipment housed in each OFIS is given in Figure 1.3.2.

Concentrations of constituents of interest will be measured using the following methods:

1. NH_3 will be continuously measured using a photoacoustic infrared detector (SOP G7).
2. H_2S will be continuously measured with a pulsed-fluorescence detector (SOP G5).
3. Carbon dioxide will be continuously measured using a photoacoustic infrared detector (SOP G7 or SOP G3, depending on the site).
4. PM_{10} will be continuously measured in real time using the tapered element oscillating microbalance (TEOM) (SOP P1) for representative exhaust locations in the barn, and the TFS FH62-C-14 Beta Monitor (SOP P4), for inlet air locations.
5. TSP will be measured for one week every 8 weeks, starting with the first week of the study, using a TSP inlet head on the TEOM or Beta Monitor.
6. $PM_{2.5}$ will be measured with a $PM_{2.5}$ inlet head on the TEOM inside the barns and the Beta Monitor outside the barns (inlet concentrations). $PM_{2.5}$ will be measured for two weeks in winter and two weeks in summer at each site.
7. Total non-methane VOCs, ethanol, methanol, and methane will be measured continuously with a multi-gas photoacoustic infrared detector (SOP G7) at certain sites (a minimum of one per species).
8. An initial characterization study of barn VOCs will be conducted on one day during the first quarter after site setup is complete, at one site for each of the four species (IN5B for dairy, IN3B for swine, IN2B for layers, and CA1B for broilers). While total VOCs are continuously monitored using photoacoustic IR along with building airflow rate, VOCs will be sampled with duplication at two barns (at the primary representative exhaust fan location, as defined in the site monitoring plan for that site). Three sampling methods will be evaluated: sorbent tubes (SOP V1) and Silcosteel canisters (SOP V2) for general VOCs, and all-glass bubblers (SOP V3) for amines. Each sorbent tube or canister sample will be evaluated using gas chromatography – mass spectrometry (GC-MS) (SOP V4 or V6, respectively); amines collected in bubblers will be analyzed by ion chromatography (IC) (SOP V5). The 20 analytes by mass for each species will be identified during this initial study. Following consultation with EPA to determine which of these analytes are present in sufficient quantity to warrant further monitoring, one or more sampling methods (sorbent tubes, canisters, and/or bubblers) will be chosen, and will be employed for the remainder of the study at sites with that species of animal.

Table 1.3.6. Residence time in sampling lines, as a function of sampling line length and sampling pump flow rate.

Tube length, ft	Flow rate (L/min)			
	4	5	7	8
0 (GSS only)	2.4	1.9	1.4	1.2
100	17	13	9.6	8.4
200	31	25	18	16
300	46	37	26	23
500	75	60	43	37
700	104	83	59	52
1000	147	118	84	74

Notes:
Tubing ID = 0.25 in (0.0064 m). Tubing internal volume = 0.97 L/100 ft
Sampling manifold is 20 in long, with a 3/8″ ID, for a volume of 0.036 L; Sampling pump has a volume of 0.06 L.

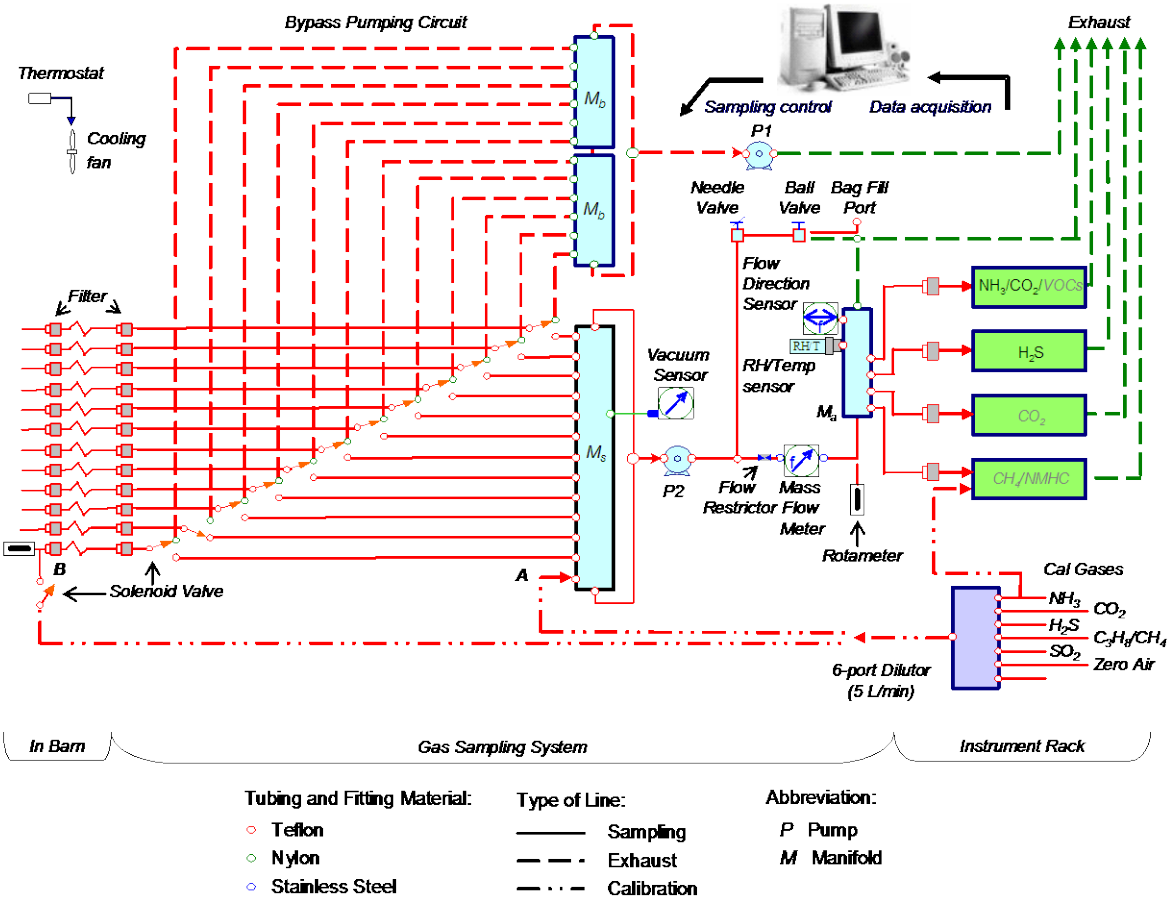


Figure 1.3.2. Schematic of GSS and instrument configuration. H_2S, CO_2, and $NH_3/CO_2/VOC$ analyzers have internal pumps, and CO_2 analyzers have internal filters.

9. Two approaches will be used to evaluate acetaldehyde concentration during the initial characterization study. The first approach will be the standard GC/MS analysis of canister and/or sorbent tube samples. However, if the GC/MS method is observed (for example in analyte stability tests with the canisters) to be unsuitable for acetaldehyde, collection of bag samples followed by quantitative analysis with FTIR will also be attempted. If acetaldehyde is not observed by either method, it will not be analyzed during subsequent measurements.
10. By the end of the first overall quarter of data collection after all sites are set up, the SA will report results of the initial characterization to EPA with recommendations on the appropriateness and validity of the selected methodologies.
11. Quarterly VOC samples using the selected VOC sampling method(s) will occur at all sites. Continuous monitoring for total non-methane VOC, and methanol and/or ethanol, as described above, will be conducted at a minimum of one site per species for the duration of the study.

Mechanically ventilated barn airflows will be estimated by continuously measuring fan operational status and building static pressure to calculate fan airflow from field-tested fan performance curves and by directly measuring selected fan airflows using anemometers.

Specific processes that directly or indirectly influence barn emissions will be measured including animal activity, manure management/handling, feeding, and lighting. Environmental parameters including heating and cooling operation, floor and manure temperatures, inside and outside air temperatures and humidity, wind speed and direction, and solar radiation will be continuously monitored. Feed and water consumption, manure production and removal, mortalities, and animal production will also be monitored. As noted above, samples of feed, water, and manure will be collected and analyzed for total nitrogen. These data will enable the development and validation of process-based emission models in the future.

Monitored farms will be further characterized using farm management data. Farms will provide vital management information regarding ventilation controls/management and scheduling of barn activities such as manure management, animal load out, animal treatment, or feeding.

1.3.8. Issues Related to the Analytical Approach

There are several issues about the on-farm methods and instrumentation that relate to the development of the data quality objectives for the measurements.

1. Hourly and daily arithmetic averages will be calculated for each pollutant.
2. There are multiple sampling locations per gas analyzer and each location is sampled for one sampling period per sampling cycle. The duration of the sampling cycle depends on the sampling period, the number of sampling locations per barn and the number of barns monitored per site. The barn gas emission rate will be calculated every minute using the barn's total ventilation rate and either the concentration measured during the same minute or linearly interpolated between two measured concentrations.

3. There will be only one sampling location per PM analyzer, which will monitor PM_{10}, $PM_{2.5}$ or TSP continuously with 1-min time resolution.
4. The pollutant concentrations will be measured at the inlet and at the exhaust of each barn or manure shed (gases only) for NH_3, H_2S, VOCs (NMHC), and PM.
5. For mechanically ventilated barns, the emission rate is the sum of the emission rates of each emission stream. The emission stream is defined as one or more fans for which one sampling location represents the exhaust concentration. The maximum number of emission streams is equal to the number of ventilation fans in the barn, which ranges from 3 to about 100 depending on barn capacity.
6. A practical maximum number of emission streams is 18 per site for gas sampling and one per barn for PM sampling.
7. Whereas fan operation is monitored continuously, the concentration of the emission stream is sampled once per sampling cycle.
8. In naturally ventilated barns, the concentration will be measured in each sidewall opening and at the ridge opening, for a total of at least three gas sampling location groups per barn.
9. The measurements will be obtained in a continuous mode during two years with exception of the VOC speciation sampling data.

The target population consists of all possible samples of each one of the six pollutants (Table 1.3.7). For gas samples, the total target population includes each one of the 10-min averaged emission rates times the number of emission streams being sampled:

Sampling units (SU) per day = $1440\frac{\min}{day} * \frac{1SU}{10\min} = 144 SU/day$ per emission stream.

Number of potential SU per location (NPSU/L) = $144\frac{SU}{d} * 365\frac{d}{yr} * 2yrs = 105{,}120$ SU

Table 1.3.7. Number of sampling units for each compound.

Parameter	Units	Sampling units	NPSL	NASL/ barn	NPSU/L‡
Gas (NH_3, H_2S, VOC)	Min	10	3-100	1-6	105,120
PM	Min	10	3-100	1	105,120

NPSL: Number of potential sampling locations
NASL: Number of actual sampling locations
NPSU/L: Number of potential sampling units per location (during the 2-yr study). These values include the sampling of the barn inlet but does not consider the down time for calibration or maintenance of the instrument.

Temporal and spatial uncertainty is influenced by the size of the barn given these assumptions:

1. There is no temporal uncertainty if data is recorded every minute; uncertainty is therefore the lowest with continuous PM measurements, and the greatest with gas measurements and long sampling cycles.
2. Spatial uncertainty is the lowest when all the barn fans are monitored, and increases as the distance between monitored and unmonitored fans increases.
3. The distance between fans increases with barn length.
4. PM is measured in only one location per barn.

5. Gases are measured at 1 to 6 locations per barn with a greater number of locations as the size of the barn increases.

While the temporal uncertainty of PM measurements remains low with continuous monitors, the spatial uncertainty of PM measurements increases with barn size. For example, with the constraint of one PM monitor per barn, the PM monitor must be placed at only one end of a tunnel-ventilated barn with fans on both end walls. In the same barn, gas sampling can be conducted at both ends sequentially which increases temporal uncertainty and results in a smaller increase in spatial uncertainty as compared with PM.

1.3.9. Project Schedule

The anticipated schedule for the NAEMS is shown in Table 1.3.8. Site selection is complete, and a list of detailed site monitoring plans for all sites is included in Appendix A of this QAPP. Purchase of equipment will begin immediately upon approval of the QAPP, and is expected to be completed by early in month 7. Initial inspections and calibration of equipment will begin as soon after the initiation of purchasing as possible (i.e. as soon as equipment is received), and will be complete by early in month 8. Training of university PIs and their designated NAEMS staff member(s) at PAAQL will take place in month 5. The combination of these events (verification of equipment performance and training of PIs) will allow deployment and placement of the mobile labs to occur during months 5-12. All mobile laboratories will be in-place and set up by the end of month 12, at which point (earlier on a case-by-case basis) data collection will begin. Data collection will continue for 24 months at each site. At the conclusion of data-collection at the last site, two months will be devoted to a) decommissioning the last sites and b) preparing the final report. The final report for the project will be submitted by the end of month 38.

1.4 Quality Objectives for Air Emissions Data

The planning team formed to develop data quality objectives (DQO) included the Science Advisor, Dr. Albert Heber, the NAEMS Operations Manager, Dr. Bill Bogan, the NAEMS Quality Assurance and Control Manager, Dr. Juan Carlos Ramirez, and Assistant Project Managers Dr. JiQin Ni, and Dr. Teng Lim.

The overall data quality objective (DQO) of this research is to generate data of sufficient quality to allow accurate quantification of the aerial emissions of six contaminants – NH_3, H_2S, volatile organic compounds, and particulate matter emissions (TSP, PM_{10}, and $PM_{2.5}$) – from representative types of dairy, swine, egg and broiler buildings. More specifically, AFOs may be subject to the notification requirements of CERCLA for releases of hazardous substances from their facilities that exceed the reportable quantity (RQ) for that substance. Among these substances are NH_3 and H_2S, both with RQ thresholds of 100 pounds per day or 18.3 tons per year. These RQs are the emissions during any 24-h period (the maximum daily emissions).

The U.S. EPA will aggregate the data collected by this study with other available data to develop tools to estimate the air emissions from livestock production. These tools will allow identifying and quantifying exceedances of CAA, CERCLA and EPCRA thresholds. The type of the study is

Table 1.3.8. Project Schedule for NAEMS.

	YEAR 1												YEAR 2												YEAR 3										
Tasks & Benchmarks	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Purchase equipment	M1	■	■	■	■	■	■																												
Calibrate & test equipment	■	■	■	■	■	■	■	■																											
Train PIs					M3	■	■	■	■	■	■	M4																							
Outfit mobile labs (at PAAQL)	■	■	■	■	■	■																													
Deploy and set up mobile labs (on-site)			■	■	■	■	■	■	■	■	■	■																							
Develop CAPECAB software	■	■	■	■	■	■	■	■	■	■																									
Initial site VOC characterizations													■	■																					
Revise/finalize VOC monitoring plans													■	■	M6																				
Collect barn data						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Collect lagoon data									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Internal (PAAQL) site audits										■	■	■	■	M5								■	■	■	■	M7									
Disassemble mobile labs																															■	■	■	■	■
Analyze data						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Establish and maintain NAEMS website	■	M2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Reports (Interim)			■			■			■			■			■			■			■			■			■			■			■		
Report (Final)																																			

Milestones:

M1 – Begin purchasing of equipment

M2 – NAEMS website on-line

M3 – Convene training session for PIs (and any available site engineers) at PAAQL

M4 – Complete on-site setup of OFIS’s at all sites and on-site training component for the Pis

M5 – Complete initial audits of all sites, during first quarter after each site's setup

M6 – Complete initial VOC characterizations, implement any necessary revisions to the QAPP for VOC analysis

M7 – Complete all internal mid-point site QA audits

M8 – Complete disassembly of mobile labs

M9 – Complete data analysis and submit final report estimation but the information will support decisions of the EPA related to compliance. For this type of intended use it is necessary to specify Performance Metrics and Acceptable Levels of Uncertainty (EPA QA/G-4, 2006, page 46).

1.4.1. Information Inputs

The primary measurements that will be collected from the NAEMS are air emission data, which include hourly, daily, monthly, and annual emission rates of NH_3, H_2S, total non-methane VOCs, total suspended particulate (TSP), PM having an aerodynamic diameter less than 10 µm and 2.5 µm (PM_{10} and $PM_{2.5}$, respectively) from each farm building.

The emission rates are calculated values based on measurements of pollutant concentration and barn ventilation rates, and these measurements depend on other primary (or independent) measurements. For example, ventilation rate depends on the differential static pressure between the indoor pressure and the ambient pressure, and the calibration and operating characteristics of each one of the fans in the barn. To standardize the moist ventilation rate (Q) to dry and STP conditions (20°C and 1 atm pressure), it is necessary to include the measurement of air temperature, pressure, and total moisture content. To calculate the air moisture content, it is necessary to measure the relative humidity.

In the same way, to calculate the pollutant concentration it is necessary to include other independent parameters. The pollutant emission rate will be expressed in mass units per unit of time. This conversion applies to all the pollutants. The gaseous pollutant concentration is obtained analytically in ppm or ppb and converted to mg per unit of volume. The PM concentrations are obtained already in the proper mass unit. For both gas and PM, their sampling volumes need to be converted to STP, which necessitates temperature and barometric pressure measurements to convert them to STP conditions.

Emission rates will also be expressed as mass per animal unit (or equivalent units). This will require the collection of farm information obtained from the producer. The producer will provide additional information that will facilitate the calculations of pollutant mass balances. This information will include, among others, nutrient volumes and composition, water consumption, animal inventories and mortalities. Manure will be sampled periodically, and analyzed to determine pH and concentrations of moisture, total Kjeldahl nitrogen, ammonia, nitrates, nitrite, and ash.

A complete list of the specific measurements and information that are required for this study are shown in Table 1.4.1. The measurement methods were selected by Dr. Albert Heber, the NAEMS SA, based on recommendations described in the NAEMS Protocol (Federal Register, 2005). As stated in the NAEMS Protocol, the SA may choose the measurement techniques that are most appropriate for the study; however, the final selection will be “dependent upon EPA approval of a comprehensive study design and budget.” More specific information about the measurement equipment that will be used in the NAEMS can be found in the NAEMS SOPs (listed in Appendix B).

1.4.2 Conceptual Model of the Environmental Problem

The problem that the NAEMS is addressing consists primarily of quantitating air emissions from livestock production facilities. The scope of the NAEMS is somewhat broad, covering four livestock species and fourteen (14) measurement sites; therefore describing the conceptual model is not straightforward. However, this exercise helps to illustrate the sources of variation in emissions and the factors that affect air emission measurements from livestock facilities. The production systems are a dynamic and active system of infrastructure, machinery, people and animals (Figure 1.4.1). The barns typically have the following systems:

1. Environmental monitoring, heating, ventilating and cooling systems
2. Equipment storage
3. Animal penning, handling and treating
4. Product collection, handling, treating, and storage
5. Feeding systems
6. Waste collection, handling, treating and storage

The inputs to a livestock production system include feed, water, new animals, and bedding. The feed and the bedding emit air pollutants to various degrees during storage and handling prior to their entry into the barn. The animals respire gases, and convert feed, water and air into manure, mortalities, and animal products, all of which emit air pollution (Fig. 1.4.1).

The livestock emission problem as it pertains to the NAEMS is conceptualized in Fig. 1.4.2. Livestock facilities emit a wide variety of air pollutants, some of which are odoriferous. Particulate matter is emitted across all three major regulated size fractions and most of the mass of particulate matter is greater than 10 µm in diameter. The PM emitted from barns contains viable particles. Barns emit NH_3 and H_2S in significant quantities. The total mass of volatile organic compounds consists of major VOCs such as ethanol, methanol, acetic acid and acetaldehyde. The greenhouse gases including methane, nitrous oxide, and carbon dioxide are also emitted in varying quantities depending on species and manure handling methods. A significant amount of water is emitted from barns making measurement and control of pollutants a greater challenge, especially when coupled with the emissions of particulate matter.

The sources of the air pollutant emissions in the barns include the animals themselves, feed, bedding and manure, depending on the time that each source is in the barn. Some barns allow animals to walk outside, e.g. freestall dairy barns with outdoor exercise lots. The feed and bedding at some livestock facilities is stored outside before delivery into the barns, e.g. dairies with outside forage piles and stockpiles of bedding (e.g. separated manure solids). The manure accumulation times in a barn varies from an hour in a scraped dairy freestall to over a year in a high rise layer barn.

Unlike many other industrial sources of air pollution, the diversity of sources among livestock facilities is very large because of the significant effects of diet, outside temperature, manure handling, animal growth and animal size. The spatial diversity of the emission sources on production sites also varies among species. Broiler sites have the least diversity because virtually all the air pollutants emit from the barn and all barns are similar in manure management (floor

Table 1.4.1. NAEMS Measurement Quality Objectives (MQOs).

Variable	Measurement Method	Reporting Units	Required Operating Range	MDL	Locations	Data Collection Periods							
						Data Reading (s)	Data Record (s)	Sampling Period, min.		Sampling Interval, min.		Interpolating Interval, min	
								Exhaust	Inlet	Exhaust*	Inlet	Exhaust	Inlet
NH_3	Infrared photo-acoustic	ppb	200,000	200	Inlet Exhaust	1	15/60	10	30	180	720	300	1440
H_2S	Pulsed fluorescence (SO_2)	ppb	10,000	50	Inlet Exhaust	1	15/60	10	30	180	720	300	1440
NMHC, CH_4, ethanol, methanol	Infrared photo-acoustic	ppb	5,000	20-200	Inlet Exhaust	1	15/60	10	30	180	720	300	1440
VOCs	GC/MS (mass spectrometer)	ppb	5,000	<10	Inlet Exhaust	24 h (canisters)	24 h (canisters)	24 h (canisters)	24 h (canisters)	3 mo	3 mo	3 mo	3 mo
VOCs (amines)	IC	ppb	5,000	<10	Inlet Exhaust	2h	2h	2h	2h	3 mo	3 mo	3 mo	3 mo
CO_2	Infrared photo-acoustic	ppm	300 to 10,000	100	Inlet Exhaust	1	15/60	10	30	180	720	300	1440
PM2.5	Tapered element oscillating microbalance (TEOM)	µg/m3	1,000	10	Inlet Exhaust	1	15/60	C	C	1 mo/2 yr	1 mo/2 yr	N/A	N/A
PM2.5 (audit)	Time integrated gravimetric	µg/m^3	1,000	5	Inlet Exhaust	48 h	48 h	2880	N/A	N/A	N/A	N/A	N/A
PM10	Tapered element oscillating microbalance (TEOM)	µg/m^3	10,000	10	Inlet Exhaust	1	15/60	C	C	7 wk / 8 wk	7 wk / 8 wk	N/A	N/A
TSP	Tapered element oscillating microbalance (TEOM)	µg/m3	30,000	10	Inlet Exhaust	1	15/60	C	C	1 wk / 8wk	1 wk / 8wk	N/A	N/A
Fan air speed	Vane anemometer	m/s	10	1	Fan	1	15/60	C	C	C	C	N/A	N/A
Fan run time	Vibration, current or rpm sensor, relays, whisker or sail switch, computer control signal	% of data record interval	100	2	Fan	1	15/60	C	C	C	C	N/A	N/A
Air velocity	Ultrasonic anemometer 3-D	m/s	40	0.01	Vents	0.1	30	C	C	C	C	N/A	N/A
Barn static pressure	Capacitive/diaphragm sensor	Pa	100	1	Indoor	1	15/60	C	C	C	C	N/A	N/A
Temperature	Thermistor or RTD	°C	0 to 50	0	Exhaust	1	15/60	C	C	C	C	N/A	N/A
Temperature	Thermocouple type T	°C	10 to 40	10	Indoor	1	15/60	C	C	C	C	N/A	N/A
Relative humidity	Thin-film capacitor (TFC)	°C	100	20	Exhaust	1	15/60	C	C	C	C	N/A	N/A
Process run time	Mechanical relay contacts Passive IR detection, etc.	% of data record interval	100	2	Manure Belts Scrapers Flushing Feeders Lights	1	15/60	C	C	C	C	N/A	N/A
Temperature	Thermistor/RTD, Passive shielded	°C	-35 to 45	-35	Ambient	1	15/60	C	C	C	C	N/A	N/A
Relative humidity	TFC, Passive shielded	°C	100	10	Ambient	1	15/60	C	C	C	C	N/A	N/A
Atmospheric pressure	Electronic barometer	atm	0.8 to 1.1	0.8	Ambient	1	15/60	C	C	C	C	N/A	N/A
Solar radiation	Radiometer	W/m^2	1500	10	Ambient	1	15/60	C	C	C	C	N/A	N/A
Wind speed	Cup anemometer	m/s	60	0.25	Ambient	1	15/60	C	C	C	C	N/A	N/A
Wind direction	Vane	degrees	360	5	Ambient	1	15/60	C	C	C	C	N/A	N/A

Table 1.4.1. NAEMS MQOs (*continued*)

Variable	Measurement Method	Reporting Units	Required Operating Range	MDL	Locations	Data Collection Periods								Data Completeness % Valid	Data Category
						Data Reading (s)	Data Record (s)	Sampling Period, min.		Sampling Interval, min.		Interpolating Interval, min			
								Exhaust	Ambient	Exhaust*	Ambient	Exhaust	Ambient		
Animal inventory	Producer	head	N/A	1	Barn	Daily	Daily	N/A	N/A	N/A	N/A	N/A	N/A	75	1
Animal mortality	Producer	head	N/A	1	Barn	Daily	Daily	N/A	N/A	N/A	N/A	N/A	N/A	75	1
Animal weight	Truck balance	kg	N/A	1	Truck	BE	BE	N/A	N/A	N/A	N/A	N/A	N/A	75	1
Manure volume	Producer estimate	gal	N/A	N/A	Barn	BE	BE	N/A	N/A	N/A	N/A	N/A	N/A	75	4
Manure pH	Electrochemical pH meter	pH units	0 to 14	0.01	Manure	Varies	Varies	Varies	Varies	Varies	Varies	Varies	Varies	75	4
Manure solids	Gravimetric	wt %	0 to 100	0.1	Manure	Varies	Varies	Varies	Varies	Varies	Varies	Varies	Varies	75	4
Manure NH_3 & N contents	Kjeldahl/titrimetric	wt %	0 to 5	0.01	Manure	Varies	Varies	Varies	Varies	Varies	Varies	Varies	Varies	75	4
Feed, bedding, milk, eggs, meat N contents	Kjeldahl/titrimetric	wt %	0 to 5	0.01	Manure	Varies	Varies	Varies	Varies	Varies	Varies	Varies	Varies	75	4
Feed input	Various. Truck weight	kg	100,000	10	Barn	Daily	Daily	N/A	N/A	N/A	N/A	N/A	N/A	75	4
Animal activity	Passive infrared detector	VDC	1	0.1	Barn	1	15/60	C	C	C	C	N/A	N/A	75	4
Sampling manifold pressure	Electronic	Pa	±20,000	±500	GSS	1	15/60	C	C	C	C	N/A	N/A	75	5
Sample flow rate	Mass flow meter	L/min	10	0.1	GSS	1	15/60	C	C	C	C	N/A	N/A	75	5
Laboratory temperature	Thermocouple	°C	-40 to 50	-40	Laboratory	1	15/60	C	C	C	C	N/A	N/A	75	5
Laboratory pressure	Electronic	Pa	±50	±1	Laboratory	1	15/60	C	C	C	C	N/A	N/A	75	5
Filter differential pressure, dP	Diaphragm	%	100%	5	Instrument	1	15/60	C	C	C	C	N/A	N/A	75	5
Temperature in raceway	Thermocouple	°C	-40 to 100	-40	Raceway	1	15/60	C	C	C	C	N/A	N/A	75	5

Notes:

* Depends on total number of locations. This is the maximum

Data Categories
1 Critical
2 Essential
3 Important
4 Auxiliary supporting data
5 QAQC variable

C: continuous

BE: Beginning and end of growth period.

MDL: Method detection limit

Data reading: Data is read every time period indicated

Data record: The data average during the time period indicated is recorded.

Sampling period: Period of time used to sample one location

Sampling interval: Period of time between sampling periods. It depends of the number of shared sampling locations. If there is only one location, sampling period and interval are the same.

Interpolating interval: Period of timeduring which there is no direct data measurement, and the data is obtained by interpolating the values between the initial and the final measurement and the data

DC: Data completeness, Number of valid data values collected a s a percentage of the scheduled measurements.

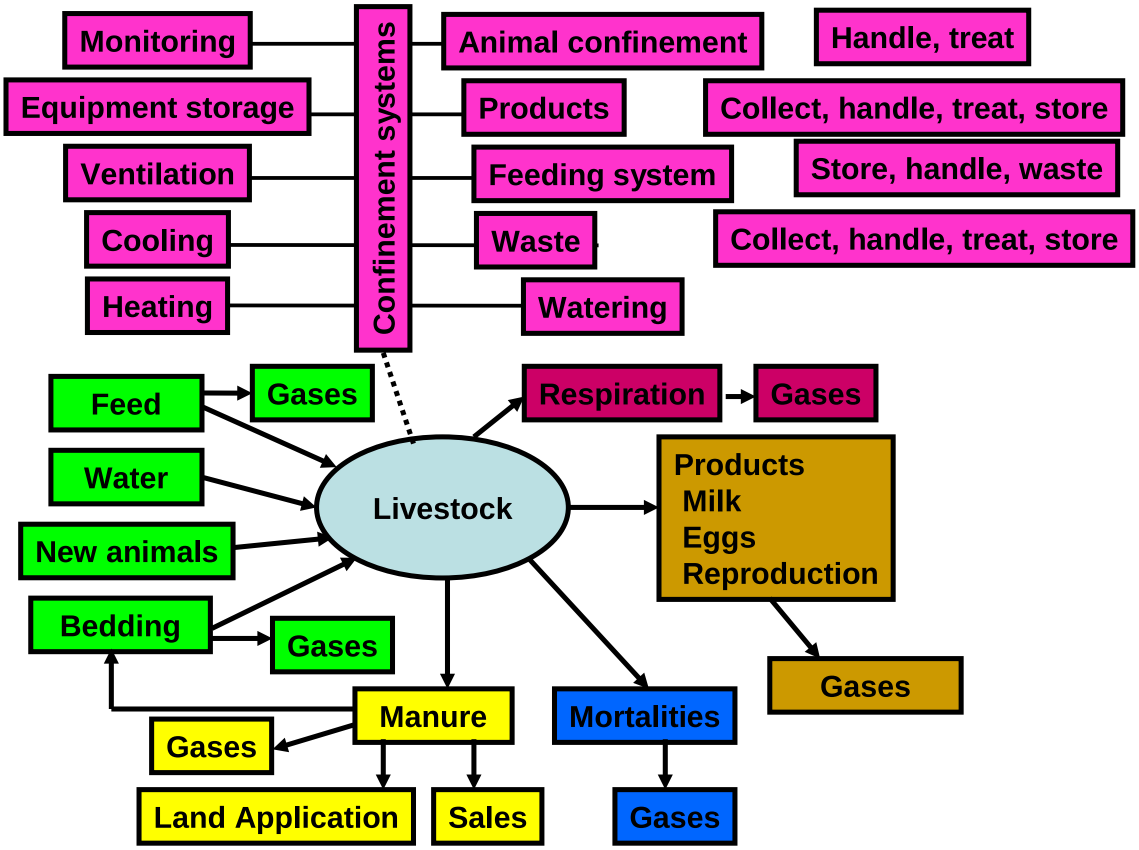


Figure 1.4.1. Various systems at confined livestock production facilities.

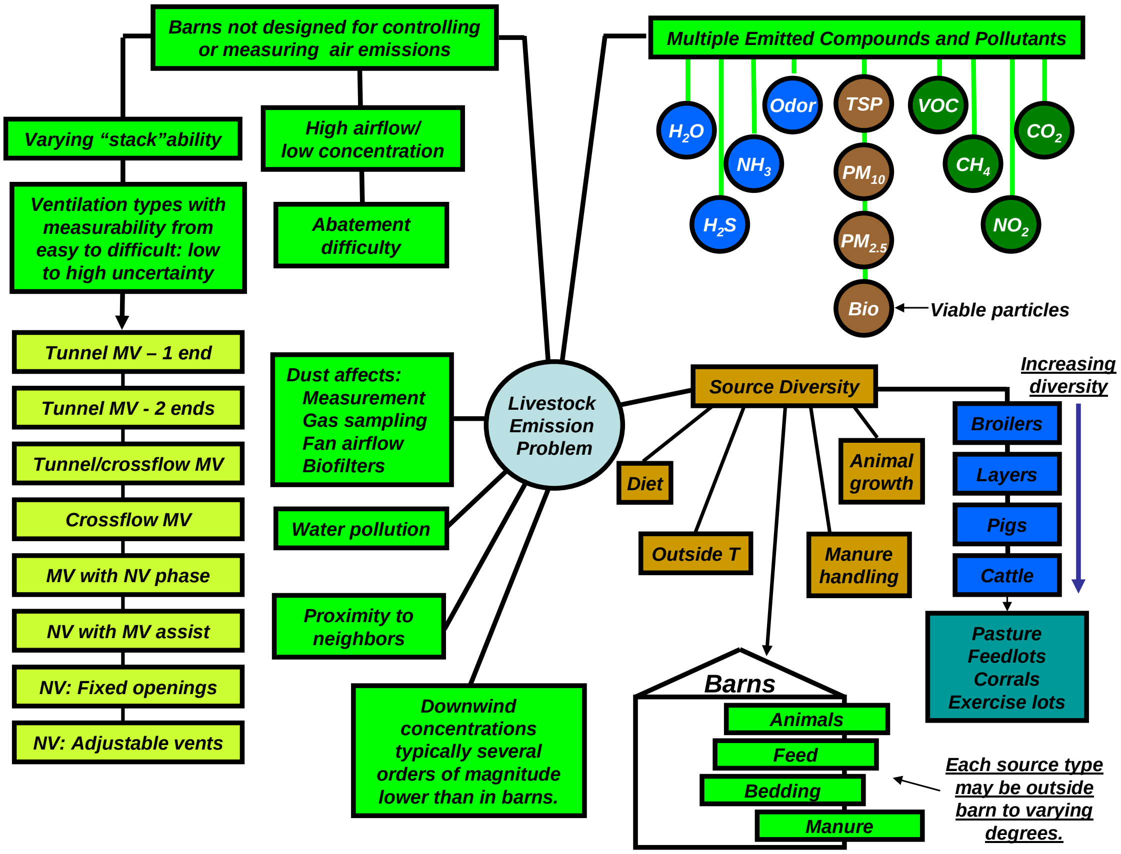


Figure 1.4.2. Measurement of farm air emissions.

litter) with no outside manure storage. Dairy facilities have the greatest farmstead diversity because of outside feed, bedding and manure storage and wide variance of site layouts ranging from tunnel ventilated freestall barns to open corrals.

Livestock barns are designed without consideration of the need for emission measurements, as compared with industrial stacks. Most barns have a multiplicity of horizontal wall-mounted exhaust fans that are characterized by low pressure and high airflow. The fans are typically protected by short weatherproof shrouds that fall way short of the EPA definition of a stack for stack testing purposes. Barns have a variety of configurations with some barns that are more conducive to emission measurements than other barns. Listed from most to least conducive, the following types of barns exist in the U.S.:

1. Tunnel ventilation year around with all the fans banked at one end of the barn (e.g. site NC3B).
2. Tunnel ventilation year around with fans banks located at each end of the barn (e.g. site IN5B)
3. Tunnel ventilation during hot weather and crossflow ventilation in cooler weather with one or more fans located along the length of the barn (e.g. site IA4B).
4. Crossflow mechanical ventilation, fans distributed on one or both sidewalls (e.g. site CA2B).
5. Mechanical ventilation with a natural ventilation phase at certain times.
6. Natural ventilation with a few fans to assist ventilation in cold weather.
7. Natural ventilation with fixed ventilation openings (e.g. site CA5B).
8. Natural ventilation with adjustable ventilation openings (e.g. site WA5B).

Mechanically ventilated barns are more likely to result in emission measurements that have less uncertainty than naturally ventilated barns because of the greater consistency of airflow, thus most of the barns in this study will be mechanically ventilated. Some of the measurement issues with mechanically ventilated barns are as follows:

1. Airflow is stepped up from low winter rates to high summer rates as outdoor temperature increases by staging the exhaust fans in the barn.
2. The number of fans in a barn ranges from 3 to 100 and they can be single speed, multiple speed or variable speed.
3. EPA Method 5 criteria cannot be met in the short shrouds that protect the fans.
4. Exhaust fans are typically distributed, banked or isolated in the barn. Sometimes the fans are located in the ridgeline of the roof.
5. The negative pressure caused by the exhaust fans can force air into the barn from attached structures such as manure sheds, milking parlors and other sheds
6. The fans are designed for low pressure operation (i.e. 5 to 30 Pa) and fan airflow is therefore affected significantly by wind, obstructions and dust buildup.

The dairy industry utilizes naturally ventilated barns exclusively in some parts of the country. The ventilation of naturally ventilated barns has the following characteristics:

1. Natural ventilation airflow induced by thermal buoyancy depends on the height of the barn, the density of the live mass in the barn and the temperature difference between inside and outside the barns. Dairy barns are low density and are kept cool, even in the winter.
2. Natural ventilation airflow induced by the wind depends on wind direction, and vent area and orientation.
3. Some barns have circulation fans inside the barn that can create strong internal airflow patterns.

Barn air pollutants come from animals, feed, bedding and manure, and ventilation air picks up and carries them out of the barn. These sources may also emit from the facility outside the barn, depending on the type of farm. Except for dairy farms where cows can sometimes walk outside into exercise lots and to and from the milking parlor, animals and birds are typically inside the barn 100% of the time. Swine and poultry feeds are typically stored outside in bins for one or more days but dairy forage is typically stored in large piles at the facility for several months. Except for alternative housing, bedding is not typically used in swine and layer barns and will not be used in the NAEMS sites. However, bedding is always used in dairy freestall barns and broiler barns (litter on floor). Dairies store bedding outside for an extended period before replacing the bedding in the barns on a daily basis. Similarly, dairies remove manure from the barns on a daily basis but typically have long-term outdoor manure storage. Swine and layer barns either remove manure often or have long term storage inside the building. Broiler manure is removed from the barn to an off-site location or to the land as fertilizer.

The study includes AFO operations from three different species – dairy, swine and poultry (broilers and egg-layers). In the “Response to Public Comments on the Animal Feeding Operation Air Agreement” (EPA, 8/2005), EPA stated that the AFO processes include a wide variety and that the mechanism to generate emissions from these operations is complex. Also, in the same document, EPA added that is impractical to expect that sufficient data could be collected in a timely manner to accurately characterize every different type of operation and practice in the AFO industry. The characteristics of the farms described in the consent agreement protocol were defined by a group of technical experts from the EPA and several universities, who concluded that “monitoring these types of operations will provide sufficient data to get a valid sample that is representative of the vast majority of participating AFOs” (EPA, 8/2005). Data will undergo quality assurance review, which will assess, among other things, representativeness, completeness, comparability, and accuracy.

1.4.3 Data Representativeness

Data representativeness is a measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point or for a process condition or environmental condition (USEPA. 1998. *EPA Guidance for Quality Assurance Project Plans*. EPA QA/G-5). Recent studies have shown that seasonal variations in gas and dust concentrations and emissions from confined animal buildings (CAB) are significant. For instance, in the case of gas emissions, NH_3 emission per animal unit in July was about four times as high as in April, and H_2S emission had even larger variations. To obtain sufficiently representative measurement data, and to fully understand the effect of season on air emissions, measurement will cover all four seasons of each of two consecutive years. To fully achieve this goal, the measurements will be conducted continuously at the same site, and in the same buildings. Otherwise, the seasonal effect cannot be effectively studied due to variations of site, building structure, farming practice, etc. Data representativeness will thus be assured by the overall sampling design, which includes high-frequency sampling and a 24-month measurement period. Furthermore, measurements are conducted at two to four similar side-by-side barns at each site, which provides a degree of replication for each site. In addition, in the case of PM emissions, total suspended particles (TSP) will be sampled using an isokinetic multipoint system. This system uses three sampling heads across the exhaust fan inlet. The sample heads are positioned in the location and orientation that meets the head-designed sample air velocity within 10% (SOP P2).

Variable and multiple ventilation exhaust air streams and potential significant background concentrations at CAB present a challenge to the selection of locations for measuring pollutant concentrations that will adequately represent the mean concentration of the total building exhaust. Data representativeness within buildings will be assured by careful selection of two to four exhaust locations (instead of only one location), and by measuring concentrations at the ventilation inlet in addition to the exhaust outlets. The allocation of the exhaust measurement points for optimal representativeness must be conducted on a site-by-site basis because of wide variations in building layouts and configurations (see the individual site monitoring plans listed in Appendix A).

1.4.4 Data Completeness

Data completeness is a measure of the amount of valid data obtained from a measurement system, expressed as a percentage of the number of valid measurements that should have been collected (*i.e*., measurements that were planned to be collected) (USEPA. 1998. *EPA Guidance for Quality Assurance Project Plans*. EPA QA/G-5). Data completeness will be achieved by assuring that a minimum of 75% of the scheduled sampling results in valid data. More data will be collected if this criterion has not been met for one or more particular sites, by continuing data collection at the site(s) until 18 months (i.e. 75% of 24 months) of valid data has been collected. A greater percentage does not seem reasonable, given the potential for lightning strikes, equipment breakdowns, university schedules, and farm-related problems, and the limited budget for additional makeup monitoring.

Data completeness will be assured by:

1) utilizing a dedicated mobile laboratory at each individual site, thus eliminating time losses due to moving from site to site
2) using properly maintained and reliable instrumentation
3) maintaining a ready supply of spare parts
4) installing electrical backups such as uninterruptible power supplies

5) regular calibration checks
6) frequent remote access to the DAQ computer to download data
7) timely review of collected data to quickly identify problems
8) producer collaboration

On a site-by site basis, substitution rules for instances where one or more measurements are deemed invalid may be implemented. For sites where this is possible, this measure will also increase the completeness of the data. For example, if a sensor failure results in a period of invalid temperature measurements for a sampling point, it may be acceptable to substitute a temperature measurement from a nearby sampling point, if both sampling points are subject to the same conditions. Similarly, default values for relatively constant variables (i.e. atmospheric pressure) may be acceptable for replacing short periods of invalid data. Any use of substitution or default values will be reported in the quarterly report.

1.4.5 Data Comparability

Data comparability will be maintained by:

1) employing similar analytical methods and sampling protocol used in recent emission studies in confined livestock and poultry facilities
2) comparing measurements with previous mass balance and emissions rate estimates reported for similar swine, dairy, egg and broiler buildings
3) comparing NH_3 emissions with mass-balances of N calculated for each test building
4) using consistent, common equipment, instrumentation, common metric, quality assurance methods, and protocols

The last of these will be ensured through two mechanisms (Section 1.5): a) extensive training sessions that will be mandatory for all University PIs and all of their staff members who will be involved in the day-to-day operations at the sites, and b) the establishment of Standard Operating Procedure (SOP) documents for all important procedures.

1.4.6 Accuracy, Bias and Precision

Accuracy is a two-part quality indicator, and includes both bias (systematic error) and precision (random error). **Bias** or systematic error is a measure of the closeness of an individual measurement (or the average of a number of measurements) to the true value (EPA QA/G5). Accuracy of the measured value will be expressed in terms of the percentage decrease or increase from the known value and in terms of the absolute difference between the measured and known value (for example, when comparing a certified gas concentration with the value obtained from an analyzer). **Precision** is a measure of agreement among replicate measurements of the same property, under prescribed similar conditions (same source). Precision is defined as the standard deviation of replicate measurements of the known pollutant gas expressed as a percentage difference from the average value. Bias and precision will be maintained by regular calibration of instruments involving challenging the measurement system to perform replicate analyses of samples with certified concentrations (Section 2.6), or using NIST traceable instruments (for example, flow meters), or using collocated instruments (for example, for PM samplers or sonic anemometers).

1.4.7 Data Quality Objectives and Indicators

The data quality objectives (DQOs) for this study of barn emissions are as follows:

1. Measure gas emissions from MV barns with total relative uncertainty of ±27%
2. Measure PM emissions from MV barns with total relative uncertainty of ±32%
3. Measure gas emissions from NV barns with total relative uncertainty of ±50%
4. Measure PM emissions from NV barns with total relative uncertainty of ±53%.
5. Validate 75% of the scheduled air emission measurements for each pollutant.

Assuming negligible uncertainties due to spatial and temporal variations within the barn, DQOs 1-4 were calculated from estimated bias and precision values for concentrations and ventilation rates for MV and NV barns, and are presented in Tables 1.4.2 and 1.4.3. Information about the independent parameters (concentration and ventilation rate) on the left side of each table consists of nominal values, bias, precision, absolute and relative sensitivity, relative systematic uncertainty and relative random uncertainty.

The uncertainties for the emission rate on the right side of the tables include the relative systematic uncertainty (B_R) and relative random uncertainty (tS_R), and the total relative uncertainty ($\pm U_R$). According to the ASME PTC 19.1-1998 (based on the ANSI/NCSL Standard Z540-2-1997), systematic uncertainty (B_i) is <u>bias</u>, random uncertainty ($S_{x,i}$) is <u>precision</u>, and the total relative uncertainty ($\pm U_R$) represents the 95% confidence interval around the calculated emission rate and is the <u>total DQO</u>.

The absolute sensitivity (Tables 1.4.2 and 1.4.3) is the partial derivative of the emission rate ($E = C * Q$) with respect to the parameter considered (C or Q), and is equal to the nominal value of the other parameter. The relative sensitivity is the absolute sensitivity multiplied by the parameter nominal value, divided by the nominal emission rate. The relative systematic and relative random uncertainty of the emission rate are associated with the emission rate calculated using the nominal C and Q, the relative systematic and random uncertainties of C and Q, and the relative sensitivities of C and Q. The total relative uncertainty of the emission rate ($\pm U_R$) is the root-sum-square of the systematic and random standard deviations of the emission rate times the Student's t_c value for the 95% confidence level.

Data quality indicators (DQI) for the measurement of the individual pollutant concentrations, and of the ventilation rate in MV and NV barns are presented in Tables 1.4.4 to 1.4.11. Each table includes a summary of the method used to assess the DQI, and references the location in this QAPP where more information is available.

Table 1.4.2. Data Quality Objectives for air emissions from mechanically-ventilated barns.

Independent Parameter									Emission Rate (E) (µg/s)			
			Bias[b]	Precision[b]						Bias[b]	Precision[b]	**DQO**
Symbol	Units	Nominal Value[a]	Relative Systematic Uncertainty	RSD	Absolute Sensitivity	Relative Sensitivity	Relative Systematic Uncertainty Contribution[c]	Relative Random Uncertainty Contribution[c]	Nominal value	Relative Systematic Uncertainty[c]	Relative Random Uncertainty[c]	Total Relative Uncertainty[c]
P_i		V_i	B_i	S_{xi}	$\Theta_i = \delta E/\delta P_i$	$\Theta_i' = \Theta_i * V_i/E$	$(B_i*\Theta_i' /2)^2$	$(S_{xi}*\Theta_i')^2$	E=C*Q	$B_R = t(\Sigma(B_i*\Theta_i'/2)^2)^{0.5}$	$tS_R= t(\Sigma(S_{xi}*\Theta_i')^2)^{0.5}$	$\pm U_R = t((B_R/2)^2 + SR^2)^{0.5}$
Ammonia (NH_3)												
C	µg/m^3	141,000	5%	5%	1.5	1.0	0.0006	0.0025	211,500	15%	22%	27%
Q	m^3/s	1.5	15%	10%	141,000	1.0	0.0056	0.0025				
Hydrogen sulfide (H_2S)												
C	µg/m^3	14,130	5%	5%	1.5	1.0	0.0006	0.0025	21,195	15%	22%	27%
Q	m^3/s	1.5	15%	10%	14,130	1.0	0.0056	0.0025				
Non-Methane Hydrocarbons (NMHC)												
C	µg/m^3	9,200	5%	5%	1.5	1.0	0.0006	0.0025	13,800	15%	22%	27%
Q	m^3/s	1.5	15%	10%	9,200	1.0	0.0056	0.0025				
Particulate Matter ($PM_{2.5}$)												
C	µg/m^3	1,000	5%	10%	1.5	1.0	0.0006	0.0100	1,500	15%	28%	32%
Q	m^3/s	1.5	15%	10%	1,000	1.0	0.0056	0.0100				
Particulate Matter (PM_{10})												
C	µg/m^3	10,000	5%	10%	1.5	1.0	0.0006	0.0100	15,000	15%	28%	32%
Q	m^3/s	1.5	15%	10%	10,000	1.0	0.0056	0.0100				
Particulate Matter (TSP)												
C	µg/m^3	20,000	5%	10%	1.5	1.0	0.0006	0.0100	30,000	15%	28%	32%
Q	m^3/s	1.5	15%	10%	20,000	1.0	0.0056	0.0100				

[a] Maximum value of the expected concentration range (Table 1.4.1)
[b] As presented in Tables 2.6.1 (gases), 2.6.3 (PM), and 2.6.8 (barn airflow) of this QAPP
[c] As presented in the ASME PTC 19.1-1998 Test Uncertainty Supplement
C: Concentration; Q: Ventilation flow rate; t: Student’s t-value = 1.96

Table 1.4.3. Data Quality Objectives for air emissions from naturally-ventilated barns.

Independent Parameter									Emission Rate (E) (µg/s)			
			Bias[b]	Precision[b]						Bias[b]	Precision[b]	**DQO**
Symbol	Units	Nominal Value[a]	Relative Systematic Uncertainty	RSD	Absolute Sensitivity	Relative Sensitivity	Relative Systematic Uncertainty Contribution[c]	Relative Random Uncertainty Contribution[c]	Nominal value	Relative Systematic Uncertainty[c]	Relative Random Uncertainty[c]	Total Relative Uncertainty[c]
P_i		V_i	B_i	S_{xi}	$\Theta_i = \delta E/\delta P_i$	$\Theta_i' = \Theta_i * V_i/E$	$(B_i*\Theta_i'/2)^2$	$(S_{xi}*\Theta_i')^2$	$E=C*Q$	$B_R = t(\Sigma(B_i*\Theta_i'/2)^2)^{0.5}$	$tS_R = t(\Sigma(S_{xi}*\Theta_i')^2)^{0.5}$	$\pm U_R = t((B_R/2)^2 + SR^2)^{0.5}$
Ammonia (NH_3)												
C	µg/m^3	141,000	5%	5%	1.5	1.0	0.0006	0.0025	211,500	30%	40%	50%
Q	m^3/s	1.5	30%	10%	141,000	1.0	0.0225	0.0025				
Hydrogen sulfide (H_2S)												
C	µg/m^3	14,130	5%	5%	1.5	1.0	0.0006	0.0025	21,195	30%	40%	50%
Q	m^3/s	1.5	30%	10%	14,130	1.0	0.0225	0.0025				
Non-Methane Hydrocarbons (NMHC)												
C	µg/m^3	9,200	5%	5%	1.5	1.0	0.0006	0.0025	13,800	30%	40%	50%
Q	m^3/s	1.5	30%	10%	9,200	1.0	0.0225	0.0025				
Particulate Matter ($PM_{2.5}$)												
C	µg/m^3	1,000	5%	10%	1.5	1.0	0.0006	0.0100	1,500	30%	44%	53%
Q	m^3/s	1.5	30%	10%	1,000	1.0	0.0225	0.0100				
Particulate Matter (PM_{10})												
C	µg/m^3	10,000	5%	10%	1.5	1.0	0.0006	0.0100	15,000	30%	44%	53%
Q	m^3/s	1.5	30%	10%	10,000	1.0	0.0225	0.0100				
Particulate Matter (TSP)												
C	µg/m^3	20,000	5%	10%	1.5	1.0	0.0006	0.0100	30,000	30%	44%	53%
Q	m^3/s	1.5	30%	10%	20,000	1.0	0.0225	0.0100				

[a] Maximum value of the expected concentration range (Table 1.4.1)
[b] As presented in Tables 2.6.1 (gases), 2.6.3 (PM), and 2.6.8 (barn airflow) of this QAPP
[c] As presented in the ASME PTC 19.1-1998 Test Uncertainty Supplement
C: Concentration; Q: Ventilation flow rate. t= Student’s t-value = 1.96

Table 1.4.4. Data Quality Indicators for ammonia (NH_3).

Instrument: INNOVA 1412

DQI	Criteria, %	QC Method	Table
Precision	±5	RSD of multiple precision checks with reference gases over time	2.6.1
Bias	±5	Mean of multiple precision checks with span gas over time	2.6.1
Completeness	75	Percentage of the total scheduled NH_3 emission rate measurements	1.4.1

Table 1.4.5. Data Quality Indicators for hydrogen sulfide (H_2S).

Instrument: TEC Model 450I

DQI	Criteria, %	QC Method	Table
Precision	±5	RSD of multiple precision checks with reference gases over time	2.6.1
Bias	±5	Mean of multiple precision checks with span gas over time	2.6.1
Completeness	75	Percentage of the total scheduled H_2S emission rate measurements	1.4.1

Table 1.4.6. Data Quality Indicators for non-methane hydrocarbons (NMHC).

Instrument: TEC Model 55I (NMHC)
INNOVA 1412 (Total VOCs, methanol and/or ethanol)

DQI	Criteria, %	QC Method	Table
Precision	±5	RSD of multiple precision checks with reference gases over time	2.6.1
Bias	±5	Mean of multiple precision checks with span gas over time	2.6.1
Completeness	75	Percentage of the total scheduled NMHC/VOC emission rate measurements	1.4.1

Table 1.4.7. Data Quality Indicators for particulate matter ($PM_{2.5}$, PM_{10}, TSP).

Instrument: TEC TEOM Model 1400

DQI	Criteria, %	QC Method	Table
Precision ($PM_{2.5}$)	±10	Collocated Partisol, operated during 2 h period	2.6.3
Precision (PM_{10})	±10	Collocated TEOM, operated during 2 h period	2.6.3
Precision (TSP)	±10	Collocated TEOM, operated during 2 h period	2.6.3
Bias	±5	Flow audit using a NIST-traceable flow meter	2.6.3
Completeness	75	Percentage of the total scheduled emission rate measurements for each PM class	Section 2.1.2

Table 1.4.8. Data Quality Indicators for ventilation rate in MV barns.

Instrument: Setra Model 260 Differential Pressure Sensor

DQI	Criteria, %	QC Method	Table
Precision	±10	RSD of multiple differential pressure sensor precision checks with a NIST-traceable differential pressure sensor over time	Table 2.6.6
Bias	±15	Flow audit with collocated FANS analyzer	Section 2.1.5
Completeness	90	Percentage of total scheduled airflow measurements that are valid	Section 2.1.5

Table 1.4.9. Data Quality Indicators for ventilation rate in NV barns.

Instrument: 3D Ultrasonic anemometer (R. M. Young Model 81000)

DQI	Criteria, %	QC Method	Table
Precision	±20	Field intercomparison with identical anemometers during 30 min when measurements should be the same	Section 2.6 Table 2.6.8
Bias	±30	Zero air velocity audit using still air hood	Table 2.6.8
Completeness	75	Percentage of total scheduled airflow measurements that are valid	Section 2.6

1.5 Special Training/Certification

Personnel assigned to the NAEMS will meet the educational, work experience, responsibility, personal attributes, and training requirements for their respective positions. Records on personnel qualifications and training will be maintained in personnel files in a location designated by the SA, and will be accessible for review during audit activities. Adequate education and training are integral to any monitoring program that strives for reliable and comparable data. Training is aimed at increasing the effectiveness of employees and the project overall.

All producers participating in the NAEMS will attend a training session that will discuss the basic aspects of the project, the importance of the instrumentation (and precautions which the farm staff must take to ensure its proper operation), and effects of farm operation on the study. The importance of accurate producer-supplied information (see above) will be emphasized. Further details about this aspect of the NAEMS training are provided in SOP S1.

Training will be provided to all new field, laboratory, sample custody and data management personnel. A 50-question pre-test will be administered to all Site Engineers, and the scores of this test will be used to identify areas needing particular attention during the training sessions. Training will cover operation and maintenance of all instruments and analyzers used in the NAEMS, software operation, sample collection and handling, and general QA/QC measures. Training will be geared to ensure conformity with all of the SOPs, and address issues identified by the pre-test. Field measurement personnel (University PIs and their staff member(s) assigned to the NAEMS) will receive training (a total of 5 d for Site Engineers and 2 d for PIs) at Purdue University (PAAQL) through a combination of hands-on workshops and classroom-style presentations that will be led by members of the NAEMS research team with related expertise. PAAQL personnel and others will emphasize relationships between SOPs where appropriate. The PIs and Site Engineers will tour a NAEMS site close to Purdue, so that the classroom and lab training can be reinforced in a field setting. Attendance of PIs and Site Engineers will be documented throughout the training session, and this documentation will be kept on file at PAAQL. Additional training will be provided as the university PIs and/or their NAEMS-designated staff interact with PAAQL staff during the initial setup at each site; one or more PAAQL staff members will assist with setup of each site, for a minimum of about one week, including travel. Field and laboratory personnel (university NAEMS staff and new PAAQL employees assigned to NAEMS) will receive documented training (Table 1.5.1).

All NAEMS-related documents (QAPP, SOPs and SMPs) will be updated and maintained by PAAQL staff over the duration of this project. Section 1.6 of this QAPP describes the processes by which modifications will be made to these documents. Copies (electronic and hard copy) of the current (original or updated) versions of the QAPP, all relevant SOPs, and the SMP for the site will be available at each research site. The binders or files containing each site’s hard copies of the SOPs, SMP and QAPP will include a signature page, which the Site Engineer and other personnel working at the site will be required to initial and date to certify reading and understanding each document. This sheet will need to be signed each time a new version of a particular document is issued (Section 1.6).

1.6 Documents and Records

Each university partner will use Microsoft Excel to maintain electronic field notes including, but not limited to: site drawings, daily notes about the monitoring operation and the production buildings, results of field quality control measures, and any deviations from this QAPP. More specifications for field notes are provided in Section 2.9.2 of this QAPP. Every sample collected for off-site analysis will be documented in the field log book (including its exact location taken, medium (e.g. manure, bedding, canister sample for VOC analysis, etc), purpose, time of collection, and the name of the person collecting the sample. This information will also be entered on the chain-of-custody form (Appendix D), which will be sent with that group of samples. Copies of all chain of custody forms will be maintained on-site. Field logs will be kept in a central location in the field laboratory. Corrections on paper documents will be made by crossing out the error with a single line, and initialing and dating the correction. This correction technique is specified in all individual SOPs. A digital camera will be kept at each site for capturing pictures, which can then be incorporated into the electronic files for the site. Management of all electronic data files is discussed in detail in SOP B5. SOP B5 contains provisions for the management and retention of non-electronic (i.e. paper) copies of documents such as the Producer Event Form (SOP S1), drawings made based on site observations, etc.

The collaborating producer will keep records of mortalities, animal inventory, weight, and production (e.g. eggs, milk), and water and feed consumption. Animal inventory will be checked every six months (or whenever a new batch of animals is introduced) by study personnel, as described in SOP S2. The producer will also document special activities or procedures (e.g., generator tests, manure removals or agitation, changes in diet and animal health, temperature set points, ventilation interventions (e.g. changes in the fan staging scheme), fan maintenance and/or cleaning, building cleaning, power failures, etc) that may affect the study. Forms and procedures for producers to submit this information are included in SOP S1, which also provides further clarification to the producer about what events need to be reported. Every attempt will be made to ensure that producers check with research staff before initiating any such changes, and that producers do not disturb, move, modify, or impede any measuring devices or systems without first notifying the researchers. Procedural details of all of these issues are provided in SOP S1.

Any modification of this QAPP, including any one or more of its component SOPs or SMPs must be approved in writing by the NAEMS Science Advisor (Heber), EPA’s Project Manager, and EPA’s QA Manager..If only small portions of the QAPP need to be updated and not large sections or the entire document, the modification will be executed by issuing an amendment that replaces one or more individual sections, while specifying the exact change(s), and stating the reason(s) for the change. For example, this process would be used to amend or replace one or more individual SOPs or SMPs, without any modifications to the body of the QAPP itself. Copies of these approvals will be kept on file by the SA for the duration of the project. As soon as changes to a particular document are approved by the SA, the updated document will be electronically transferred (by e-mail and or remote access to site computers by PAAQL staff) to all sites for which the document is relevant. Site personnel will be notified of the specific change(s) in the document (for example, in the form of a Word document with changes tracked), and will replace electronic and/or hard copies of the document at the site with the new version (a .pdf file with changes accepted). They will also be required to sign and date the signature page in the site document binder or file as certification that they have read and understood the change(s) in the document. Any NAEMS-related personnel at any of the participating entities may suggest changes to any document.

Electronically-stored data will be backed up through several distinct mechanisms (SOP B5). A progressive backup of the on-site project folder, from the primary hard drive of the on-site computer to a secondary hard drive, will be conducted automatically daily, so that all files modified in a given day are backed up at the conclusion of that day. Additionally, the on-site project folder will be backed up to a CD or DVD, which will be kept off-site, every two weeks, or whenever there are changes in Category 2 and/or Category 3 data files, as follows:

Category 2 files

- Hardware configuration files (e.g. FieldPoint configuration files)
- Configurations of firewalls, virus protection, etc
- Email accounts, address books, message rules
- Favorite lists

Category 3 files

- Files provided by vendors (e.g. instrument manuals and quotations)
- Instrument communication software

Several different file types will also be emailed from the site PC (by the AirDAC program) to the responsible site PIs, and to the PAAQL Data Analyst assigned to the site (Section 2.9, SOPs B2 and B5). These individuals will archive the files to his/her departmental network server.

Manure analysis data files from Midwest Laboratories will be downloaded from the company's secure web server, using a project-specific password. They will then be filed by the Data Analyst assigned to the individual site, and managed according to SOP B5. These data are checked for accuracy at the company, by an Area Supervisor, after entry and before release to PAAQL.

Once submitted to the IMC, all NAEMS-related data files will be archived on the administrative server for the Purdue University Agricultural and Biological Engineering (ABE) Department, the contents of which are automatically backed up daily. Data will be inspected (pre-processed) by PAAQL personnel, in accordance with SOP B3, within 2 d of data collection. It is during this pre-processing/inspection phase that data outliers indicating system problems will be identified. Full processing of the data will be conducted with the custom-designed CAPECAB program (SOP B6). The mathematical derivation of many of the individual functions of the CAPECAB program are discussed in SOP B4, which also specifies the procedure for correcting data that was obtained in the interval between a passed calibration check and a failed one.

An electronic copy of the most recent version of the QAPP (including the SMP for each particular site and all relevant SOPs) will be stored in the on-site project file. The QAPP, all SOPs, and all SMPs will also be stored electronically at PAAQL on the departmental server in read-only format (i.e. locked pdf files), in a location accessible to all project staff.

Records from this project will be retained for a period of not less than six (6) years following the end of the project. Midwest Laboratories will maintain all NAEMS data for seven (7) years.

2. Data Generation and Acquisition

The following sections describe the methods that will be used to generate and acquire data. The first section (2.1) describes the experimental design of the project and the sampling methods, and clarifies which SOPs contain the full procedure for each method. The other, subsequent sections describe analytical methods (again, with reference to SOPs for full detail), sample handling procedures, and data management.

2.1 Experimental Design, Selection of Sampling Locations, and Sampling Methods

The basis for the experimental design of this project is continuous measurements of gas and PM concentrations and building ventilation rates. Other types of sampling that are conducted periodically include air sampling for volatile organic compounds (VOCs), and manure sampling for determination of various manure chemical parameters. A list of all SOPs related to sampling is provided in Table 2.1.1.

Table 2.1.1. Sampling-related SOPs in the NAEMS.

Parameter	Sampling method	SOP(s)
Exhaust and inlet air	Custom-built gas sampling system (GSS)	G1
$PM_{2.5}$	Tapered element oscillating microbalance (TEOM)	P1
PM_{10}	Tapered element oscillating microbalance (TEOM)	P1
TSP	Tapered element oscillating microbalance (TEOM)	P1
Fan air speed	Vane anemometer	A3
Fan run time	Vibration or rpm sensor on fans, current switch on fan power supply, and/or fan stage relay monitoring	A7 & S4
Air velocity	3-D Ultrasonic anemometer	A6
Barn static pressure	Capacitive/diaphragm sensor	A5
Temperature	Thermistor or RTD	E2
Temperature	Thermocouple (type T)	E1
Relative humidity	Thin-film capacitor (TFC)	E2
Process run time	Mechanical relay contacts, vibration sensors	A7 & S4
Atmospheric pressure	Barometric pressure transducer (within TEOM)	P1
Solar radiation	Pyranometer	E3
Wind speed	Cup anemometer	E4
Wind direction	Vane	E4
VOCs	Canisters, sorbent tubes	V2 & V1
Amines	H_2SO_4 bubblers	V3
Manure	Various sampler configurations	M1
Animal Inventory	Producer-supplied data, manual counting, truck scales	S1 & S2
Animal Activity	Passive infrared sensor	S3

For each site, the cost and benefit of each sample location group (SLG) needs to be weighed against each other. The following assumptions and factors were taken into consideration in choosing sampling locations:

1. The best sampling strategy must be determined on a site-specific basis.
2. Uniform air mixing in the barn is assumed. The exhaust location is therefore a good representation of the animal exposure for every barn type except high-rise laying houses, where all the air is exhausted from the manure pit. Also, the pollutant concentration at one fan can represent that at other fans.
3. Monitoring another exhaust location is more important than a second inlet sample. Since inlets for incoming ventilation air are distributed throughout the building (ridges, eaves, leaks) and wind blows in all directions, a truly representative single inlet location at any given time is unlikely.
4. In the case of cool cells (evaporative pads), the inlet sample should be taken outside the cool cell, and not inside the cool cell.
5. In the case of side-by-side tunnel ventilated houses, one sample between the buildings at the curtain end should suffice for both houses because the fans are grouped together in one bank of fans.
6. The inlet sample for representing the eave and ridge inlet air can be represented by one sample for both buildings at an outside location in between the buildings.
7. One SLG can be split between (5) and (6), which allows one more SLG to be used for exhaust measurements.
8. In the case of banked fans, one location can represent the air leaving any and all of the fans. It is preferable to pick the fan that runs most of the time and let that SLG represent all the fans rather than allocating additional SLG’s to fans belonging to higher stages. There is less need to check the spatial variability with banked fans than there is in a laying house with 75 fans distributed along 1200 ft of sidewall.
9. Reject repeat measurement of exhaust SLG until inlet air is sampled. A tunnel-ventilated barn site illustrates how exhaust measurements could be maximized. All the fans are represented by one SLG at a continuous 36″ fan, so that the emission streams are E1, E2, and E3 for barns 1, 2, and 3 exhausts, respectively. Assigning one SLG for the tunnel inlet (called Ae, Figure 2.1.1) between the buildings and one SLG for the eave inlets (called Ai) between the buildings, the sampling schedule would be as follows: (E1, E2, E3), Ae, (E1, E2, E3), Ai, (E1, E2, E3), (E1, E2, E3), ..., and the (E1,E2,E3) cycle is kept rotating until 12 h later, when the Ae and Ai locations are sampled again. This option would mean that exhaust in each barn is measured every 30 min at the longest, when the sampling times are 10 and 30 min for the exhaust and inlet air, respectively. Inlet air is measured 8.3% of the time. Based on a 4-min equilibrium time, the total time of useful data will be 368 min, or 26%.
10. Item 9 presents another scenario, namely, that the sampling location could either be repeated or the sampling time for the exhaust SLG be increased effectively to 20 min or more. Here is an extreme case for the tunnel ventilated barns: (E1, E2, E3), Ae, (E1, E2, E3), Ai, (E1, E2, E3), …, and the (E1,E2,E3) cycle is kept rotating until 12 h later to sample the Ae and Ai locations again. This option would mean that exhaust in each barn is measured every 90 min at the longest, when the sampling times are 20 and 30 min for

the exhaust and inlet air locations, respectively. Inlet air is also measured 8.3% of the time. Based on the same 4-min equilibrium time, the total useful data minutes in this case will be 1160 min, or 81%, as compared with the 26% with the scenario under point 9.

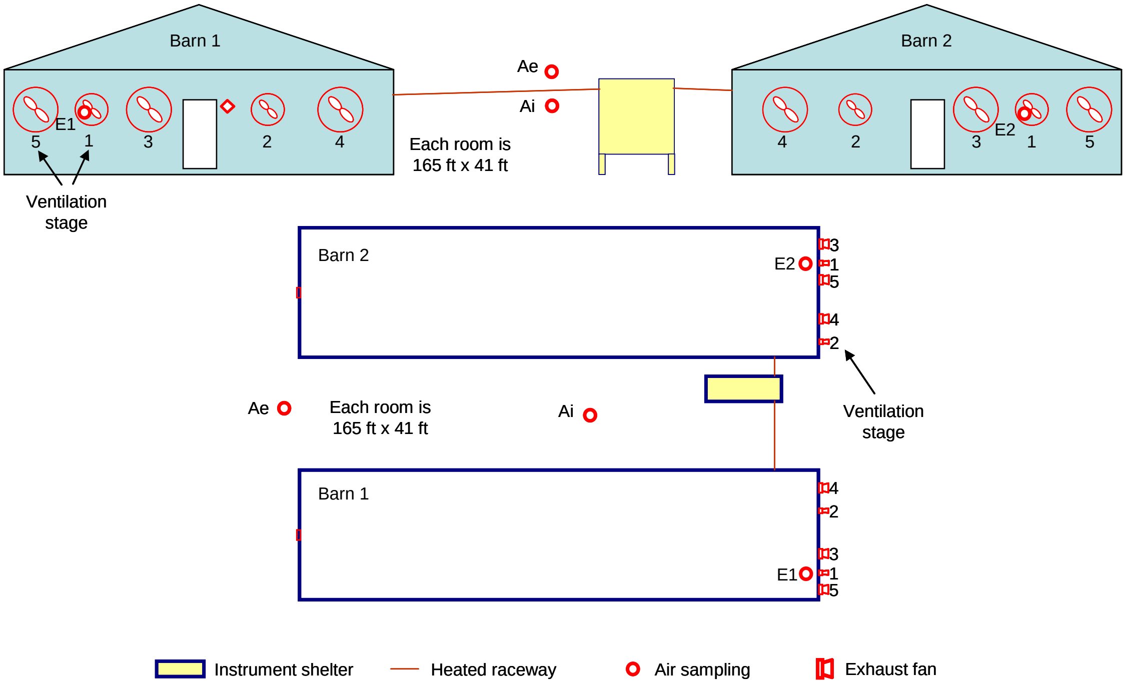


Figure 2.1.1. Sample location groups in two tunnel-ventilated swine barns. A third barn at this particular site is not shown.

11. The order of sampling locations could be randomly chosen between the two barns. However, exhaust samples at each location will be taken at equal intervals in each barn, e.g. 30 min intervals for 9ai above.
12. Use of ceiling inlets for the inlet location is less desirable than outside the barn because:
    a. The ceiling inlet is susceptible to reverse flow from the warm room. This may occur due to mismanagement of fans, mismanagement of inlets, or pressurization of the barn due to wind.
    b. Any inlet measurement inside the building requires explanation and justification. While the attic is typically not an emission source or sink, the assumption that attic concentrations are equal to inlet concentrations needs verification. Also, the assumption that there is no reverse flow of inside air to the attic sampling location needs proof.
13. Some barn ventilation systems are less conducive to emission measurements than others. Producers may have unorthodox and undesirable fan control strategies, and this was strongly considered during the site-selection process. However, in NAEMS and in past projects, several producers were willing to modify minor aspects of their ventilation systems specifically to enhance data quality for the study. In all cases, modifications were

within common industry practices, so that sites were representative of their industry as a whole. For example:

  a. The natural ventilation phase was eliminated from one tunnel-ventilated dairy freestall barn (NY5B in NAEMS).
  b. Stages 1 and 2 fans were switched at one site to bring the OFIS closer to the minimum fans (IA4B in NAEMS).
  c. Duty cycling of two minimum winter fans was switched to continuously running one fan, to ensure that there would be one fan that always had an exhaust stream. This was not necessary at any NAEMS sites.
  d. Variable-speed minimum fans have, in the past, been changed to single-speed fans; however, this was not done at any NAEMS sites.

14. Avoid starting the sampling cycle at the same times during each day. This can be accomplished by adding the two daily 30-min inlet samples to the sampling schedule, which will push the timing forward by 60 min each day.

The measurement locations, number of samples, and sampling frequency are given in the SMP for each site (Appendix A). If the monitoring site becomes inaccessible (for example, as the result of a weather-related or barn-operation emergency), the farm personnel should be contacted immediately for safety issues. If possible, simple immediate maintenance tasks can also be performed by the farm personnel with clear instructions given. A webcam connection, which will be included with each on-site computer, can be used for the purpose of guiding farm staff to perform operations in the trailer if, for any reason, access to the site by research personnel becomes impossible. Even if a site cannot be physically visited, it can still be monitored via the Internet, using PCAnywhere to access the AirDAC program running on the site computer.

2.1.1 Gas Sampling

Using the gas sampling system (GSS, SOP G1), gas samples will be obtained from between one and 22 exhaust air locations per barn, and a ventilation inlet or ambient air location group. In the NAEMS, it is more important that the latter sample represent as closely as possible the air that is entering the barns (the inlet air), although this might not truly be the ambient air for the site (i.e. the upwind air with no or baseline contaminants). This is true because the goal of the NAEMS is to quantify the pollution output of the barns, and this requires data for the inlet air. Gas sampling location groups (GSLGs) will consist of one or multiple sampling locations and tubes that bring air into a mixing manifold from one or more discrete sampling points. For example, a GSLG within a large naturally-ventilated dairy barn could consist of 6 sampling tubes that bring air into a mixing manifold from six discrete sampling points in one large opening of the barn (e.g. open sidewall). The fewer sampling points that are taken, the more important it becomes to assume uniform mixing in making extrapolations to the barn as a whole. The exact number and locations of the sampling points will vary from site to site, and are specified in the SMP documents for each site.

Certain farms require fewer gas sampling points because of site-specific fan locations and numbers. Since large buildings have multiple exhaust fans, it is not advisable to use the concentration found at one fan to represent that at many other fans, especially if the fans are separated by large distance, or if one is a pit fan and the others are wall ventilation fans. There is spatial variation between the exhaust locations: Pit exhaust fans probably will have higher gas concentrations, since they are closer to the gas source (i.e. manure) than wall exhaust fans, but will likely have lower PM concentration, since they are further from the source of PM (i.e. animals). Thus, there is a need for measuring several representative exhaust points. If the fans are grouped together, e.g. tunnel ventilation, a single point may then be representative of air exhausting from the entire group of fans. All of these considerations have been taken into account when developing the site-specific Site Monitoring Plans.

While sample air can be collected from multiple exhaust fan locations and composited (e.g. four pit exhaust fans, five end wall tunnel fans, etc. (Heber et al., 2001)) for measurement, it is preferable to have individual sampling points. For example, if one of the fans in a group which is being composite-sampled fails, the data for the whole group must be invalidated. When composite sampling is used, only one mean value is available for the entire group, and the differences between each point are unknown. Also, all fans that are included in a sample group must be operating at approximately the same speed for composite sampling to be appropriate.

Air from each location will be sampled and measured continuously for 10 min before switching to the next location. Thus, for a site with 12 sampling locations, a 120-min sampling cycle (without the inlet air sampling) will be applied, resulting in 11 to 12 sampling periods per day per location, depending on the number of inlet air sampling points. The first several minutes of gas-concentration data will be ignored to allow the measurements of the gas analyzers to stabilize. To ascertain that a specific equilibrium period will allow each analyzer to achieve at least a 95% response to a step change in the input concentration, the response time of the system will be initially tested by attaching a 50-L bag of calibration gas at the end of the longest sampling tube in the GSS. If the equilibration time of a particular gas analyzer (e.g. the MSA Model 3600 CO_2, analyzer (SOP G3)) is shorter, then less data from that analyzer will be ignored. The gas sampling system (GSS) is equipped with a bypass sampling pump that composites the flow from all GSLGs which are not currently being supplied to the gas analyzers, and purges them simultaneously, with a total flow of about 10 L/min. The bypass pump operation shortens the equilibration time and avoids idle barn air in the sampling system.

The sampling time for the inlet location will be 30 min, and this location will be sampled twice per day. The longer sampling period allows enough time for all gas analyzers to reach equilibrium, because the concentration difference (e.g. step change) from the previous sample may be significant. The lower sampling frequency is feasible because inlet analyte concentrations are more stable when compared with those of barn exhaust or animal areas.

Based on the size of facilities being monitored in this study and the number of GSLGs, the shortest sampling cycle will be one hour, and the longest sampling cycle will be just over three hours (190 min). The average cycle duration for the 14 sites will be just under two hours (approx. 105 min). This is assumed to be sufficient to capture the variations in emissions, especially when there are multiple exhaust locations in each building. With this configuration, the pollutant concentrations in exhaust air from each individual exhaust location will be measured at least 8, and as many as 24 times daily, with an average for all sites of approximately

12 times daily. This will result in a total of approximately 24 to 60 measurements daily per building (assuming that each building will have 1-5 GSLs or GSLGs).

The duration of sampling at a given location can be calculated as the total number of samples times the number of readings per sample. For a monitoring site that has ten sampling cycles per day, the minimum sampling duration will be 20 (measurements per building) x 3 min (after 7-min equilibration time per sampling cycle) = 60 min or 4.2% of the day. Although this seems like a small percentage of the time, the long-term measurement and sampling at different times of day (Step 14 of Sec 2.1) help to ensure representative sampling. The 20 three-minute samples from each location are distributed throughout the day, thus capturing the diurnal variations of emissions.

2.1.2 Particulate Matter (PM) Sampling

2.1.2.1 PM_{10}

PM_{10} (10-µm particles and smaller) will be monitored using the Thermo Electron (formerly Rupprecht & Patashnick (R&P)) TEOM (Tapered Element Oscillating Microbalance) 1400, which is a continuous PM monitoring device. With the appropriate inlet, the TEOM is designated by USEPA as an equivalent method for PM_{10} (EPA Designation No. EQPM-1090-079) (USEPA 1999a). See SOP P1 for more details on the description, operation, calibration and maintenance of the TEOM.

PM_{10} concentrations will be measured continuously with the TEOM, generally at one minimum winter ventilation fan in each building, and generally side by side with an exhaust air gas-sampling point. The sampling location will be inside the building near the inlet of the fan, however, far enough away to avoid concerns about anisokinetic sampling. The one exception to this rule is in the belt-battery portion of the IN2B layer site, where, because of space limitations in the barn, the TEOMs located upstream of the manure drying tunnels will be downstream of the barn exhaust fans feeding into the drying tunnel. The air velocity around the sampling head should be 2 m/s (400 fpm) or less. This corresponds to the minimum air velocity in a tunnel-ventilated building in the summer.

2.1.2.2 $PM_{2.5}$

Concentrations of $PM_{2.5}$ will be measured using the Thermo Electron TEOM 1400 continuous sampler, and audited at sites IN2B, IN3B and IN5B with the TFS Partisol Model 2000 single-channel sampler; both of these will be equipped with $PM_{2.5}$ sampling inlets. The Model 2000 sampler is designated as a FRM (RFPS-0498-117) for collection of $PM_{2.5}$ when used with the WINS (Well Impactor Ninety-Six) impactor and the VSCC (very sharp cut cyclone). The sampler draws air through the PM_{10} inlet, $PM_{2.5}$ WINS impactor, and a 47-mm Teflon sample filter, which traps the $PM_{2.5}$ fraction. The sample filter is conditioned and weighed before and after sampling. The resulting difference in mass is the collected $PM_{2.5}$ mass (µg). Electronic systems in the sampler are designed to monitor and maintain the volumetric flow rate, and to record the elapsed sampling time, enabling the R&P Model 2000 to calculate the total sample volume (m^3). This allows the mean $PM_{2.5}$ concentration (µg/m^3) for the sampling period to be calculated. Further details on the $PM_{2.5}$ equipment and methodology are given in SOP P1 (TEOM) and

SOP P3 (Partisol). The TEOM 1400 will be fitted with $PM_{2.5}$ inlets for a sampling period of two weeks in the summer (June-August) and two weeks in the winter (December-February) during the first year of data collection, with a goal of obtaining data for both hot and cold conditions. Site personnel will consult the 15-day weather forecast for their site(s) before finalizing the scheduling, to avoid nonrepresentative weather conditions. They will also avoid nonrepresentative operational conditions inside the barns.

2.1.2.3 Total Suspended Particulate (TSP)

The TSP concentration of the exhaust air stream will be determined using the TEOM sampler, equipped with an R&P TSP inlet. The TSP inlet will be installed onto the TEOM inlet system for one week in every eight weeks for continuous TSP concentration measurement while temporarily interrupting the PM_{10} measurements. The sampler works exactly as the TEOM PM_{10} sampler, except the PM_{10} inlet is replaced with the TSP inlet. There is no size separation, because the inlet is designed to allow very large PM to pass through. However, precipitation and PM with very large fall velocities are prevented from entering the sampling system. Filters are replaced more frequently than that of PM_{10} and $PM_{2.5}$ measurement, depending on the PM loading and site maintenance schedule. Further details of the TSP measurement and equipment are provided in SOP P1. TSP results will be checked by comparing them with the gravimetric samplers (SOP P2) at one dairy site (IN5B), one swine site (IN3B), and one layer site (IN2B). It will be assumed that the particulate profiles for layers and broilers will be sufficient that it will be unnecessary to conduct the check at the CA broiler site.

2.1.3 Temperature and Relative Humidity Measurements

Up to sixteen copper-constantan (Type T) thermocouples per building (depending on the size and complexity of the building) will be used to sense temperatures at the following locations: 1) heated raceways, 2) animal pens/cages, 3) summer and winter air inlets, and 4) exhaust fans. The thermocouples will be used with a 16-bit thermocouple module (FP-TC-120, National Instruments, Austin, TX). The sensors will be two-point calibrated prior to and following the 24-month monitoring period using heated (50 ºC) and ice-water baths, and will be periodically checked in-place with a NIST-traceable portable temperature sensor. Further details of the thermocouple-based temperature measurements are presented in SOP E1.

An electronic RH/temperature transmitter (NOVUS Model RHT-WM, Omni Instruments, Arroyo Grande, CA) will also be used to monitor temperature and RH at representative exhaust locations and other locations in each building (as detailed in the SMP for each site), as described in SOP E2. The same transmitter, equipped with a passive solar radiation shield, will be used to measure temperature and RH at a representative outdoor location (SOP W1). The Omni RHT-WM has accuracies of ±1.5% RH and ±0.5 ºC at 25ºC.

2.1.4 Pressure Measurements

Building static pressure will be monitored continuously at locations near the exhaust fans. Pressure measurements will be made with differential pressure (dP) transmitters (Model 260, Setra Systems, Boxborough, MA) with a range of -100 Pa to +100 Pa, and an accuracy of ±1% full scale. These sensors will be 9-point calibrated with NIST-traceable standards by the manufacturer. The pressure sensor will be shunted to calibrate zero and compared with reference pressure transducer to calibrate it at various span pressures. Pressure snubbers will be used to minimize effects of air movement from wind or ventilation fans on the measurement. Further details of the pressure measurement methodology are presented in SOP A5.

Atmospheric pressure will be monitored with a barometric pressure transducer in the TEOM, as described in the TEOM SOP (SOP P1).

2.1.5 Ventilation Fan Monitoring

Sites with MV barns will have the status and airflow of the PREF fans (at a minimum) continuously monitored using a bi-directional impeller anemometer (Model 27106, R.M. Young Company, Traverse City, MI). The advantages of the impeller anemometer, which is much smaller in diameter than the fan, are that the significant effects of wind and building static pressure are accounted for with the technique and real-time measurements are made. These anemometers will be calibrated during the in-field tests with the FANS analyzer (SOP A3) and, if feasible, during BESS tests. The operation of individual fans will also be measured using vibration sensors (SOP A7) rpm sensors (SOP A11), or current switches. Each fan monitoring sensor will be connected to the data acquisition system (SOP B1). Open impeller anemometers and rpm sensors also provide performance information about the exhaust fans that can be used in airflow rate estimations. The operating status (operating time, %) of fan stages will be monitored via auxiliary contacts of fan motor control relays (SOP A4). A mean of sixty 1.0-Hz readings will be recorded every minute.

In the case that a site has large barns (with over 20 ventilation fans each), and employs dedicated farm personnel for checking and maintaining the fans on a daily basis, the monitoring of each individual fan is unnecessary. Instead, fan monitoring equipment will be assigned to representative fans based on the following criteria: 1) airflow from every PREF and one representative fan of every other fan model employed at a site will be monitored with an open impeller anemometer; 2) all variable speed fans will be monitored using an rpm sensor or an open impeller anemometer; 3) up to two fans for every ventilation stage will be monitored using either an rpm sensor or vibration sensor; and 4) up to two additional fans for every ventilation stage will be monitored using current switches activated by fan motor current. Criteria 4 may be replaced with or used in conjunction with fan stage relay monitoring.

The airflow of a fan can be estimated by taking the published fan performance curves for the particular fan model and interpolating at the measured exhaust fan dP. However, a systematic error is generally inherent with this method, because the performance of fans deteriorates due to dust buildup, belt wear and shutter degradation. Based on unpublished tests (Heber, 2002), actual airflows are expected to be 5 to 50% less than would be expected based on the published fan curve data. Therefore, a FANS analyzer (Becker 1999; Gates et al., 2002), a calibrated anemometer system with multiple traversing impellers, will be used to spot-measure actual fan capacities in the field. The FANS analyzer will first be calibrated (preferably but not necessarily with each fan model removed temporarily from the buildings, or with another identical fan with an identical configuration) using the University of Illinois BESS Lab. Use of the FANS analyzer in the field is detailed in SOP A2. The BESS lab can measure fan capacity with an accuracy of ±2% using a standard method (AMCA, 1985), which is described in SOP A1. The spot measurements with the FANS will be conducted at least once per eight months, and will each consist of at least two to three replications at each fan that is tested. The FANS (or field-collected) data will be used to adjust the estimated fan airflow rate generated using the published fan performance curve.

Airflow rates of representative fans will be determined using the FANS analyzer (SOP A2), or a portable anemometer and the traversing method (SOP A8) if the FANS cannot be used due to limited access or tight spaces. The number of fans to be tested at each farm should be as many as practical and needed for accuracy. It seems feasible that a minimum of 25 fans per barn (or 25% in barns with more than 100 fans) should be measured (specific numbers for each site will be delineated in the SMPs), but this depends on the age and condition of the fans, and the number of static pressures tested with each fan. Other requirements are as follows:

1. The airflows of all the fans whose exhausts are sampled to determine gas or PM concentration will be tested.
2. A minimum of 2 fans per stage should be tested. These should be randomly selected from among all fans operated in the stage.
3. Once 2 or more fans per stage have been selected, the remainder of the fans to be tested (25 or 25%, whichever is greater) should be randomly chosen from other stages with extra weight given to lower-stages.
4. If a barn has more than one fan model, a minimum of 25% of the fans of each model should be tested.
5. Variable-speed fans should be tested at a minimum of three speed settings that must include the minimum and maximum speed settings used by the producer.

A minimum of two runs will be conducted per fan; if the airflows from these two runs do not agree to within 5% or less, additional runs will be conducted until the difference is less than 5% for two consecutive runs. However, all runs conducted will be considered valid data for that fan unless there is evidence that the test was flawed. If the RSD of the airflows of the entire group of same-model, same-speed, and same-stage (if a stage effect exists) fans is greater than 5% and $n > 10$, then additional fans will be evaluated, unless all fans in the barn have already been tested.

The accuracy of airflow measurements will be improved if the fans can be tested at more than one static pressure. If it is possible to manipulate the static pressure in the barn, then it should be conducted at a minimum of two static pressures so that the fan performance can be known through the operation of the fan.

The total building airflow rate will be calculated (SOP A4) by summing the individual airflow rates of all operating fans. The accuracy in measuring daily mean building airflow with this method (with data from either the FANS analyzer or traversing) is estimated at ±10%.

Wind speed and direction will be monitored continuously with a wind direction vane and a cup anemometer (SOP E4). Wind information will be used to correlate with and confirm wind-induced static pressure influences on fan airflow.

Airflow through barns that are not mechanically ventilated (i.e. open dairy barns at sites CA5B and WA5B) will be determined using 3-Dimensional Sonic Anemometry, as described in SOP A6. The 3-D sonics will be placed in the ventilation openings, as shown in Figure 2.1.5.1, which shows how multiple anemometers will be spaced in each wall and in the ridge to better determine a true average flow through each of these locations.

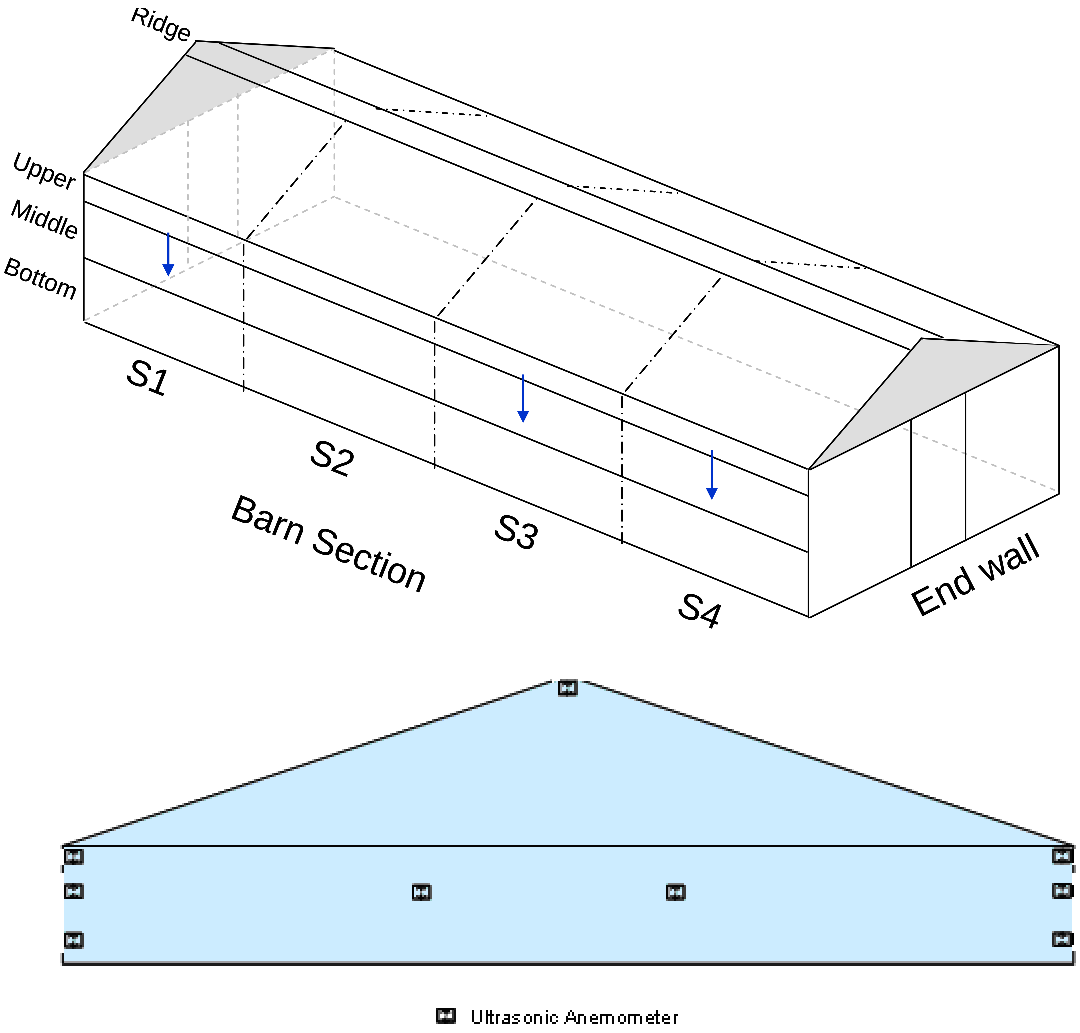


Figure 2.1.2. Locations of sonic anemometers in a naturally-ventilated freestall barn. In this case, the top (eave) sidewall anemometers can be shifted down into the middle sections (arrows) during periods when the sidewall curtains are fully open.

2.1.6 Animal Inventory and Productivity

Producers will be required to provide their animal inventory (i.e. head count) at the beginning of the study, assuming that occurs in the middle of a growth period. Otherwise, the initial inventory will be submitted as soon as the barn is filled at the beginning of the next growth period. Inventories will be regularly updated whenever livestock are removed from or added to a barn, or whenever mortalities occur (in the latter case, producers typically maintain their own daily mortality logs, which will be supplied to the study personnel). Producers will supply data on feed consumption. To the greatest extent possible, this will be barn-specific; if not, whole-farm data will be converted to barn-specific data based on the number of head in the entire facility *versus* the individual barn. Layer and dairy producers will also supply data on the number of eggs or the amount of milk produced, so that these may be used, together with the compositional data of these materials, as inputs (along with manure and bedding data) for an N balance of the facility (SOP S5). This will serve as a theoretical check on the amount of N that is determined through sampling to be emitted as NH_3. Details of the collection of this information from producers is provided in SOP S1. Periodic checks of both counts and weights of livestock will be conducted by study personnel, and are described in SOP S2. Specifically, every six months, study personnel will verify the head counts at each swine and dairy site by counting animals in the study barn. Weights of swine and cows will not be checked, but will rely on producer-supplied information. At layer sites, birds will be counted and weighed in 0.1% of the total cages in each barn. Bird handling for this procedure can be conducted by study personnel, or farm staff under observation by study personnel. The same percentage of birds at the broiler site will also be counted and weighed; again, the study personnel can either conduct the counts and weighings themselves, or observe the farm staff doing them. Poultry counts and weights will be verified every six months.

2.1.7 Animal Activity

Activity of animals, and barn workers, will be monitored using Passive Infrared (PIR) detectors. These detectors operate according to the pyroelectric principle; a crystalline sensor inside the PIR detector generates a surface electric charge when exposed to heat (infrared radiation). A filter window is incorporated to establish an incoming IR range that is most sensitive to animal- and human-body thermal radiation. The pyroelectric sensor has two sensing elements. A body, the radiation source, passing in front of the sensor will activate the first element and then the other. The radiation source must pass across the detector in a horizontal direction if the detector is vertically installed. The detector output is proportional to the temperature difference between the object and the background, and to the velocity of the object. The Visonic Model SRN-2000 PIR detector has a maximum range of 18 m, depending on the detector configuration and mounting. Details on the methodology and equipment used for activity measurements are given in SOP S3.

2.1.8 Other Periodic Sampling

2.1.8.1 Air Sampling for Volatile Organic Compounds (VOCs)

Air sampling for VOCs will be conducted at the primary representative exhaust fans (PREFs) for each building. The PREFs are identified in the respective SMPs. Two different “broad spectrum” methods will be used for VOC sampling, to increase the number of analytes measured that contribute to the total VOC mass, since each method can only detect limited types of analytes. In the first method, Carbopack X/C sorbent tubes will be used, as described in SOP V1. This methodology is adapted from USEPA Compendium Method TO-17, “Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling onto Sorbent Tubes” (USEPA 1999c). The stated detection limit for this method is between 0.5 and 25 parts per billion (ppbv) concentration in the tested air stream. In the second method, samples will be collected using pre-conditioned canisters, in accordance with SOP V2. Canisters will be cleaned and certified according to SOP V7, which is derived from TO-15 and TO-14.

Volatile amines will be collected (SOP V3) using midget bubblers filled with dilute H_2SO_4, in a method adapted from the American Public Health Association’s “Tentative Method of Analysis for Primary and Secondary Amines in the Atmosphere (Ninhydrin Method)”, and the Occupational Safety and Health Administration’s Instruction CPL 2-2.20, and USEPA Conditional Test Method CTM-027 (“Procedure for Collection and Analysis of Ammonia in Stationary Sources”) (USEPA 1997).

The specific choice of VOC collection technique(s) that will be applied at each site depends on the results of the initial site VOC characterization. All subsequent VOC sampling will be conducted at the primary representative exhaust fan (PREF) for the building in question. Sampling will be conducted every three months or every quarter. Duplicate samples will be collected at each PREF location during each sampling event, so that the precision of the sampling and analytical method combination can be assessed.

2.1.8.2 Manure Sampling

Manure samples will be collected from various storage or treatment facilities, including building deep pits, storage basins, lagoons, and storage piles. The exact sampling locations are specified in the SMP for each site. Different sampling equipment and techniques are employed, based on manure characteristics (liquid or dry samples) and/or limitations of facilities (SOP M1). It is important to take a sufficient number of samples to be representative of the manure storage or treatment unit. To develop an accurate model for nutrient (N) balance, it is also important that the manure sample represents the average holding time encountered by the manure in the monitored housing unit, and any manure treatments that occur within the housing unit that may affect the form of N and/or its release to the air. For example, with respect to holding time prior to land application, if only manure that has been stored the maximum time is sampled, its N content will be lower than average, and NH_3 emissions will be overestimated. Conversely, if the manure sample is fresher than the average storage time, N content will be overestimated, and emissions underestimated. To achieve this, it is necessary that the manure be well-mixed prior to or during sampling.

The number of samples and sampling frequency are specified in the Site Monitoring Plans for the individual locations (Appendix A). Furthermore, each individual sample is generally composited from a number of subsamples, which depends upon site-specific factors, and is specified in the SMPs. Subsamples are taken, and either mixed in a bucket or pail, or spread out on a plastic tarp and mixed, until a homogeneous state is achieved, at which point a sample is collected. Further details of these procedures, and information on the types of containers that should be used and volumes to collect, are given in SOP M1.

2.2 Sample Handling and Custody

Filters used for $PM_{2.5}$ sampling when the FRM method (SOP P3) is used as a periodic check on the performance of the TEOMs or Beta Monitors, and other sampling devices (such as canisters, sorbent tubes, and bubblers) will be inspected for contamination and defects and cleaned before use. Details on these processes, including the detailed certification program for canisters (SOP V7) and the conditioning process for sorbent tubes (SOP V1), are provided in the respective SOPs. After sampling, they will be visually inspected prior to delivery to the laboratory. Considerable care will be taken when handling sampling equipment, according to the precautions that are described in the individual SOPs. For example, care must be taken when recovering filters from PM sampling devices, to ensure that the collected PM cakes are not lost or disturbed. Manure samples must be placed on a sufficient amount of ice before shipping that they remain cold throughout transit. In general, samples collected should be sent to the laboratory for analysis as soon as possible, and certain time constrains should be applied according to each SOP, such as the necessity of having the samples analyzed within a certain time frame. Samples that do not require special preservation, such as TSP and $PM_{2.5}$ filters, can be kept in the OFIS for up to a month before they are sent in as a group for analysis. Details of sample preparation and shipping are described in the relevant SOPs.

Samples will be labeled and logged on standard field data sheets as they are collected, or will be logged into the field log book or electronic field notes. Details of labeling the individual samples, numbering systems, and use of specific types of tags or labels are included in the SOPs. The samples will then be gathered, stored and transferred to the laboratory for evaluation. All field data will be recorded and checked for completeness and accuracy before leaving the site. Chain of custody will be documented with signatures of those who relinquish and receive the samples. Chain of Custody (COC) sheets (Appendix D) will be filled out electronically, and will be sent along with the samples. Electronic completion of the forms will enable them to be emailed to the lab, so that the lab will have the tracking information, and be able to plan for the arrival of the samples. Upon receiving the samples, laboratory personnel will sign on the chain of custody form and check the conditions and completeness of the samples. The laboratory personnel designated to receive VOC samples at PAAQL will be Dr. Changhe Xiao, who will serve (Figure 1.1.1) as the NAEMS VOC Manager. Specific personnel will be designated by Midwest Laboratories, which has a designated Sample Receiving Supervisor, as the recipient(s) for manure, bedding, feed, milk, and egg samples that are sent there for analysis. Midwest Laboratories stores the samples in a chain-of-custody cooler, and then uses an in-house Accountability Record, which each person handling the sample must sign, and record the date and time that the samples were checked out and returned. Completed COC forms for samples arriving at Midwest Laboratories will be forwarded to PAAQL after analyses of the samples are complete, although Midwest will retain the samples themselves. Any abnormal conditions, such as warm manure samples, broken sample containers, turned-over filters, uncapped sorbent tubes, sampling canisters with improper pressure, etc. will be recorded on the COC, and in the laboratory data sheets. Responsible personnel will be informed, and corrective actions (e.g. scheduling for repeat sampling) will be taken immediately and recorded. In the case of VOC samples, it is anticipated that this will entail PAAQL personnel contacting the PI for the particular site. In the case of samples received by Midwest Laboratories, they will contact the PAAQL Data Manager/Data Analyst assigned to the site, and he/she will contact the site PI. All of the related data sheets, including field sampling, chain of custody, and laboratory data sheets will be kept in a designated binder in the laboratory. Copies of COC forms for all groups of samples sent from a particular site will also be maintained in a designated binder in the OFIS at that site.

2.3 Analytical Methods

2.3.1 List of Analytical Methods

Table 2.3.1 summarizes analytical methods that will be employed in the NAEMS. Greater detail on each method is provided after the table.

Table 2.3.1. Analytical methods used in the NAEMS. See cited SOPs for further details.

Variable	Measurement Method	PAAQL SOP
NH_3	Infrared photoacoustic	G7
H_2S	Pulsed fluorescence (as SO_2)	G5
VOCs	GC/MS (mass spectrometer)	V4 (Sorbent tubes) V6 (Canisters)
Amines	Ion chromatography	V5
CO_2	Infrared photoacoustic	G3, G7
Gas cylinder composition	FTIR	G12
Manure pH	Electrometric (KCl electrode)	M2
Manure solids content	Total solids – Drying @ 103-105°C Volatile solids – Heating @ 550°C	M3
Manure nitrogen	Micro-Kjeldahl + Titrimetric	M4
Manure NH_3	Micro-Kjeldahl + Titrimetric	M5
Nitrogen content of feed, milk and eggs	Micro-Kjeldahl + Titrimetric	S6

2.3.1.1 Ammonia

Two different types of analyzers (chemiluminescence, photoacoustic infrared) are available to measure NH_3 concentrations in the NAEMS. Although the same instruments will be used at each site, the measurement range will depend on the expected atmospheric NH_3 concentrations at the site. The expected concentration depends on the species (layer and broiler are typically higher than dairy or swine), manure removal frequency, and season (NH_3 levels are typically higher in winter, when ventilation rates are lower).

In the first method, NH_3 will be measured with a chemiluminescence NH_3 analyzer (Model 17C, Thermal Environmental Instruments (TEI), Franklin, MA), which combines an NH_3 converter and a nitrogen oxides analyzer (SOP G4). The NH_3 analyzer's full scale will be set at 20 to 200 ppm, depending on the expected maximum levels in the building (e.g. 150 ppm for layer houses, 24 ppm for swine finishing, etc) (Table 2.6.2 provides information on the maximum expected concentrations at each site). If initial NO and NO_2 measurements are negligible, the analyzer will be operated in the N_t (total N) mode (SOP G4), which will decrease its response time (thus allowing for collection of more usable data) and reduce the cost of scrubber replacements.

NH_3 concentrations in air will be measured using photoacoustic infrared (IR) detection with the INNOVA Model 1412 Multi-gas Monitor (Innova AirTech Instruments, Ballerup, Denmark), which is capable of measuring several gases (including NH_3) simultaneously. With this method, a gas sample is introduced into an acoustic cell, where it is exposed to pulsing infrared light of specific wavelength. Gas selectivity in the Model 1412 is achieved through the use of optical filters; by installing up to five of these filters in a central filter wheel, concentrations of up to 5 component gases (and water vapor) can be simultaneoulsy measured in an air sample. Almost any gas that absorbs infra-red light can be measured by this method. If, for example, the sample contains NH_3, it will absorb an amount of infrared light at an NH_3-specific wavelength (976 µm) proportional to the concentration of NH_3 in the sample. When gas molecules absorb this infrared light, their temperature rises as the molecules increase in kinetic energy, resulting in a pressure wave inside the acoustic cell. The audible pressure pulses corresponding to the light pulses are detected by a microphone located inside the chamber, and are proportional to the concentration of NH_3 molecules. Measurement accuracy is ensured by the Model 1412's ability to compensate for temperature and pressure fluctuations, water-vapor interference and interference from other gases known to be present. The Model 1412 has range of 0-2000 ppm, which makes it suitable even for the most extreme cases expected in NAEMS (poultry houses during periods of lower winter ventilation). Use of the INNOVA Model 1412 is discussed in further detail in SOP G7.

2.3.1.2 Hydrogen Sulfide

Hydrogen sulfide (H_2S) will be measured in real time with a pulsed fluorescence SO_2 detector (TEI Model 450I), in accordance with USEPA Method EQSA-0486-060 and EMTIC TM-006C. H_2S is converted to SO_2 through exposure to a molybdenum-based catalyst operating at a temperature of 325-370°C in a converter (Thermo Electron Model 340). Corrections for SO_2 present in the original sample are made by shunting one subsample so that it bypasses the converter. This value is subtracted from the result with the converted subsample to calculate the H_2S concentration. This system and its use are described further in SOP G5.

2.3.1.3 Hydrocarbons (Total Non-methane VOC)

Concentrations of total non-methane hydrocarbons (NMHC) will be measured using one of two methods. The first of these methods is the INNOVA Model 1412, equipped with a 987-µm filter. Because this filter will also read methane in the air sample, it is necessary to measure CH_4 (at 968 µm), and subtract the total CH_4 from the total hydrocarbon concentration detected at 987 µm. The remaining two filter spaces in the Model 1412's filter wheel will, at some sites, be used to measure ethanol (at 974 µm, after correction for NH_3, which also absorbs IR light at this wavelength), and methanol (at 936 µm). Further details on the quantitation of these gases with the Model 1412 are provided in SOP G7.

In the second method, concentrations of non-methane hydrocarbons (NMHC) will be measured using the TEI Model 55C, which incorporates a back-flush gas chromatography (GC) system with a proprietary column, which is capable of achieving complete separation of methane from all other hydrocarbons, including C_2 compounds. An FID detector provides automated measurement of both methane and non-methane hydrocarbons. The detection limit of the method is 20 ppb for methane and 50 ppb for NMHC (as propane). The range of the instrument (for both analytes) is from 0 to 5000 ppm. This instrumentation is discussed in SOP G6, and will be used at one swine site (IN3B), two dairy sites (CA5B and IN5B), and one layer site (IN2B) as a check on the performance of the INNOVA. Doing so may require rotation of units, but it will be possible to have a 55C at each of these sites for a minimum of 8 to 12 months.

2.3.1.4 Individual VOCs

Two different methods will be used to analyze barn air samples for individual component VOCs. As described above, these methods will be used to quantify those VOCs that are determined (in consultation with EPA) to be present at levels that warrant monitoring.

VOC samples on sorbent tubes (See above and SOP V1) are subjected to a brief dry purge (as part of addition of an internal standard) to remove most water vapor, and are then thermally desorbed, in what is referred to as the primary desorption step. Analytes driven off the tube in the primary desorption step are refocused on a secondary trap (the cooled injection system), which concentrates them into a very small volume. Rapid desorption of the trap (the secondary desorption step) follows, and then injection/transfer of target analytes into the GC. The above steps are accomplished using a GERSTEL TDS (ThermoDesorption System) 2 unit, and/or a GERSTEL TDS A 20-tube autosampler unit. Identification of target compounds is accomplished by comparing their GC retention times and mass spectra (determined using an Agilent Model 5975 MSD) with those of authentic standards. Quantitation of each compound is then accomplished by comparing the response (preferably peak area of its primary characteristic ion, but peak height may also be used) relative to that of an internal standard (1,4-dichlorobenzene-d_4, naphthalene-d_8, and/or acenaphthene-d_{10}). This methodology (SOP V4) is based on: USEPA Compendium Methods TO-17 ("Determination of Volatile Organic Compounds in Ambient Air

Using Active Sampling onto Sorbent Tubes") (USEPA 1999b); TO-15 ("Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)") (USEPA 1999b); and Method 8270C ("Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)") (USEPA 1996b). Because of possible contamination of sorbent tubes that can occur over long periods of storage between sampling and analysis, all sorbent tube phenol/VFA samples will be analyzed within 30 d of sample collection, in accordance with Compendium Method TO-17. The initial characterization of the site will include a TO-17 "uncharacterized atmospheres" test (SOP V1), which will determine the net amount of analytes sorbed per unit volume of air for 1-L and 4-L sample volumes. The linearity (or absence thereof) of these results will allow the analyst to determine whether the sampling tubes would become saturated at the higher sampling volume. If, in subsequent tests, the amount of analyte recovered from a tube is more than 25% higher than the highest amount that is known to be possible without saturating the tube (i.e. allowing breakthrough of analytes to occur), that test must be repeated with a lower sampling volume.

Samples collected in canisters (SOP V2) are analyzed similarly, except that dry purging is not conducted. Canisters are leak-checked after arrival in the laboratory, and are pressurized (if necessary) with humidified ultra high-purity nitrogen. An aliquot of sample (250-500 mL) is withdrawn from the canister, and introduced into a solid multisorbent concentrator. Sample water content can be reduced, if necessary, by dry purging the concentrator with helium, while retaining target compounds. The analytes are thermally desorbed from the concentrator into a cryofocusing unit coupled to a gas chromatograph (GC) inlet. The remainder of the analytical process is the same as described above for sorbent tube samples. This methodology, which is fully described in SOP V6, is based on USEPA Compendium Method TO-15 ("Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)") (USEPA 1999b), and Method 8270C ("Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)") (USEPA 1996b). Several loss mechanisms exist for analytes collected into sampling canisters, including physical adsorption, dissolution into separate water phases, chemical reactions, and biodegradation of analytes. Compendium Method TO-15 states that most VOCs can be recovered from canisters near their original concentrations after storage times of up to 30 d; thus, the period between collection and analysis of canister samples will never exceed 30 d.

2.3.1.5 Amines

The chromatographic separation of individual amines in collected air samples is achieved using a column packed with cation-exchange resin, as described in SOP V5. The amines, which are protonated in the acidic trapping solution, display varying affinity for the resin, and are therefore separated as the mobile phase moves through the column. The column that is used, the Dionex IonPac® CS17, is a hydrophilic, carboxylate-functionalized cation exchanger that is specifically designed for analysis of amines. The overall Ion Chromatography (IC) system (Dionex Corporation, Sunnyvale, CA) consists of a Model AS40 autosampler, Model GP50 gradient pump, Model CD25 conductivity detector, Model LC20 column enclosure, IonPac® CS17 cation exchange column, IonPac® CG17 guard column, Cation Self-Regenerating Suppressor (CSRS®

ULTRA), and Cation Trap Column (4-mm CTC-1). The mobile phase consists of a mildly acidic (dilute methanesulfonic acid) solvent/water mix. Temperature control of the column is included to improve reproducibility of retention time. Detection is based on conductivity increases monitored in the mobile phase as the individual amines elute from the column. This method is adapted from USEPA's CTM-027 ("Procedure for Collection and Analysis of Ammonia in Stationary Sources"), with modifications based on Dionex product-application literature. Amines samples will be analyzed within 30 d of their collection. SOPs V3 and V5 include provisions for assessing if the bubbler trapping system has become saturated (i.e. if the concentrations of analytes are the same in each of the two sequential trapping bubblers). If this occurs, the sample must be collected again, with a reduced sampling volume.

2.3.1.6 Carbon Dioxide

Concentrations of CO_2 will be measured at some sites using 10,000-ppm (1%) or 5,000-ppm (0.5%) photoacoustic infrared CO_2 analyzers (Model 3600, Mine Safety Appliances, Co., Pittsburgh, PA). The sensor utilizes dual frequency photoacoustic infrared absorption and is corrected for water vapor content. This instrumentation is discussed in SOP G3. However, since this instrument is no longer in production, sufficient quantities are not available for all NAEMS sites. Thus, CO_2 levels at all other sites will be determined using the INNOVA Model 1412 Multi-gas Monitor (Section 2.3.1.1 & SOP G7).

2.3.1.7 Gas Cylinder Compositional Verification

Fourier Transform Infrared (FTIR) spectroscopic methods will be used to analyze the concentrations of certified standard gases in cylinders purchased from outside vendors, and to ensure that the gas cylinders that are used for calibrations and/or performance checks of gas analyzers and other analytical instruments contain gases at their stated concentrations. The FTIR gas spectrometer (Nexus 670, Thermo Electron Corporation, Palatine, IL) consists of a KBr beamsplitter, a mercury cadmium telluride High D* (MCT-High D*) detector (cooled with liquid nitrogen), an IR source, a heated stainless steel gas absorption cell, an electronic package, and a computer. The sample gas can be delivered to the gas absorption cell either directly from the gas cylinder (continuous purge mode), or from a sample bag to the vacuumed gas cell (batch mode). The latter is used if the gas cylinder is not available onsite with the FTIR, but must be used judiciously, as data exists to show that Tedlar sample bags do allow substantial losses of certain gases (e.g. ammonia), even after short periods of time. Using OMNIC QuantPad software (Thermo Nicolet Instrument Corporation, Madison, WI), quantitative analysis methods can be created which allow analysis of spectra from gas- or condensed-phase samples using the Classical Least-Squares (CLS) quantitative analysis algorithms. FTIR methodology, discussed in detail in SOP G12, is taken from USEPA Test Method 320 ("Measurement of Vapor Phase Organic and Inorganic Emissions by Extractive Fourier Transform Infrared (FTIR) Spectroscopy").

2.3.1.8 Manure Characterization

Several manure parameters that are known to influence emissions, particularly emissions of NH_3 and H_2S, will be determined. Manure pH will be determined (SOP M2) in accordance with USEPA Method 9040C, “pH Electrometric Measurement” (USEPA 2004), which is suitable for aqueous wastes and those multiphase wastes (including manures) where the aqueous phase constitutes at least 20% of the total volume of the waste. Any dried manure samples that consist of <20% water will be equilibrated with water (SOP M2) for 30 min, at which point the pH of the resultant slurry will be taken. The content of total and volatile solids in manure samples will be measured (SOP M3) using USEPA Method 1684 (2001 Draft version), which includes a drying step at 103ºC to 105ºC to drive off all of the water in the sample. This step allows for the determination of total solids. Following cooling, the total-solids portion of the sample is heated to 550ºC, in a step that causes the volatile solids to be released. Total N and NH_3 contents of manures are determined using micro-Kjeldahl techniques, as described in SOP M4 and SOP M5, respectively. The digestion methodology described in these SOPs is taken from USEPA Method 1687 (2001 Draft version), and the distillation and titrimetric analysis are taken from USEPA Method 351.3 (USEPA 1974).

2.3.2 Analytical Failures

Individual site PIs will be responsible for the operation of the gas analyzers, and for addressing and documenting analytical failures. In general, when failure of a gas analyzer occurs, the problem must be corrected as soon as possible, but the data captured (if any) by the improperly-operating instrument cannot be recaptured, and must be flagged as lost or invalid. Analyses of VOCs and amines will be conducted at PAAQL; thus, documentation and troubleshooting will be the responsibility of PAAQL personnel (specifically, Dr. Changhe Xiao, who will serve as VOC Manager for NAEMS). When an individual analysis of amines (collected in bubblers) or canister-sampled VOCs fails, these samples can be re-run after the problem is corrected; thus, they can still result in valid data. However, samples of VOCs from sorbent tubes are destroyed in the analytical process – as such, if an analysis of one of these samples fails, that sample is lost. Unless a duplicate sample was taken at this location and time (as is done with a minimum of 10% as a QA/QC measure, as described in SOP V1), no valid data can be obtained from this sample. Manure characterization will be conducted by a subcontracted commercial laboratory (Midwest Laboratories, Omaha, NE); the staff at this laboratory will document and address all analytical failures. In general, sufficient manure sample should be available that re-analysis is possible after addressing the cause(s) of analytical failure.

2.3.3. Sample Disposal

The exhaust streams of the gas analyzer chambers (consisting of any sampled gas that remains at the conclusion of the analysis) will be conveyed through flexible tubing to an exhaust port which is part of the air exhaust system of the OFIS. In the cases of most of the analyzers, the exhaust contains only sample, and is therefore identical in composition to the air at the sampling point (i.e. in the barn); however, in the case of the TEI Model 17C, the exhaust does contain significant concentrations of ozone. As discussed in SOP G4, incorrect plumbing between the analyzer and the OFIS exhaust port could lead to elevated ozone levels in the trailer, causing a potentially significant safety hazard.

VOC samples collected on sorbent tubes are destructively analyzed, so disposal of these is not an issue. Liquid waste from the bubblers used for amine sampling will be disposed of through the Purdue University Department of Radiological and Environmental Monitoring, which is charged with disposal of chemical wastes under the guidance of the Purdue University Chemical Hygiene Plan.

Manure samples will be autoclaved or otherwise sterilized prior to disposal, which will be the responsibility of Midwest Laboratories.

2.4 Quality Control Requirements

Quality assurance and quality control measures will be performed throughout the sampling, measurement, and data processing procedures. These include real-time monitoring of the entire measurement system, review of measurement data and test notes in a timely manner, and quality control of specific equipment. This last element includes periodic calibration or precision checks using certified calibration gases with known concentrations, and proper maintenance of the instruments (Section 2.5). The QA/QC also includes the use of properly maintained and reliable instrumentation, approved analytical methodologies and standard operating procedures, external data validation, well-trained analysts, audits, and documentation.

2.4.1. QC Procedures

QC activities are used to ensure that measurement uncertainty is maintained within acceptance criteria for the attainment of the DQIs. All necessary regularly-scheduled QA/QC activities for a particular site will be contained in a “Site Maintenance/Calibration Schedule” spreadsheet that will be developed by PAAQL personnel and provided to each site. This spreadsheet will then serve as documentation that the QA/QC activities have been performed. Site personnel will initial and date the appropriate box on the spreadsheet whenever an activity is completed. The spreadsheet is printed out and posted on the wall of the OFIS or maintained electronically.

2.4.1.1 Calibration

Calibration is the comparison of a measurement standard or instrument with another standard or instrument to report, or eliminate by adjustment, any variation (deviation) in the accuracy of the item being compared. The purpose of calibration is to minimize bias. Calibration requirements and procedures for the critical field, laboratory equipment and other sensors are discussed in detail in Section 2.6 of this QAPP, and in the various SOPs referenced in Section 2.6.

2.4.1.2 Bias Checks

In this section, we used the equations presented in the CFR Title 40, Part 58, Appendix A, Section 5. (Quality Assurance Requirements for State and Local Air Monitoring Stations (SLAMS)). Four different types of precision checks will be used in this project:

1. Certified calibration gases as known standard to check the responses of gas analyzers. All atmospheric gaseous measurements will be traceable to dual-analyzed and certified standards. The certified gas standards will be traceable to NIST, and are described in Section 2.6.
2. Precision check standards that will be used with analyses of VOCs (by GC/MS and IC) and manure and other solid and liquid samples for N and NH_3 contents. The former of these will be prepared using chemical stocks that are the highest commercially-available grades. The latter (standards for manure N content, pH, and solids content) will be NIST-traceable. Details of these standards are provided in the individual SOPs.
3. Check of accuracy using the sampler flow rate check (for TSP, PM_{10}, and $PM_{2.5}$)
4. Collocated sampler reference methods (for $PM_{2.5}$).

<u>Bias of Gases and Accuracy of PM Samplers (TEOMs) Using Flow Rate</u>

For each precision check of a gas analyzer using calibration gas(es) of known concentration or PM sampler (TEOMs) using a standard flow rate, the percent relative bias (or accuracy in the case of PM samplers) d_i is calculated with equation 2.1:

$$d_i = \frac{Y_i - X_i}{X_i} \times 100\% \qquad (2.1)$$

Where:

X_i = True value of the parameter (certified gas concentration or standard flow rate)

Y_i = Reported value of the parameter (gas concentration or flow rate measured by the primary instrument, which is that used to officially report the data for the site)

The average (D) of several biases can be obtained using equation 2.2.:

$$D = \frac{1}{k}\sum_{j=1}^{k} d_j \qquad 2.2$$

To obtain the weighed average of averages when each individual average is the average of different number of percent differences (bias) use equation 2.3:

$$D = \frac{n_1 d_1 + n_2 d_2 + ... + n_k d_k}{n_1 + n_2 + ... + n_k} \qquad 2.3$$

Where n_k represent the number of averages used to obtain d_k.

For gas analyzers, the true values of the parameter are the concentration of certified calibration gases.

2.4.1.3 Precision Checks

Precision is defined as the measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. To meet the data quality objectives for precision, it is necessary to ensure that the entire measurement process is within statistical control.

Precision is calculated using the following methods:
- Response check at certified concentrations (for gas analyzes)
- Collocated samplers (for TEOMs used to measure TSP, PM_{10} and $PM_{2.5}$).

Gas Measurement Precision

To calculate the precision using precision checks (called audits in the CFR), we need to calculate the percent difference (di) for each precision check using equation 2.1. Then we calculate the standard deviation using equations 2.4, 2.5, or 2.6:

$$S_j = \sqrt{\left(\frac{1}{n-1} \left[\sum_{j=1}^{n} d_i^2 - \frac{1}{n} \left(\sum_{i=1}^{n} d_i^2 \right)^2 \right] \right)} \tag{2.4}$$

$$S_a = \sqrt{\left(\frac{1}{k} \sum_{j=1}^{k} S_j^2 \right)} \tag{2.5}$$

$$S_a = \sqrt{\left(\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2 + \ldots + (n_k - 1)S_k^2}{n_1 + n_2 + \ldots + n_k - k} \right)} \tag{2.6}$$

Equation 2.4 is used for a single analyzer. Equation 2.5 is used to obtain the average standard deviation (S_a) when the S_j values were obtained using the same number of individual precision checks. This equation can be used to obtain the quarter or annual average S_a for an analyzer using the individual or quarter standard deviations. Equation 2.6 is used to obtain a weighed S_a when different number of precision checks were used to calculate each S_j.

For each pollutant, the 95 Percent Probability Limits for the precision of an instrument are calculated using equations 2.7 and 2.8:

Upper 95 Percent Probability Limit = $D+1.96S_a$ 2.7

Lower 95 Percent Probability Limit = $D-1.96S_a$ 2.8

To calculate the average of averages (D) use equation 2.2.

PM Measurement Precision

For manual methods, the precision for each set of collocated PM samplers when the collocated instrument is not an FRM (for example, when two TEOMs are collocated to measure TSP, PM_{10}, or $PM_{2.5}$), the percent relative difference d_i is calculated with equation 2.9 (Section 5.5.2 of 40CFR58, App. A):

$$d_i = \frac{Y_i - X_i}{\left(Y_i + X_i\right)/2} \times 100\% \qquad 2.9$$

Where:

X_i = Value recorded by the collocated sampler (the sampler used as reference)

Y_i = Value recorded by the primary sampler (the sampler used to report data for the site)

The coefficient of variation (CV), for a single check is calculated by EPA by dividing the absolute value of the percent relative bias, d_i, by the square root of two:

$$CV_i = \frac{|d_i|}{\sqrt{2}} \qquad 2.10$$

Precision of a single instrument, j, during the quarterly, q, is calculated with:

$$CV_{j,q} = \sqrt{\frac{\sum_{i=1}^{n_j} CV_i^2}{n_{j,q}}} \qquad 2.11$$

Where:

$CV_{i,q}$ = Precision of a single instrument at a quarterly basis

$n_{i,q}$ = Number of precision checks

The 90 percent confidence limits for the single instrument's CV are calculated with:

$$Lower\ \ Confidence\ \ Limit = CV_{j,q}\sqrt{\frac{n_{j,q}}{\chi^2_{0.95,n_{j,q}}}} \qquad (2.12)$$

$$Upper\ \ Confidence\ \ Limit = CV_{j,q}\sqrt{\frac{n_{j,q}}{\chi^2_{0.05,n_{j,q}}}} \qquad (2.13)$$

Where,

$\chi^2_{0.05,df}$ = The 0.05 quantiles of the chi-square (χ^2)

$\chi^2_{0.95,df}$ = The 0.95 quantiles of the chi-square (χ^2)

2.4.1.4 Corrective Actions and Interpolation of Data Points

Correction actions that will be taken for any instrument if the quality control checks fail are described in detail in Section 2.6 of this QAPP. The procedure for interpolating data in between sampling points is given in SOP B4; for the purposes of the NAEMS, the maximum interval that interpolation will be applied to is 300 min. SOP B4 similarly states the procedure for correcting data taken between a passed precision check and one that is out of the control limits.

2.4.1.5 Control Charts

Control charts will be used extensively. They provide a graphical means of determining whether various phases of the measurement process are in statistical control. Control charts are described in SOP Q1. Control limits will be set for each measured parameter that is being tracked with control charts; values outside these limits will trigger corrective action.

2.4.2. Real-time Measurement Checks

Measurement limits (MQOs) defined in the data quality objectives for each individual variable (Section 1.4) will be used for monitoring and reviewing the continuously measured data.

2.4.2.1 Visual Alarms and Remote System Check

All of the continuous measurement variables will be displayed real-time by the AirDAC software (SOP B2) in the on-site computer. Pre-set minimum and maximum ranges for individual variables will be checked by AirDAC at every data point (i.e. every second). If the measured variable exceeds the pre-set limits, a visual alarm will be displayed indicating the name of the variable, its current value, and its pre-set range.

Two hours of historical data will also be displayed in graphical form on the site computer for all measurement and control variables. Abnormal measurements will be easily identified in the history display. For example, signals from disconnected or unresponsive sensors will be displayed as a flat line.

Alarms and history graphs will allow quick identification of any problems with the instruments or the data-acquisition hardware and help to fix them. See SOP B2 for further details.

Research personnel, both local and at PAAQL, will check the on-line display via high-speed internet at least once daily, particularly on days when local site personnel do not visit the site.

2.4.2.2 Email Alarms

AirDAC allows configuring whether an alarm email should be sent for each individual out-of-range variable, and whether the sampling location at which the out-of-range variable was encountered should be indicated when this alarm occurs. AirDAC will be configured such that emails will be sent to notify the responsible site personnel whenever an out-of-range measurement is detected for the selected variables, so that instrumentation problems can be promptly addressed. At minimum, all instruments involved in the collection of Category 1 data (as defined in Table 1.4.1.) will be included in the alarm list. A second email message will be sent when the problem is resolved, and the measurement is again within the acceptable range for the particular instrument.

2.4.3. Quality Control Measures for Specific Equipment and Procedures

1. Measurements of certified zero air will be included as field blanks for all gas analyzers. Precision checks of gas analyzers, using both zero air and a span gas, will be conducted at least weekly. More frequent precision checks will be applied to newly-installed analyzers to monitor their stability. There are usually two different causes for “out of tolerance” zero or span responses. One is sudden failure of the instrument, and another is the normal drift of the instrument sensitivity. Data will be invalidated for instrument failures. Data will be flagged going back to the last good precision (z/s) check, but can be corrected to compensate the drift by using z/s check results during data processing, if it has drifted steadily in one direction. A replicated multipoint calibration of all gas analyzers will be performed at the analyzer’s initial setup at the site, and will be repeated whenever the precision checks for any individual analyzer are beyond the acceptable limits. Calibration records will be maintained in the project log book and electronic field notes. Further details on the multipoint calibration procedure are given in SOP G8, and details about the precision checks of gas analyzers are given in SOP G9. If the analyzer’s response to the calibration gases is beyond the adjustable range using the built-in adjustment feature and its responses to calibration gases are not consistent, the analyzer will be sent back to the manufacturer for repair. A spare unit will be provided by PAAQL, or by the manufacturer, to avoid interrupting the on-going measurement.

2. If possible, the compositions of gases in the gas cylinders that are used for calibration of the gas analyzers will be checked using Fourier Transform Infrared (FTIR) spectroscopy, in accordance with SOP G12. At minimum, all gases that are suitable for IR quantitation that are sent to each site at the beginning of the study will be checked with FTIR, to verify their compositions and concentrations per the supplier’s certification. Later cylinders can then be checked on-site against these known cylinders using the individual gas analyzers. Procedures will be instituted (SOP G2) to ensure that sufficient gas remains in a given cylinder to conduct this comparison with its replacement, and that the existing cylinder is not replaced until one with suitable composition and concentration is received to take its place. If the gas concentrations obtained by the FTIR check are not within ±5% of those certified by the gas provider, the gas provider will be contacted for further verification or re-certification, if necessary.

3. Vane anemometers will be subjected to initial performance checks that will include checks of the starting torque and transducer output as a function of rotational speed. Each anemometer will be periodically spot-checked in the field and compared to factory-specified values. Further details are provided in SOP A3. If the anemometer's performance does not meet the factory specifications, it will be repaired or replaced.

4. Proper operation of all fan stage monitoring equipment, anemometers, vibration sensors, current switches and rpm sensors will be visually verified once a week. Any abnormality will be addressed as soon as possible either by repair or replacement. Output from rpm sensors will be compared with that from an optical tachometer, if available.

5. Each FANS unit will be calibrated at the UIUC BESS Lab annually to ensure that it is functioning properly. If possible, a new (field) FANS measurement will be performed on any individual fan that has undergone any maintenance that is likely to significantly change its performance (such as installation of a new motor, cleaning, or belt tightening). Producers will be asked to keep belts tightened by using automatic belt tighteners on their fans, to minimize this last source of error.

6. Zero checks, and precision checks (based on the agreement of several collocated anemometers) will be performed on the ultrasonic anemometers that are used for naturally ventilated barns. Each of these is described in detail in SOP A6.

7. Thermocouples will be calibrated before and after the 24-month data collection period, and in-place spot-checks of each sensor (by comparison with a NIST-traceable temperature standard) will be conducted every six months (SOP E1). If the error of a thermocouple is >±2 °C, further checks will be performed on the thermocouple wire and the data acquisition hardware. Problematic thermocouples will be replaced. Non-working thermocouple channels in the analog data acquisition module will be replaced by reserved working channels.

8. Temperature and relative humidity probes will be tested with a NIST-traceable standard, as described in SOP E2. Probes that do not meet the criteria specified in SOP E2 will be replaced and repaired.

9. Calibrations of the differential pressure transmitters will be conducted before and after the study. Zero checks will be conducted monthly, and span checks against a reference standard (either a recently calibrated sensor, an inclined manometer, or a precision micromanometer) will be conducted quarterly. Alternatively, sensors (three or more) can be collocated to verify that they agree within this limit. See SOP A5 for further details. If the error of a transmitter is >±10 Pa, further checks will be performed on the transmitter. If the error cannot be corrected by adjusting the internal calibration potentiometers, the transmitter will be replaced and repaired.

10. All National Instruments FieldPoint analog input modules used for data acquisition will be manufacturer-calibrated and come with NIST-traceable calibration certificate to

ensure accurate, reliable analog measurements. The manufacturer's calibration is valid for two years after the manufacturing date. The channels on the modules will be checked with 0 VDC and 5 VDC after installation on-site to assure that no errors were introduced through the installation process (e.g. through improper grounding).

11. Data will be managed to avoid data from being lost. Details are provided in Section 2.9 of this QAPP, and SOP B5.

12. Site personnel will be trained to run all equipment (Section 1.5 of this QAPP).

13. Internal performance and system audits will be performed to evaluate the accuracy of field measurements of NH_3, H_2S and VOCs. The delivery of samples to the analysts in the field will be coordinated by the Project QA Manager on an announced single-blind basis (only QA Manager knows the concentration). The samples will be purchased from a reputable vendor, will be dual-analyzed and certified, and will, if possible, be checked with the FTIR. The samples will be delivered to an inlet of the sampling system, not directly into the analyzer. Acceptable ranges provided by the manufacturer of the samples will be used to determine if the measurement system is performing acceptably. If not within the accepted range, corrective action will be performed before further analysis continues.

14. Surge suppressors will be used to protect the PC and the instruments (SOP U1). An uninterruptible power supply with battery backup will be used to prevent damage to sensitive equipment and data loss in case of power failure (SOP U6).

15. All VOC sampling (sorbent tubes, canisters, and bubblers) will include suitable field, laboratory and trip blanks, as described in the respective SOPs (V1, V2 and V3). The number of blanks and the methods to prepare and handling them are based on USEPA methods. Pumps and mass flow meters used for collection of VOC samples (via the bubbler or sorbent-tube method) will be calibrated according to manufacturer's instruction, and flow rates will be noted at the beginning and end of each sampling time (at minimum). Pumps that do not hold the required flow rate (within 10%, as per SOPs V1 and V3) for the entire sampling time will be repaired and re-calibrated. Analyte concentrations will be calculated based on a sampling volume that represents the average flow rate during the sampling period.

16. GC/MS analyses will incorporate extensive QA/QC procedures, including: a) daily instrument performance checks, b) daily single-point (mid-range) calibration checks, c) full five-point calibrations initially and whenever significant maintenance is performed, d) periodic system precision checks, and e) initial demonstrations of each analyst's proficiency. Internal standards will be included in all samples and standards. Details on these QA/QC procedures are provided in SOP V4 and SOP V6.

2.5 Instrument/Equipment Testing, Inspection, and Maintenance

All analytical equipment will be properly maintained, and tested regularly to ensure proper function, following the manufacturer's recommended intervals and acceptance parameters. Equipment will be repaired as soon as possible upon discovery of a problem. Manufacturer's instructions for routine maintenance of equipment will be followed. All testing, inspection and maintenance activities will be documented in the field project log book or electronic field notes.

All instruments and equipment will be inspected for damage and tested before usage. The SOPs and manuals for the instruments and equipment give procedures on inspecting and testing the specific equipment (including calibration and zero/span checks, and any other necessary checks). In general, the inspection procedure is as follows:

- Check the shipping container for damage.
- Remove the instrument with extra care from the shipping container and set on a table or bench that allows easy access to the front, rear, and sides of the instrument/equipment.
- Check the outside of the instrument for any damage.
- Remove the instrument cover to expose the internal components and visually check for possible damage during shipment. (Remember when working with electronic components the operator must be grounded)
- Check that all connectors and printed circuit boards are firmly attached.
- Check all wiring for damage.
- Check for missing parts
- Check that there are no useful parts remaining in the interior of the box.
- Do not discard the box until the instrument has been verified totally. Keep the box in case the instrument needs to be returned.
- Do not install or operate the instrument if damage is suspected.
- If damage has occurred, document the damage in the field notes and take photographs of the damage. Contact PAAQL, site PI, and the carrier about the damage.
- Install the unit in a dry and secure place

The instruments and equipment will be tested, either at PAAQL or by the site PI, prior to usage to ensure good working condition. This applies to all newly-purchased equipment, and to pre-existing equipment used in the NAEMS. The gas analyzers will be calibrated and tested with precision checks according to procedures in SOPs G8 and G9. Any other analyzer-specific tests are described in the analyzers' respective SOPs. All instruments, equipment, and gases for which certifications are provided by the manufacturer or supplier will have the certifications on file at PAAQL and in the OFIS at the site at which they are being used. Any instrument or piece of equipment that needs recalibration and certification will be shipped back to the manufacturer for the certification. Table 2.5.1 lists the acceptance criteria of the instruments and equipment (both new and used) when initially tested at PAAQL before being sent to the field site for use in the NAEMS. All inspections listed in Table 2.5.1 will be documented in the electronic field notes.

Table 2.5.1. Acceptance criteria of the instruments and equipment.

Equipment to be Tested	SOP	Parameter	Acceptance Criteria
GSS			
Pumps	G1	Flow rate	10 L/min
Solenoids		Switching	Pass / fail
Mass flow meter		Flow rate	0 -10 L/min
RH/T		Temperature	-10-40°C
RH/T		RH	20 to 95% RH
Pressure meter		Pressure	±5 psi
Leak test		Flow rate	<60 mL/min @ -6000 Pa
Temperature		Temperature	30-60°C
TEOMs (TSP, PM_{10}, $PM_{2.5}$)			
Flow rate standards	P1	Accuracy	±2% of full scale @ 20 L/min
$PM_{2.5}$ Partisol			
Flow rate standards	P3	Accuracy	±2% of full scale @ 20 L/min
Temperature standard		Resolution & accuracy	±0.1°C (res); ±0.5°C (acc)
Pressure standard		Resolution & accuracy	±1 mm Hg (res); ±5 mm Hg (acc)
Beta Gauge			
Flow rate standards	P4	Accuracy	±2% of full scale @ 20 L/min
RH/T Sensor	E2	Range	-40-120°C & 20-95% RH
Activity Sensor	S3	Signal	Pass / fail
Vibration Sensors	A7	Signal	Pass / fail
Wind Anemometer & Vane			
Wind speed	E4	Range	0-25 m/s
Wind direction		Range	0-355°
Solar Sensor	E3	W/m^2	0-1300 W/m2
Ultrasonic Anemometer			
Zero	A6	Velocity	<0.4 m/s (all 3 dimensions)
Drift		Precision	SD of collocated sensors <0.1 m/s
DAQ System			
Transformers	B1	24 VDC & 5 VDC	Pass / fail
Fieldpoint modules	B1	Signal	Pass / fail
AirDAC (Software)	B2	Signal processing	Pass / fail
TEC 450I			
Analog output	G5	Signal	0-10 VDC or 4-20 mA
Calibration (zero air, SO_2, H_2S)		AirDAC reading (ppm)	Pass / fail
Linearity		RSD	±5%
Precision		R^2	>98%
Response times (to H_2S)		t(95%)	<180 s
Response times (Downfall)		t(95%)	<120 s
MSA 3600 CO_2 MONITOR			
Analog output	G3	Signal	0-10 VDC or 4-20 mA
Calibration (zero air, CO_2)		AirDAC reading (ppm)	Pass / fail
Linearity		RSD	±5%
Precision		R^2	>98%
MSA 3600 CO_2 MONITOR			
Response times (to CO_2)	G3	t(95%)	<100 s
Response times (Downfall)		t(95%)	<100 s

Table 2.5.1. Acceptance criteria of the instruments and equipment (continued).

Equipment to be Tested	SOP	Parameter	Acceptance Criteria
INNOVA 1412			
Linearity	G7	RSD	±5%
Precision		R^2	>98%
Response times (all tested gases)		t(95%)	<300 s
Response times (Downfall)		t(95%)	<120 s
Environics Diluter			
Calibrate MFCs	G11	Flow	100-110% of full rated flow
FTIR			
Power supply	G12	Function	Pass/fail of standard diagnostic tests.
HeNe laser			
Light source			
Electronics			
Beamsplitter and detector			
Desiccant		Condition	Pass/fail “check desiccant” test
Detector signal		Intensity	Comparison with usual level
Filter prior to FTIR		Condition	Visually clean
GC/MS			
Injection port inertness and column performance (SPCCs)	V4 & V6	Peak geometry	Normal peak area or height response, no peak tailing
Response Factors (RF) of SPCCs		RF (peak area vs. concentration)	RF ≥ 0.05
Spectrum of PFTBA		*m/z* ratios	See ion profile criteria in SOP V6
Sorbent Tubes			
Cleanliness & conditioning	V1	Concentration of target analytes in zero air	<0.2 ppbv for all analytes
Recovery		% Recovery	90 - 110% for all analytes
Canisters			
Cleanliness of canisters & sampling train	V7	Concentration of target analytes in zero air	<0.2 ppbv for all analytes
Recovery		% Recovery	90 - 110% for all analytes
Sampling train leak test		Pressure stability	Stable for 1 - 2 min
Canister leak test		Pressure stability	Pressure (60.8 in Hg) remains ± 4.08 in Hg for 24 h
Canister pressure check		Pressure	(0.002 in Hg
Critical orifice & flow controller		Flow rate	2-4 sccm
Analyte stability		Analyte recovery after 5d, 10d, 20d, & 30d	Recovery remains ≥80%
Pressure gauge		Reading	0

The various instruments and equipment will be inspected on a regular basis after they are deployed to the field, to ensure that all components remain in proper working order throughout the course of the study. The site PIs and their personnel are responsible for the testing, inspection, and maintenance of the instruments, equipment, and OFIS. The schedule for inspecting the various pieces of equipment, the parameters that must be checked, and how to appropriately document the inspection are provided in Table 2.5.2.

Table 2.5.2. Inspection schedule for on-site and lab equipment for the NAEMS.

Item	SOP	Inspection Frequency	Inspection Parameter	Remedial Action	Documentation
Thermocouples	E1	Daily	Signal (-20 to 40°C)	Locate & fix problem, then recalibrate as necessary	Field notes
RH/T Probe	E2		Signal (20-95% RH) (-20-40°C)		
Wind Anemometer & Vane	E4		Signal (0-25 m/s) (0-360°)		
Solar Sensor	E3		Signal (0-1300 W/m^2)		
Roof-Mounted Weather Station	E5	Quarterly	Damage	Repair damage	
TEC 4501	G5	Daily	Signal & Analyzer Alarms	Check connection; Address alarms, PC; MPC	
Pressure		At every calibration & precision check	400-1000 mm Hg	Check for blockage	
Sample flow			0.35-1.4 L/min	Check pump	
Frequency			10-50 KHz	Replace lamp	
Lamp voltage			500-1200 V	Adjust into normal operating range	
MSA 3600 CO_2 Monitor	G3	Daily	Signal	Check connection & flow; PC; MPC	
INNOVA 1412	G7	Daily	Signal & Analyzer messages	Address Error message; Reset analyzer; PC; MPC	
Environics Diluter	G11	At every Calibration & precision check	Communication to computer; Delivery of gas to the GSS	Check connection & flow; Ensure cylinders are connected correctly & open	

Table 2.5.2. Inspection schedule for on-site and lab equipment for the NAEMS (cont.)

Item	SOP	Inspection Frequency	Inspection Parameter	Remedial Action	Documentation
TEOMs (TSP, PM_{10}, $PM_{2.5}$)	P1	Daily	Signal	Check connection & flow	Field notes
Filters			Particulate loading	Change filter at 70% loading (Maximum)	
Pump			Signal, L/min	Check connection & flow; Precision check; Calibration	
$PM_{2.5}$ PARTISOL	P3	Every site visit	Signal	Check connection & flow	
Cassette & rubber seals		Daily	Clean/inspect cassette & rubber seals	Clean & replace as necessary	
Inlet water jar			Water	Drain	
Pump			L/min	Repair and retest	
Perform a leak test		Monthly & every 5 samples	Flow	Find & fix leak; repeat leak test	
O-rings, gaskets and seals	P3	Monthly	Dust, deterioration, damage	Clean or replace as necessary	
Sampler clock time			Correct time	Correct	
Single-point flow check			Flow	Locate problem, repair & retest	
Temp. & pressure sensors			Check Temperature & Pressure	Locate problem, repair or replace, & retest	
Sampler interior & inlet		Every 6 Months	Verify as-is condition of sampler interior, inlet	Clean, locate problem, repair & retest	
WINS impactor & leak test			WINS impactor & leak test	Locate problem, repair & retest	
Main computer board battery			Check	Replace	

Table 2.5.2. Inspection schedule for on-site and lab equipment for the NAEMS (cont.)

Item	SOP	Inspection Frequency	Inspection Parameter	Remedial Action	Documentation
Beta Gauge	P4	Daily	Signal	Check connection, flow, fix the problem	Field notes
Activity Sensors	S3		Signal	Locate problem and repair or replace	
Vibration Sensors	A7				
Pressure Sensors	A5				
GSS	G1				
Filters			Sample pressure drop ≤ -8000 Pa	Replace filter in barn; Replace filter in OFIS; Check sample line for damage & blockage	
Sampling pump			Signal (Flow 3-8 L/min)	Locate problem and repair or replace	
Pressure sensor			Pressure (Pa) (±5 psi)		
Mass flow meter			Flow rate (L/min)		
Humidity / temperature sensor			Signal (20-90% RH) (-20-40°C)		
Fan			GSS Temperature		
Solenoids			Signal; Sample flow; Pressure		
Bypass pump		Weekly	Is the pump on?		
ULTRASONIC ANEMOMETERS	A6	Daily	Signal, flow rate		
OFIS					
Shelter structure	U1	Daily	Check for damage	Locate damage and repair	Field notes
AirDAC hardware	B1		Computer & Fieldpoint modules, transformers		
FieldPoint modules			Signal		
Computer			Power on?		
E-mail data			Check list of outgoing emails & verify that the data has been received.		

Table 2.5.2. Inspection schedule for on-site and lab equipment for the NAEMS (cont.)

Item	SOP	Inspection Frequency	Inspection Parameter	Remedial Action	Documentation
OFIS					Field notes
HVAC	U1	Daily	Temperature ≥ barn dew point?	Locate damage and repair	
Heated raceway	U3		Signal (T)	Locate problem and repair or replace	
OFIS filters	U1	Weekly	Clogging of filter with dust	Clean	
AC filters					
Carbon filter (air recirc.)		Monthly		Replace	
Surge protected power strip		Monthly	Plugged in? Are instruments plugged into the surge protectors?	Locate problem and repair or replace	
UPS	U6		Instruments plugged in (via surge protectors)? Test battery		
Site Inspection					
Tubing & wiring	U2	Daily	Signal, Pressure drop, Flow rate change	Locate problem and repair or replace	
Tubing	U2	Weekly	Damage to tubing		
Fans			Is the fan on? Check AirDAC for fan or sensor signal	Inform the farm of the problem to get it fixed	
Fan motors			Power to fan		
Belt			Broken belt		
Fan housing			Damage to fan housing		
Shutters			Shutters undamaged & functional		
Curtains			Holes in the curtain; Is the curtain closed properly?		
Water			Leaking and/or wet spots in pit		

Table 2.5.2. Inspection schedule for on-site and lab equipment for the NAEMS (cont.)

Item	SOP	Inspection Frequency	Inspection Parameter	Remedial Action	Documentation
FTIR Spectrometer	G12	Daily (every 4 h if continuous sampling)	Background spectrum	Check cell temperature, pressure and alignment. Correct problem and take a new background	Field notes
Purge gas flow rate		Daily	Flow rate	Set at 30 scfh.	
Detector signal			Signal intensity	Add enough liquid N_2 to cool detector, realign	
Leak check			Pressure ratio change ≤4%	Check tubing connections, fix and retest	
Span gas concentrations		Monthly	Span gas concentrations	Check connection & flow; check detector signal, and recalibrate	
Filter prior to FTIR			Visual	Replace filter	
Gas absorption cell		Yearly	Compare detector signal before and after removing gas absorption cell	Ship to factory for cleaning & realignment	
VOC Sampling Equipment					
Sample sorbent tubes	V1	Every sampling event	Flow rate	Recalibrate/ repair pump/ MFM	Field notes, sorbent tube log
Sample sorbent tubes			Contaminants in chromatogram	Recondition tube & retest	
Canisters	V2	Every sampling event	Initial pressure (≤ 0.05 in Hg)	Do not use canister; Return to lab for testing & repair	
Mass flow controller			Constant flow (±10% for 24 h)	Return sampling train to lab for repair, cleaning or replacement of the orifice	
Canisters			Final pressure (7 in Hg)	Invalidate sample if > ±10% off	Field notes, canister log

Table 2.5.2. Inspection schedule for on-site and lab equipment for the NAEMS (cont.)

Item	SOP	Inspection Frequency	Inspection Parameter	Remedial Action	Documentation
VOC Sampling Equipment (cont.)					
Canister & sampling train certification	V7	Every time the canisters & sampling train are prepared for a sampling event	Humidified zero air blanks <0.2 ppb_v for any of the target compounds; % recovery of target compounds between 90 % to 110%	Clean & retest	Field notes
Sampling train leak test			Pressure stable for 1 - 2 min	Check & tighten all connections; retest for leaks	
Canister leak test			Pressure (60.8 in Hg) remains within ± 4.08 in Hg for 24 h		
Canister (Pressure check)			Pressure (0.002 in Hg)	Locate leak & repair	
Critical orifice & flow controller			Flow rate (2-4 sccm)	Replace orifice	
Canisters - analyte stability	V3	Before first use of canister & after every 10th use	Concentration of any single target analyte does not decrease >20% over 5d, 10d, 20d, & 30d.	Reclean & retest; remove from service if fails twice.	
Bubblers		Every sampling event	Stable flow rate (1.0 L/min)	Check pump, repair, recalibrate	
Bubblers			Pressure (leak test) 10 in Hg	Fix leak, retest, or use different bubbler	
Bubblers			Blank (lab or field) must not have analyte > the MDL	Return to lab; clean & retest	

Table 2.5.2. Inspection schedule for on-site and lab equipment for the NAEMS (cont.)

Item	SOP	Inspection Frequency	Inspection Parameter	Remedial Action	Documentation
GC/MS					
Visual inspection	V4 & V6	Monthly	Condition (visual)	Locate problem; repair or replace parts	Lab notebook
MS Tuning		Daily	Peaks in tuning standards display proper m/z ratios; peak width at half peak height is correct to within 0.1 amu	Recalibrate and tune	
Column			Normal chromatogram (peak shape, sensitivity, retention time, etc.)	Trim 0.5 - 1 m from column front; Replace inlet liner & septum and clean inlet; Replace column	
Inlet septum			Condition (visual)	Replace	
Response Factors (RFs) of system performance check compounds (SPCCs)			RFs for SPCCs are ≥0.05	Clean injection port; Trim or recondition column; Replace column; Retest	
Single-point calibration			Daily RRF is within ±30% of mean RRF in most recent full calibration	Clean ion source; Change column; Clean injection port; Perform a full calibration	
Foreline Pump		Weekly	Oil level & pressure	Add or replace oil	
TDS leak test		After every servicing of the system	Total flow rate & pressure	Check for leak and fix; Check flow settings	
Laboratory & field blanks		Lab: Two per sampling event Field: Min. two per sampling event, plus one for every 10th canister	No target analyte present at > 3X MDL; No non- target compounds with RT and mass-spectral features that would interfere with analyses	Clean injection port; Clean ion source; Recondition, trim, or change column; Recalibrate	

Table 2.5.2. Inspection schedule for on-site and lab equipment for the NAEMS (cont.)

Item	SOP	Inspection Frequency	Inspection Parameter	Remedial Action	Documentation
GC/MS (cont.)					
System precision checks		Once every tenth batch of samples, or quarterly	Agreement between six calibration check standards	Clean injection port & ion source, change & condition column, check source for contamination; recalibrate	Lab notebook
lnlet gold or stainless steel seal		Every 6 months	Visual	Replace	
IC system					
Visual Inspection	V5	Monthly	Condition (visual)	Repair or replace parts	Lab notebook
Eluents		Daily	No bubbles	Degas eluents	
System pressure			Within range	Locate and clear blockage	
Chromatograph baseline			Low and stable	Check for air bubbles/leaks; Check CSRS & proportioning valve; Prime pump; Flush detector cell;	
Leak check			No leaks	Check lines, connections, valves & seals; Repair/replace	
Peak resolution		Daily	Good peak separation	Check for overloading; verify pH; Flush/replace column	
Internal standard			90 - 110% recovery	Check sample loop, column, CSRS, detector cell; Clean or replace	
Gradient Pump			Proper pressure & flow	Check for dirty, blocked, leaky, or defective piston seals, valves or inlet filters. Check/ re-prime pump; Verify pressure limits; Check fuse, pressure transducer	

The instruments and equipment will require regular maintenance for proper operation and valid data. To perform regular maintenance, a supply of consumables such as filters and calibration gases must be maintained in the OFIS. Spare parts are critical for continuous operation of the instruments and equipment. The critical spare parts and the locations where spare parts are to be stored (e.g. at PAAQL or at the field site) are given in the SOPs for instrumentation and equipment. Critical spare parts will be located in the OFIS. A complete list of spare or replacement parts is also provided in the instrument and equipment manuals. Copies of these manuals will be kept at each field site. All vendors of the instruments and equipment are available to order spare parts. Vendor phone numbers, websites, and addresses are listed in the instrument and equipment manuals; the most commonly used vendors (in most cases, the instrument suppliers themselves) are also listed at the end of each instrument SOP, in the "Contact Information" section. A maintenance and calibration schedule, which will include the tasks listed in Table 2.5.3, will be maintained in each OFIS, either in hard copy form on the wall or electronic form in the site PC. Site personnel will initial and date each entry on the schedule as certification that the tasks were completed in a timely manner.

Table 2.5.3. NAEMS maintenance schedule for instrumentation and equipment.

Item	SOP	Frequency	Task
RH/T Probe	E2	Weekly	Cleaning
Wind Anemometer & Vane	E4	Quarterly	Performance check
Solar Sensor	E3	Monthly	Cleaning
TEC 450I	G5	Monthly	Visual inspection
External dust filters on analyzer		Weekly	Clean
Lamp voltage			Check & replace as necessary
Exhaust tubing			Inspect & clean as necessary
Flow check		6 months	Leak test
MSA 3600 CO_2 Monitor	G3	Monthly	Visual inspection
Exhaust tubing		Weekly	Inspect & clean as necessary
Sample flow		6 months	Check
Exhaust flow			Check
Internal filter		Annually	Inspect & replace as necessary
INNOVA 1412			
Ventilation filter on analyzer	G7	Monthly	Inspect & clean as necessary
Stainless steel frit			Clean
External dust filter			Clean/Replace
Leak test (sample inlet & outlet)			Test inlet and exhaust flow
Leak test (analyzer manifold)		6 months	
Environics Diluter	G11	Monthly	Visual inspection
Flow calibration		Annually	Check MFC flow
TEOMs (TSP, PM_{10}, $PM_{2.5}$)	P1	Monthly	Visual inspection
Screens		Every site visit	Clean
Inlet head		Weekly	Clean
Filters		+50% loading	Replace
Stored data		Monthly	Download
Flow rate verification		60 days	Verification
Leak test		60 days	Check
Air inlet system		60 days	Clean
In-line filters		6 months	Change
Analog board		6 months	Recalibrate

Table 2.5.3. NAEMS maintenance schedule for instruments and equipment (continued)

Item	SOP	Frequency	Task
TEOMs (cont.)			
MFM & MFC	P1	Annually	Audit MFM, calibrate MFC
Pump		Every 10,000 hours	Rebuild
$PM_{2.5}$ Partisol	P3	Monthly	Visual inspection
WINS impactor well		Every 5 samples	Service
Air intake filter and fan		Monthly	Clean
Interior of sampler		Monthly	Clean
PM_{10} inlet, downtube, WINS		Every 14 samples	Disassemble and clean
Large in-line filter		Every 6 months	Replace
Pump		Every 10,000 hours	Rebuild
Beta Gauge			
Inlet head	P4	Biweekly	Check/clean
Visual inspection		Monthly	
Inlet			Clean
Filter tape			Check & replace as necessary
Airflow		Quarterly	Check
Temp & barometric pressure			Check
Pump		Every 10,000 hours	Rebuild
Activity Sensors	S3	Monthly	Check alignment, clean as needed
Vibration and/or rpm sensors	A7/A11	Weekly	Compare to fan status & stage signals
GSS	G1	Monthly	Visual inspection
Filters			Check, replace every 6 months or as necessary
Leak check		Bimonthly	
Bag Test (NH_3)		Every 6 months	
Sample & bypass pumps		Every 10,000 hours	Rebuild
Exhaust & manifold pressures		Annually	Verify
Pressure sensor & MFM			Calibrate
Ultrasonic Anemometer	A6	As needed	Clean
OFIS HVAC	U1	Weekly	Check OFIS and AC filters, clean as needed
OFIS Computer	B5	Monthly	Backup all data files
OFIS Power (UPS)	U6	Weekly	Self-test
FTIR Spectrometer	G12	Monthly	Visual Inspection
Detector signal		Daily	Check
Purge gas flow			
Filter prior to FTIR		Monthly	Replace
Desiccant	Manual	Every 6 months	Check
Power supply		Whenever system is not performing properly	Run diagnostic tests
HeNe laser			
Light source			
Electronics			
Beam splitter and detector			
Gas absorption cell	G12	As needed/annually	Clean and realign
IC System	V5	Monthly	Visual inspection
Piston seals (salt buildup)		Daily	Rinse before and after use
Vacuum degas assembly			Thoroughly flush with deionized water
Cation Trap Column			Flush at end of day
Seals (primary and rinse seals)		Every 6 months	Replace in each pump head

Table 2.5.3. NAEMS maintenance schedule for instruments and equipment (continued)

Item	SOP	Frequency	Task
Mass Spectrometer	V4 & V6	Monthly	Visual inspection
Mass Spectral Detector (MSD)		Daily	Tune
		As needed	Lubricate side plate or vent valve O-rings; Replace filaments & electron multiplier horn
Ion source		As needed	Clean
Pump	Manual	First oil change	Tighten foreline pump oil box screws
		Every 3 months	CI MSD using ammonia reagent gas
		Every 6 months	Replace the pump oil
Gas Chromatograph	V4 & V6	Monthly	Visual Inspection
Inlet liner		Weekly	Check liner; replace as needed
Liner O-rings		Monthly	Replace if worn
Syringe needle or syringe		Every 3 months	Clean or replace
Inlet hardware		Every 6 months	Check for leaks and clean
Split vent trap		Every 6 months	Replace
Gas purifiers		Every 6-12 months	
GC hardware		Annually	Replace worn, scratched or broken parts
Flowmeter		Every 2 years	Recalibrate
Ferrules		When changing or trimming the column	Replace

2.6 Instrument/Equipment Calibration and Frequency

Multipoint calibration of the gas analyzers will be conducted according to Table 2.6.1, using the Environics Series 4040 Computerized Gas Dilution System (SOP G11) with a certified calibration gas and zero air (SOP G8). Each instrument will have an associated quality control spreadsheet that records its calibrations, precision (zero/span) checks, calibration curves, and maintenance history (SOP's G8, G9, & Q1). Accuracy and precision of the analyzers will be determined from these measurements. The concentrations selected for the multipoint calibrations will be 30, 60, and 90% of the analyzer range.

Routine zero/span checks (precision checks) (SOP G9) will be conducted according to Table 2.6.1 by introducing a certified calibration gas, the concentration of which is approximately 70% of the maximum measured gas concentrations, into the in-barn sampling port. Using this method, the calibration gas will flow through the same plumbing that the samples flow through to the analyzers in the OFIS. Any analyzer that fails the precision check (i.e. is outside the 10% control limits) must be subjected to corrective action, followed by a new multi-point calibration and a repeat of the precision check.

Control charts (SOP Q1) will monitor the zero and span drift performance of each analyzer. The control chart is used as a quality assurance tool to assess data quality, measurement variability, and to evaluate long term trends in the performances of instrument/equipment. Control charts provide a graphical presentation of the zero/span responses over time, which can be applied to gas analyzers and to other measurement devices. Control charts maintain data quality by using control limits (upper and lower limits). If the drifts become excessive and fall outside the control limits, a corrective action must be taken to maintain data quality.

Bag tests will also be conducted to assess the performance of the entire system with respect to precision and response (equilibration) time, and as a check for problems (leaks, obstructions, etc) with the sampling lines themselves. Because NH_3 is the worst-case analyte in terms of loss in sampling systems, this method will be conducted with NH_3. Fifty-Liter Tedlar bags will be filled with NH_3 at a concentration that is similar in magnitude to concentrations being measured in the barn, yet different enough that the two sources can be distinguished. For example, in a barn with average NH_3 concentrations around 25 ppm, a suitable bag test concentration might be around 35 ppm. The gas will be introduced at each of the sampling points, and the concentration obtained by the gas analyzer will be compared to that obtained when the same NH_3 concentration is introduced to the analyzer manifold (M_a) of the GSS. The sampling time for the bag test must be the same as that which is actually used for sampling barn exhaust (10 min). Discrepancies between the concentrations obtained from the sampling points and the concentration at the M_a must agree to within 10%, or corrective action must be taken to isolate the problem on the line(s) in question. All information collected from the bag tests will be recorded, along with the date of the test, in the electronic field notes for the particular location.

Certifications for calibration gases will be according to EPA protocol (except for NH_3, which will be dual-certified by NIST-traceable gravimetric formulation), and analysis based on the vendor reference standard, where available, for a given concentration. The certified calibration gases used at all sites will be zero air, NH_3 in N_2, SO_2 in N_2, H_2S in N_2, and CO_2 in N_2. At some sites (those where a range of VOCs are measured), calibration gases will also include CH_4/propane (blend) in N_2, ethanol in N_2, and/or methanol in N_2. As described above, the compositions of the initial gas standard cylinders (NH_3, SO_2, CO_2) will be verified by FTIR (SOP G12). Copies of calibration gas certifications will be kept in the OFIS at the site, and at PAAQL. The concentration used for a given cylinder will be that certified by the gas supplier. The approximate measurement ranges (expected maximum and minimum concentrations), and the calibration gas concentrations suitable for these analyte concentrations, are listed in Table 2.6.2. If, during the course of the NAEMS, the maximum encountered concentration of any analyte is substantially different than the expected value, and this difference is persistent and/or affects multiple sampling points, the concentration of the calibration gas will be adjusted accordingly. If the maximum encountered concentration is higher than expected (higher than that of the calibration gas), a higher-concentration calibration gas will be substituted. If the maximum encountered concentration is much lower than expected (less than 10% of the concentration of the calibration gas, as this would be at the limit of the Environics system to dilute the calibration gas), a lower-concentration calibration gas would be required.

The concentration of each cylinder that is sent out to the site with the OFIS will be checked at PAAQL using FTIR Spectroscopy (SOP G12), to ensure that the concentration certified by the supplier is accurate. Subsequent cylinders of the same gas that are received directly from the manufacturer/supplier at each site will then be compared (using the appropriate gas analyzer) against the cylinder being replaced (which must not be either expired or below the 150 psi threshold, as indicated in SOP G2). Thus, a cylinder with a concentration traceable to an FTIR verification will always be used to compare with an incoming cylinder.

The performance of each gas analyzer must fall within the limits established in Table 2.6.1. If the gas analyzer does not fall within those limits, it must be recalibrated. After calibration, if the gas analyzer still does not fall within the performance limits of Table 2.6.1, the analyst will consult the relevant maintenance steps in Section 2.5 above, and the relevant sections of the SOP for that particular analyzer. The instrument should be sent to PAAQL or the manufacturer for further repair if it cannot be fixed in the field. The gas-dilution system (Environics Series 4040) will also be subjected to flow calibration (SOP G11), at the frequencies listed in Table 2.6.1.

Table 2.6.1. Calibration schedule, types, and objectives for gas measurements.

						Criteria				
QA Tool	**Acceptance Type**	**Reps.**	**Points**	**Interval, d**	**Variable**	**NH_3**	**H_2S**	**CO_2**	**NMHC***	**Corrective Action**
Multipoint Calibration	Precision, %	2	4	180	RSD	±5	±5	±5	±5	Recalibrate
	Linearity, %	2	4	180	R^2	>98	>98	>98	>98	Recalibrate
Precision Check	Calibration drift, %	1	2	7	Δs	±10	±5	±5	±10	Fix and recalibrate
	Zero drift, %FS	1	2	7	Δz	±5	±5	±5	±5	Fix and recalibrate
	Sampling system bias, %	1	2	30	Δs	±10	±10	±10	±10	Fix sample system
	Downfall, zero gas, s	1	2	30	t(95%)	<300	<120	<100	<140	Fix analyzer
	Response, span gas, s	1	2	30	t(95%)	<120	<180	<100	<140	Fix analyzer
Bag Test	Bias, %	1	1	60**	RSD	±5	±5	±5	±5	Fix and recalibrate
	Equilibration time	1	1	60**	t(95%)	Within equilibration time set in AirDAC software				Find error in system
Control Chart	Zero gas repeatability, %	-	-	-	RSD	±5	±5	±5	±5	Fix and recalibrate
	Zero gas accuracy, %FS	-	-	-	Δz	±5	±5	±5	±5	Fix and recalibrate
	Span gas repeatability, %	-	-	-	RSD	±5	±5	±5	±5	Fix and recalibrate
	Span gas accuracy, %FS	-	-	-	Δs	±10	±10	±10	±10	Fix and recalibrate
External Audit	Performance audit, %	1	1	365	Δs	±10	±10	±10	±10	Find error in system
MFC Calibration	Diluter flow	1	1	365	Flow	100-110% of MFC's full rated flow				Adjust and recalibrate

*Includes total NMHC and individual HCs (e.g. ethanol, methanol)

**Initial bag tests are done with all gases at the longest sampling line. Subsequent bag tests are done with NH_3 only.

Table 2.6.2. Concentrations and compositions of calibration gas cylinders needed for the NAEMS. Each cylinder concentration can be diluted to 10% using the diluter.

Analyte	Expected Measurement Range (ppm)			Maximum Calibration Gas Concentration Needed (ppm)			Specs for relevant commercially available (Praxair) gases			
							Balance	Full Range	Certification	
									Analytical[1]	Months
	Dairy	Poultry	Swine	Dairy	Poultry	Swine				
Ammonia	0-50	0-200	0-100	50	200	100	Nitrogen		±1%	6
Hydrogen Sulfide	0-1	0-1	0-10	4	4	10	Nitrogen	4 ppm to 300 ppm	±2% (4 - 25 ppm)	12
Carbon Dioxide[2]	0-10,000	0-10,000	0-10,000	10,000	10,000	10,000	Nitrogen	0.3% to 50%	±1%	36
Methane	0-100	0-10	0-1000	100	10	1000	Nitrogen	1 ppm to 1000 ppm	±1% (1 - 100 ppm)	36
									±2% (>100 ppm)	36
Nitric Oxide	0-1	0-1	0-1	4	4	4	Nitrogen	10 ppm to 2.9%	±1%	24
Sulfur Dioxide	0-1	0-1	0-1	5	5	5	Nitrogen	2.5 ppm to 4%	±2%	6
Propane	0-10	0-10	0-10	10	10	10	Nitrogen	1 ppm to 13%		36
Methanol	0-10	0-10	0-10	10	10	10	Nitrogen	1 ppm - up		6
Ethanol	0-10	0-10	0-10	10	10	10	Nitrogen	1 ppm - up		6

[1] Certified accuracy in the concentration range(s) relevant to NAEMS

[2] Must contain 2.5% CH_4

The TEOM $PM_{2.5}$ and Model 2000 measurement systems will be calibrated prior to the beginning of the study, and then verified according to the schedule presented in Table 2.6.3 below. The analyst will consult the maintenance steps in Section 2.5 of the QAPP, and the relevant sections of SOP P1 (TEOM) or P3 (Model 2000) if the limits listed in Table 2.6.3 cannot be met by the instrument. If, after maintenance is completed, the instrument still does not have readings within the required limits, the instrument will be removed. If the instrument cannot be fixed onsite, it will be returned to PAAQL or Thermo Fisher for further service. All information collected from the calibration checks will be recorded, along with the date of the calibration, in the electronic fieldnotes for the particular location.

Table 2.6.3 Calibration schedule, types, and objectives for PM_{10}, $PM_{2.5}$, and TSP measurements.

Parameter	QA Tool	Acceptance Type	Points	Interval, d	Criteria Variable	Limits	Corrective Action
Flow rate	Control chart	Accuracy	48*	60	% of target**	±5%	Recalibrate
Flow rate	Control chart	Stability/ precision	48*	60	RSD %	≤ 2%	Fix problem and recalibrate
Mass flow meter	Verification	Accuracy, %FS	1	60	Standard (TS)	≤ 5% of TS	Fix problem and recalibrate
Mass flow meter	External audit	Accuracy, %	1	365	Δs	±5% of TS	Find error in system
Leak test	Verification	Maximum leakage flow	1	60	L/min	0.15	Locate and repair leak; repeat leak test
Mass Concentration	Collocated identical monitor	Precision	1	365	Δs	≤ 25%	Report differences, recalibrate, use additional samplers

*24 h of 30-min averages as recorded internally by the TEOM.

**Target flow rates for the TEOM are 13.7 and 3.0 L/min.

The filter-weighing microbalance of the TEOM sampler will be calibrated with a NIST-traceable pre-weighed filter prior to the initiation of the study. TEOM airflows will be measured and calibrated using precision airflow calibrators (Raeco M-30 Mini-Buck Calibrators, 100 ccm-30 L/min flow rate). For TSP and PM_{10} measurements, flow rate audits (Section 8.6); leak checks (Section 7.6), mass transducer calibration verifications (Section 8.5), and downloading of stored internal data (including time and date setting/checks) (Section 4.10) will be conducted according to the periodic maintenance table in SOP P1. The electronic barometric pressure sensors in the TEOM units at each site will be compared with each other. All information collected from the calibration checks will be recorded, along with the date of the calibration, in the electronic field notes for the particular location.

Comparison and verification of TEOM TSP, $PM_{2.5}$ and PM_{10} mass concentrations will be conducted by collocating two of the TEOM samplers at the site. Gravimetric FRM samplers will not be used at each site for the comparison because they provide only a very limited number of results for the comparisons, thus lacking the dynamic diurnal PM concentration information. Furthermore, the FRM sampling inlets are often not suitable for high PM concentration sampling, and the barn ceiling heights do not allow its use in many locations. The FRM (Partisol) will be used to verify the TEOM TSP results at one location per species. The IN5B site will represent dairy PM. The IN2B site will represent poultry PM (both layers and broilers), and the IN3B site will represent swine PM. The FRM units will fit at these sites. The comparison will be conducted during the first quarter after all sites are set up, for a total of one week at each site.

The analyst will consult the maintenance steps in Section 2.5 of the QAPP and the relevant sections of SOP P3 if the performance of the Partisol instrument does not fall within the limits established in SOP P3. If, after maintenance, the Partisol instrument continues to display readings outside the required limits, the Partisol instrument will be removed. If the instrument cannot be fixed on site, it will be returned to PAAQL or the manufacturer (Thermo Fisher) for further service.

Thermocouples (Type T) measuring ambient (inlet), fan exhaust, raceway and OFIS temperatures will be calibrated prior to commencing the study. Hot (50-60 ºC) and ice water baths and precision ASTM alcohol thermometers will be used for calibration, as described in SOP E1. Subsequent calibration checks (Table 2.6.4) will be conducted with NIST-traceable temperature probes. All information collected from the calibration checks will be recorded, along with the date of the calibration, in the electronic field notes for the particular location.

The analyst will consult the maintenance steps in Section 2.5 of the QAPP, and the relevant sections of SOP E1 if the temperature readings do not meet the performance limits established in Table 2.6.4. If maintenance on the thermocouple does not yield satisfactory performance, the thermocouple wire will be removed and replaced with a new wire, following the setup procedures in SOP E1 and Section 2.1 of this QAPP.

Table 2.6.4. Calibration schedule, types, and objectives for temperature measurements.

				Interval, d				Limits			
QA Tool	**Acceptance Type**	**Reps**	**Points**	**Exhaust**	**Inlet**	**Lab**	**Criteria Variable**	**Exhaust**	**Inlet**	**Lab**	**Corrective Action**
Multipoint calibration	Precision, °C	2	3	730	730	730	SD	±0.5	±0.5	±2	Recalibrate
	Linearity, %	2	3	730	730	730	R^2	>99	>98	>95	Recalibrate
Calibration check (Omni RH/T Probe)	Calibration drift, s	1	1	60	60	180	Δs	±1	±1	±2	Fix and recalibrate
Calibration check (Thermocouples)	Calibration drift, s	1	1	180	180	180	Δs	±2	±2	±2	Fix and recalibrate
Temperature calibration check (Ultrasonic anemometer)	Calibration drift, s	1	1	365	365	-	Δs	±2	±2	-	Fix and recalibrate
Control chart	Repeatability, °C	-	5	-	-	-	SD	±1	±1	±2	Fix and recalibrate
	Accuracy	-	5	-	-	-	Δs	±1	±1	±2	Fix and recalibrate
External audit	Performance audit, °C	1	2	365	365	730	Δs	±1	±1	±2	Fix and recalibrate

The capacitance-type humidity/temperature sensors will be factory-calibrated prior to commencing the study, and will be checked periodically (Table 2.6.5) with a NIST-transfer device (mercury- or alcohol-filled psychrometers, depending on the site) . All information collected from the calibration checks will be recorded, along with the date of the calibration, in the electronic fieldnotes for the particular location.

If the RH/temp sensor is not within the limits set in Table 2.6.5 at the beginning of the study, the analyst will consult the steps in found in the Quality Control and Quality Assurance Section of SOP E2. If the sensor is still not within the established performance limits of Table 2.6.6, the sensor will be replaced and returned to the manufacturer.

Table 2.6.5. Calibration schedule, types, and objectives for humidity measurements.

QA Tool	Acceptance Type	Reps.	Points	Interval, d	Criteria Variable	Limits	Corrective Action
	Response time, s	2	1	730	T	100	Fix and recalibrate
Calibration check	Calibration drift, %RH	1	1	60	Δs	±10	Fix and recalibrate
Control chart	Repeatability, %RH	-	5	-	SD	±10	Fix and recalibrate
	Accuracy, %RH	-	5	-	Δs	±10	Fix and recalibrate
External audit	Accuracy, %RH	1	1	365	Δs	±10	Find error in system

The differential pressure transmitters will be factory-calibrated using NIST-traceable standards prior to shipment. The calibration of the differential pressure transmitter can be verified with the use of a micromanometer, an inclined manometer, or an identical pressure transmitter that has been properly calibrated, or by collocating 3 or more sensors in the same location. Performance verifications of the differential pressure transmitter will be conducted according to Table 2.6.6 and the calibration section of SOP A5. All information collected from the calibration checks will be recorded, along with the date of the calibration, in the electronic field notes for the particular location. Barometric pressure sensors within the TEOMs and Beta Gage at each site will be compared with each other to ensure that they are all functioning properly.

If the differential pressure transmitter does not meet the performance specifications set forth in Table 2.6.6, the analyst will consult the maintenance steps in Section 2.5 of the QAPP, and the relevant sections of SOP A5. If the differential pressure transmitter cannot be fixed in the field, the instrument will be sent back to the manufacturer.

Flow rate and leakage tests of the GSS will be conducted according to Sections 9.4 and 9.5 of SOP G1, respectively, using the GSS pump. Both leak checks and flow checks will be performed after construction of the GSS is completed at PAAQL, after initial GSS installation at the site, and after any significant changes to the system. The GSS pressure will be verified according to the intervals and limits established in Table 2.6.6, and the flow of the GSS will be verified according to the intervals and limits established in Table 2.6.9. All information collected from the calibration checks will be recorded, along with the date of the calibration, in the electronic field notes for the particular location.

The analyst will consult the maintenance steps in Section 2.5 of this QAPP, and the relevant sections of SOP G1 if the performance of the GSS does not fall within the limits established in Table 2.6.6.

Table 2.6.6. Calibration schedule, types, and objectives for pressure measurements.

Pressure Type	QA Tool	Acceptance Type	Reps	Points	Interval, d	Criteria Variable	Limits, Pa	Corrective Action
Barn static	Multipoint calibration	Precision	2	3	365	SD	±1	Fix and recalibrate
Barometric (PM monitors)		Verification	1	1	90	Δs	±1000	Fix and recalibrate
Lab		Verification	1	2	730	Δs	±5	Fix and recalibrate
GSS manifold		Verification	1	1	365	Δs	±200	Fix and recalibrate
Barn static		Linearity, %	2	3	365	R^2	>97%	Fix and recalibrate
Barn static	Precision check	Calibration drift	1	2	90	Δs	±2	Fix and recalibrate
Barn static	Zero check	Zero drift	1	1	30	Δs	±2	Fix and recalibrate
Filter differential		Verification	1	2	365	Δs	±10	Fix and recalibrate
Barn static	Control chart	Repeatability	-	5	-	SD	±2	Fix and recalibrate
Barn static		Accuracy	-	5	-	Δs	±2	Fix and recalibrate
Barn static	External audit	Performance audit	1	1	365	Δs	±3	Find error in system

All solar radiation sensors used under SOP E3 are calibrated against an Eppley Precision Spectral Pyranometer by the manufacturer (LiCOR) prior to shipping. Once the solar sensors have been deployed, their proper calibration will be verified in the field through comparison with a similar solar sensor that has been calibrated at the factory, but has not been used in the field. All verifications will be conducted according to the schedule established in Table 2.6.7, following the steps found in SOP E3. If the solar sensor is not within the limits established in Table 2.6.7, the analyst will consult Section 2.5 of this QAPP and the relevant sections of SOP E3. If the sensor cannot be fixed in the field, it will be replaced and sent to PAAQL or LiCOR. All information collected from the calibration checks will be recorded, along with the date of the calibration, in the electronic field notes for the particular location.

All wind direction and speed sensors (Wind Sentrys) will be calibrated by the manufacturer before shipment. The wind speed calibrations will be verified with a Model 18802 Rotational Calibration Unit, and a Model 18314 Anemometer Torque Disc will be used periodically to verify that the bearings have not degraded. All verifications will be conducted according to the schedule established in Table 2.6.7, following the steps found in SOP E4. All information collected from the calibration checks will be recorded, along with the date of the calibration, in the electronic field notes for the particular location.

If the instrument fails to meet the performance limits established in Table 2.6.7, the analyst will consult the maintenance steps in Section 2.5 of this QAPP, and the relevant sections of SOP E4. If the wind speed and direction sensor cannot be fixed in the field, it should be sent to PAAQL for further repair and/or return to the manufacturer.

Table 2.6.7. Calibration schedule, types, and objectives for meteorological measurements.

Measurement Type	QA Tool	Acceptance Type	Reps	Points	Int., d	Criteria Variable	Limits	Corrective Action
Wind direction	Compass	Accuracy	1	4*	365	Δs	±5	Rotate until criteria met
Air velocity (vane anemometer)	Torque disk	Free rotation	1	2	90	Δs	≤1.2 g-cm	Replace bearings
	RPM anemometer drive	Accuracy	1	4	90	Δs	±1%	Fix and calibrate
Solar radiation	Collocate second sensor	Accuracy	1	2 d	365	Δs	±5%	Fix and recalibrate

*E, W, N and S

All National Instruments FieldPoint analog input modules used for data acquisition will come with NIST-traceable calibration certificate to ensure accurate, reliable analog measurements. This certification is valid for two years, which will cover the duration of the project.

Vane anemometers will be calibrated by the manufacturer before shipment. The performance of the vane anemometers will be verified using a Model 18802 Rotational Calibration Unit and a Model 18310 Anemometer Torque Disc according to the “Calibrations” section of SOP A3. If the anemometer does not fall within the limits established in Table 2.6.8, the analyst will consult Section 2.5 of this QAPP and the relevant sections of SOP A3. If the sensor cannot be fixed in the field, it should be replaced and sent to PAAQL for repair and/or return to the manufacturer.

The FANS analyzers are calibrated by the manufacturer before shipment. Calibrations after the manufacturer’s initial calibration will be conducted at the University of Illinois (Urbana-Champaign) BESS Lab. All calibrations and verifications of the FANS analyzer will be conducted according to Table 2.6.8 below.

The 3-D sonic anemometers used to measure airflow in naturally-ventilated barns will be subject to the tests (zero checks and field intercomparisons between collocated instruments) described in SOP A6, at the frequency listed in Table 2.6.8. Zero checks will be conducted by enclosing the anemometer (in place) in a cardboard box. Field intercomparisons are described in SOP A6.

Table 2.6.8. Calibration schedule, types, and objectives for airflow measurements.

Measurement Type	QA Tool	Acceptance Type	Rep.	Pnts	Int., d	Criteria Variable	Limits	Corrective Action
Airflow	Multipoint calibration	Verification of fan curve	1	3	365	Δs	±5%	Adjust fan performance curve
Fan test chamber	Calibration of FANS	Performance audit	1	6	365	Δs	±5%	Recalibrate the FANS
Fan status	Visually observe on/off status	Verification	1	-	7	Δs	±1%	Fix the problem
GSS	Leak test	Check	1	1	60	Δs	±10% FS	Find & fix leak
GSS airflow	Mass flow meter	Verification	2	2	365	Δs	±0.2L/min	Recalibrate
Ultrasonic anemometer (zero)	Box	Zero check	1	1	90	Δs	<0.1 m/s	Return to vendor, replace
Ultrasonic anemometer (precision)	Field intercomparison	Verification	1	60 min	90	SD	±0.4 m/s	Recalibrate

Analytical instruments used in the laboratory quantitation of VOCs (GC/MS and IC systems) will have calibration curves (five points, at minimum) associated with each batch of samples, where a batch is defined as a maximum of ten samples collected during the same sampling event. For GC/MS analysis, a daily single-point calibration check, equal in concentration to that of the middle standard in the five-point curve, will be conducted daily before any samples are run. This calibration check must meet the criteria described in SOP V4 (sorbent tube samples) or V6 (canister samples) before the stored calibration curve is considered valid for the samples being analyzed. The process for introducing standards for GC/MS analysis of VOCs in canister samples is described in SOP V6, while those for VOC samples on sorbent tubes is given in SOP V4. Calibration standards for ion chromatographic quantitation of volatile amines will be run in duplicate, and will bracket the sample batch. IC standards are discussed in further detail in SOP V5. In all three cases (canisters, sorbent tubes, and amine bubblers), the lowest concentration of the standard curve will be about ten (10) times the detection limit for each target analyte. Procedures for determining the detection limit are given in the respective SOPs.

When analyzing manure, feed, bedding, milk, and eggs for their N and (in the case of manure) NH_3 contents, Midwest Laboratories will employ a five-point calibration curve (SOPs M4 and M5). Similar to the VOC analyses, the lowest concentration on this curve will correspond to a level ten (10) times the detection limits of the analytical methods. Calibration standards for determination of manure solids content are discussed in SOP M3. Electrochemical pH meters will be calibrated at pH 7 and 4 for acidic samples, or 7 and 10 for alkaline samples, as described in SOP M2.

2.7 Inspection/Acceptance of Supplies and Consumables

All atmospheric gaseous measurements will be traceable to dual-analyzed and certified standards. The certified standards will be traceable to NIST. EPA web sites documenting the performance of major gas-cylinder vendors, based on the results of a round robin test conducted every two years, will be consulted as part of the vendor-selection process for gases. The NH_3 span gas will be dual-certified by NIST-traceable gravimetric formulation and analysis based on vendor reference standard. FTIR spectroscopy will be used to verify concentrations of all cylinders that are initially sent to each individual site, so that incoming cylinders can then be compared against them using the individual gas analyzers.

All consumable supplies, spare parts, and newly-purchased instruments will be inspected immediately upon receipt, and returned to the vendor if found unusable. This will be the responsibility of the PI and/or site engineer for materials and supplies delivered directly to them or to the field site, and the responsibility of PAAQL personnel for supplies sent directly to Purdue. All shipping packaging will be inspected for damage as an indicator of possible damage to the product. Copies of all certifications of analysis, inspection, calibration, performance, etc, that are provided by manufacturers will be forwarded to the NAEMS QA/QA Manager, Dr. Juan Carlos Ramirez, who will maintain them for the duration of the project, and for at least six years thereafter. Signed packing slips for all supplies will constitute certification of inspection and acceptance, and will also be kept on file by Dr. Ramirez.

A supply of spare parts in working condition will be maintained to ensure continuous data collection. Each individual SOP lists the consumable supplies (including tools and spare parts) that must be kept on hand, either on-site (i.e. with each individual instrument) or centrally (i.e. at PAAQL to support the entire network of instruments). Also, SOP U1 lists general consumables that should be kept in the OFIS at each site.

At the initiation of the study, PAAQL personnel will equip each site's OFIS with spare parts, tools, and consumable supplies, and will advise site PIs about other supplies to purchase. This will be conducted before the OFIS is transported to its site. Individual PIs and their site engineers will be responsible for ensuring that the site-specific spare parts stocks (and the stocks of general consumables for the OFIS, as listed in SOP U1) are maintained in accordance with the individual SOPs. Dr. Bill Bogan of PAAQL will, as the NAEMS Operations Manager, have the responsibility of maintaining the centralized stock of spare parts and consumables at Purdue.

Consumable supplies will be stocked in "last-in, last-out" order, and will be kept under controlled indoor conditions (in labs at PAAQL or at the PI's University, or in the environmentally-controlled OFIS at the site itself). Both PIs/site engineers (for on-site consumables) and PAAQL (for in-house consumables) will maintain Microsoft Excel spreadsheets with the expiration dates of all consumables that will expire during the course of the project (i.e. before the conclusion of the data-collection phase in 2009). These spreadsheets will be checked (i.e. sorted by the expiration date column in ascending order) on a weekly basis, at minimum, to rapidly identify any soon-to-expire items, and ensure that any consumable supply that expires prior to use is replaced in a timely manner. PIs/site engineers or PAAQL personnel (as appropriate) will also ensure that all consumables that will expire during the course of the project are clearly labeled with their expiration date (on each individual or discrete container), so that expired supplies will not be inadvertently used. To reduce the amount of expired unused supplies that must then be disposed of, all supplies with expiration requirements will be ordered in the smallest quantity that will meet the needs of the project and avoid repetitive ordering.

These same guidelines, as described in their Corporate QA Manual, are followed by Midwest Laboratories for their inventory control.

2.8 Data Acquisition Requirements (Non-Direct Measurement)

Not applicable to this project.

2.9 Data Management

The objective of data management is to ensure data security, easy identification and retrieval, and efficient publication.

2.9.1. Overview of Data Flow

Figure 2.9.1 illustrates the flow of data and data files. Originally, the majority of the data will be acquired by the data acquisition system and automatically saved in the site PC. Data acquisition and control system configuration data will also be automatically saved. Instrument calibration/precision-check and test notes (field notes) will be entered manually by typing or entering in electronic files. Farm management data, if its electronic version is not available, will be entered into the site computer manually. Other project-related data (e.g. manure analysis results) will also be entered manually (in this case, by Midwest Laboratories personnel, as the data will be obtained by PAAQL in spreadsheet format).

The data stored in the site PC will be backed up according to a regular schedule (SOP B5). Acquired data will be sent to the Site PI and Site Engineer, and to PAAQL, via automatic email every day at midnight. Newly- and manually-entered data, including test notes at the site, will be sent to the same recipients at the end of the day’s work using manually controlled email software (e.g. Outlook Express). The data received by the administrative server will be backed up automatically everyday into the ABE Department’s backup device at Purdue University.

The Purdue data analyst will pre-process the measurement data (SOP B3) to produce data graphs and summarized results, including hourly and daily means of all measurement variables, within two (2) working days. This will provide a quick review of the data and a check on the measurement systems’ performance. The results (daily graphs of all measurement variables, at a minimum) will be sent to the site personnel for their review, and for storage on the site computer. Site personnel will also have access to the data pre-processing software in the event tabular data or re-formatted data is desired on the site computer. Within 2 working days of receiving the data, the data analyst will also review the data in conjunction with the site fieldnotes and make note of any inconsistencies or suspected problems with the data set. These data analysis notes will be stored in tabular form in a spreadsheet on a continuous basis, and serve as a reference for flagging invalid data during data processing. The current data analysis notes will be sent to the site personnel to alert them of suspected problems, confirm events recorded in the fieldnotes, and serve as reminders of outstanding items that need to be resolved.

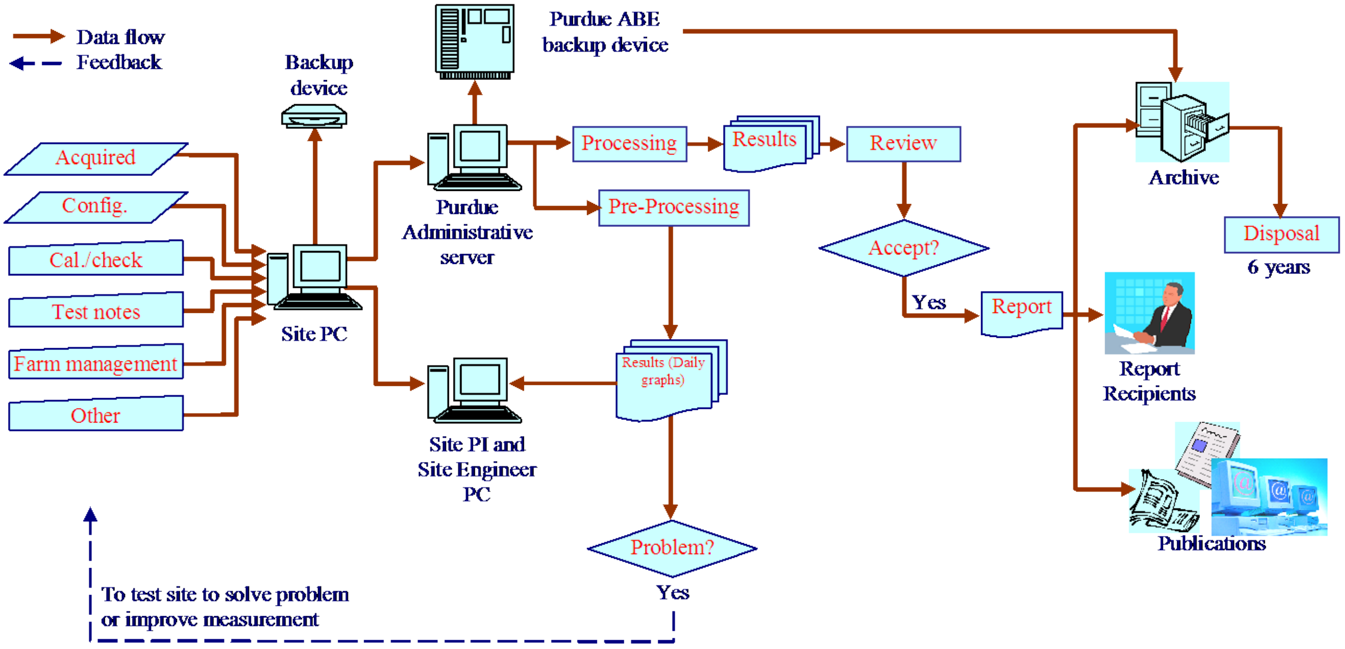


Figure 2.9.1. Diagram of data flow.

The graphs and summarized data will be archived at PAAQL, the Site PI's university, and the site computer, and used as reference throughout the study and during final data processing at PAAQL. The final data processing procedures are described in SOPs B4 and B6. The Site PI will be involved with the final data processing to various degrees, depending on the PI.

The quarterly results of the data will be reviewed by a second data analyst using CAPECAB software. The primary data analyst will also present the results for review by the Site PI, Site Engineer and SA. A report will be generated documenting the results and significant events that affected the data results, data completeness and data quality during the quarter. Corrective actions will be taken if any data quality objectives are not met. The SA will forward the quarterly report for each site to EPA within one quarter of the end of the data collection period.

The final report for the project will be written based on accepted final results and distributed to report recipients. All raw data and processed data will be provided to EPA, and will also be archived for at least six years before disposal.

2.9.2. Data Handling Equipment

An on-site computer with CD or DVD rewritable drive and/or a portable hard drive, and a second hard drive will be used to acquire, store, back up, and transfer data. The purpose of the rewritable/portable drive is to back up data files to disks that can be used for off-site backup. The second hard drive is used to back up all files in the first hard drive. More detailed information on data handling equipment can be found in SOP B5.

An administrative server in the Agricultural and Biological Engineering Department at the Purdue University West Lafayette campus will be used to store and archive all NAEMS-related data. All files on the administrative server are backed up by the Purdue University Engineering Computer Network on a daily basis.

File binders and file cabinets will be used to classify and store hard copies of data table, data graphs, and quarterly and final reports.

2.9.3. Individuals Responsible for Data Management

The Site PIs will be responsible for managing the data generated at the site, including backing up, occasional pre-processing (as necessary), archiving, and delivering to the administrative server.

The data analysts at PAAQL will be responsible for managing the data received from all sites including inspecting, pre-processing, processing, and archiving data.

2.9.4. Classification and Organization of Electronic Files

In the data acquisition computer at each individual site, all project-specific files will be arranged in a single default folder called *YY*X*n*, where *YY* is a two-letter abbreviation for the state, X is a numeric code for the animal type (1 = broiler, 2 = layer, 3 = finisher, 4 = sow, 5 = dairy) and *n* is "A" for area sites, or "B" for barn sites. For example, the three sites in California are identified in this filing system as CA1B (broiler, barn), CA2B (layer, barn) and CA5B (dairy, barn).

All project-related electronic files are classified into four categories, according to their importance and recoverability. All files are saved in an organized folder structure (SOP B5).

2.9.5. Data Security

All project computers and servers are protected. Data security will be accomplished through a variety of measures.

2.9.5.1 Passwords

All users of the project computers must be authorized and receive a password necessary to log on. Those authorized to access research data will use strong passwords, which will be changed on a regular basis (quarterly, at minimum). Only authorized personnel will have access to the site computer. The site PI and site engineer will have the password to remotely connect to the site computer. The project managers and data analysts will have passwords to the computers that are connected to the administrative server. No one person is authorized to change original raw data files, as explained in SOP B5.

2.9.5.2 Data Access Privileges

Different privileges are given to each authorized user, depending on that person's need. Data integrity and security software will be selected and used for the data security and audit trail. The following privilege levels are defined:

- Data entry privilege: The individual may see and modify only data within the system that he or she has entered. After a data set has been "committed" to the system by the data entry operator, all further changes will generate entries in the system audit trail.
- Report privilege: This privilege permits generation of data summary reports available under the system. No data changes are allowed without additional privilege.
- Data administration privilege: This privilege allows change of data as a result of QA screening and related reasons. All operations resulting in changes to data values are logged to the audit trail. The data administrator is responsible for performing the following tasks on a regular basis:
  - Merging/correcting the duplicate data entry files
  - Running verification and validation routines and correcting data as necessary
  - Generating summary data reports for management.

2.9.5.3 Datalogging

Data security in the data acquisition system in the site computers will be accomplished through the use of access control to the computer. All NAEMS trailers are expected to be locked when the site personnel are not present. Visitors to the site will be expected to sign a visitor log, and/or be recorded in the electronic fieldnotes. Remote access to the site PC via PCAnywhere is password-protected. All site PCs will have firewalls, spyware protection, and up-to-date virus scanning software.

At midnight of each day, the day's data file will be e-mailed to Purdue University. One recipient of the data file is an automated Eudora system that immediately saves the original data file into a secure directory on the Purdue University Engineering Computing Network. As part of this process, Eudora imprints the file upon receipt with an electronic timestamp that will identify it as the originally e-mailed datafile from the site in question for the day in question. Comparison of this timestamp with the "modified on" date for the file will verify that the raw data file has not been tampered with. Access to this directory is strictly password-protected, and is made available only to PAAQL personnel with clearance to work with NAEMS datafiles.

2.9.5.4 Data Backup

A progressive backup of the on-site project folder, from the primary hard drive of the on-site computer to a secondary hard drive, will be automatically done on a daily basis. Additionally, the on-site project folder will be backed up to a CD or DVD that is kept off-site, every two weeks, or whenever there are changes in Category 2 and/or Category 3 data files, as defined in SOP B5.

Email will be used to deliver electronic files to designated responsible site PI, data analyst and to the administrative server computer, in a timely manner. The emailed files will include AirDAC data files, AirDAC configuration files, manually recorded field notes, and any visual image files. Any project-related paper drawings will be scanned with the on-site scanner, stored in the on-site computer, and emailed. Any project-related digital photos will be transferred to the on-site computer before being emailed.

Files in the administrator server computer at PAAQL will be backed up daily on the Purdue University backup system.

2.9.6. Data Recording

2.9.6.1 Automatic Recording from Continuous Measurement

AirDAC, a data acquisition and control program developed by PAAQL using LabVIEW software (National Instruments, Co., Austin, TX), will be used to acquire data, automate sampling location control, display real time data, and deliver data and system operation status to the investigators. AirDAC will acquire data at 1 Hz, average the acquired data every 15 s and 60 s, and save the averaged data in text format in two separate data files every 60 s. Raw data will also be saved in a secure Purdue ECN directory for security using Eudora. AirDAC will generate new data files every day at midnight and upon start-up of the program. Data file names will be composed of site name and dates. All data saved in the data files will have time stamps. AirDAC is fully described in SOP B2.

2.9.6.2 Manual Data Entry

Data from off-line sample analysis by laboratories, weather data from the nearest weather station, data obtained from the producer, manure characteristics, laboratory notes, and visual observations will be entered and saved within the project folder structure in the on-site computer. The files will be backed up onto the second hard drive and the off-site administrative server.

Entry of these data will be made either electronically if the electronic files are available (e.g. digital photos) or manually. Table 2.9.1 lists relevant SOPs that provide procedures and/or data forms for filling out the manually-entered data. Where appropriate, data forms are included with these SOPs. In other cases, data is entered directly into the electronic field notes.

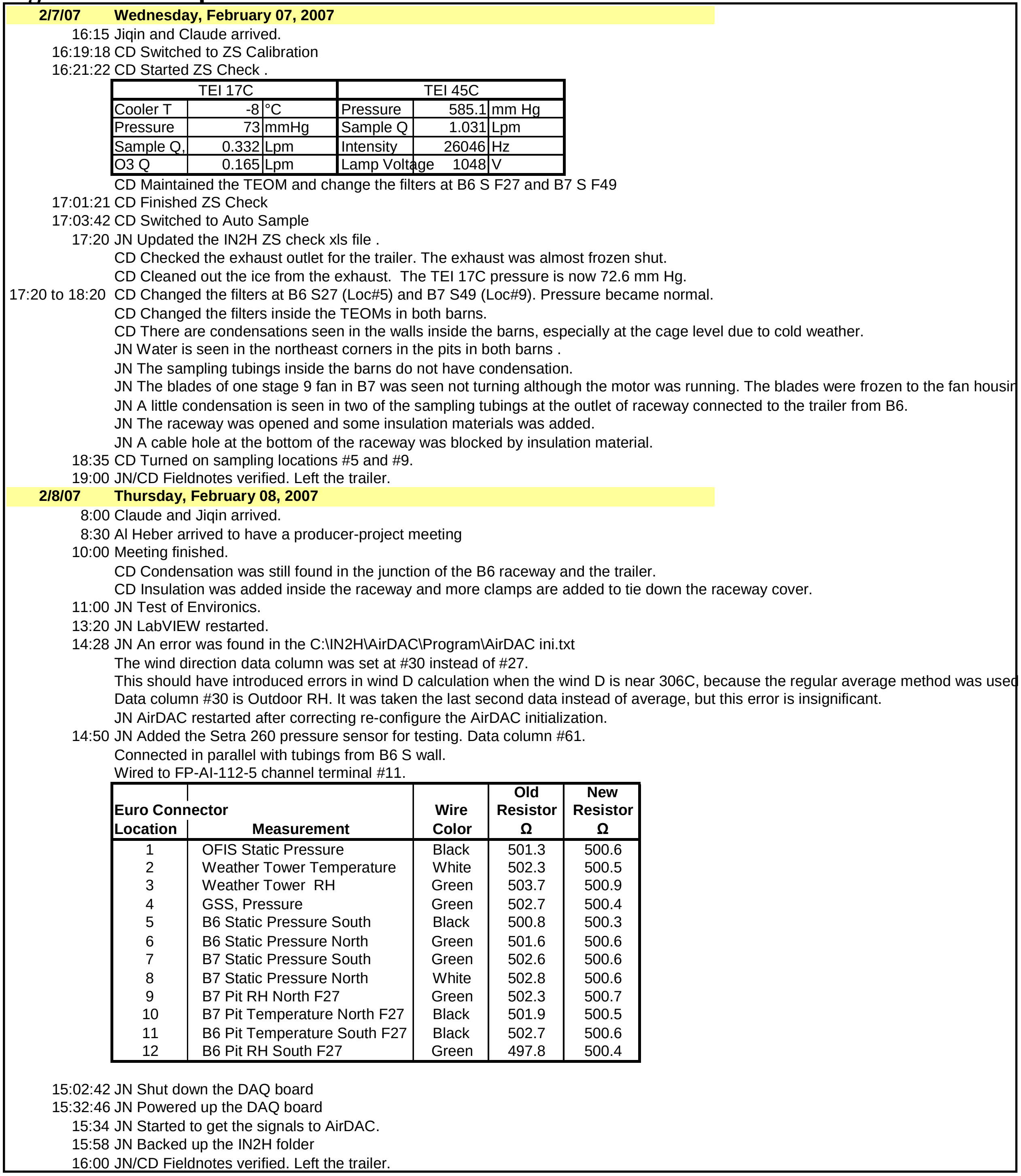
Table 2.9.1. List of the NAEMS SOPs requiring data entry.

SOP	Title	Data description
A1	Laboratory Fan Testing	Barn Airflow
A2	Testing Fans with Portable Tester (FANS)	Barn Airflow
M1	Manure Sampling from Barns	Manure Characteristics
M2	Manure pH Evaluation	Manure Characteristics
M3	Manure Total Solids Evaluation	Manure Characteristics
M4	Manure Total Nitrogen Evaluation	Manure Characteristics
M5	Manure Ammonia Evaluation	Manure Characteristics
P2	Gravimetric Multipoint TSP samplers	PM Measurement
P3	Gravimetric $PM_{2.5}$ Method	PM Measurement
S2	Recording Animal Inventory	Source Information
S5	Nutrient Balance	Source Information
S6	Feed, Bedding, Milk, and Eggs Analysis	Source Information
V1	VOC Sampling Using Sorbent Tubes	Volatile Organic Compounds
V2	VOC Sampling Using Canisters	Volatile Organic Compounds
V3	Amine Sampling Using Bubblers	Volatile Organic Compounds
V4	VOC Analysis Using GC/MS and Thermodesorption	Volatile Organic Compounds
V5	Amines Analysis Using IC	Volatile Organic Compounds
V6	VOC Analysis (GC/MS) of Canister Samples	Volatile Organic Compounds

2.9.6.3.Electronic Field Notes

An example of electronic field notes in the format that will be used for NAEMS is contained in Fig. 2.9.2.

Figure 2.9.2. Sample of NAEMS electronic field notes in Microsoft Excel format.



2/7/07 Wednesday, February 07, 2007

16:15 Jiqin and Claude arrived.

16:19:18 CD Switched to ZS Calibration

16:21:22 CD Started ZS Check .

TEI 17C			TEI 45C		
Cooler T	-8	°C	Pressure	585.1	mm Hg
Pressure	73	mmHg	Sample Q	1.031	Lpm
Sample Q,	0.332	Lpm	Intensity	26046	Hz
O3 Q	0.165	Lpm	Lamp Voltage	1048	V

CD Maintained the TEOM and change the filters at B6 S F27 and B7 S F49

17:01:21 CD Finished ZS Check

17:03:42 CD Switched to Auto Sample

17:20 JN Updated the IN2H ZS check xls file .

CD Checked the exhaust outlet for the trailer. The exhaust was almost frozen shut.

CD Cleaned out the ice from the exhaust. The TEI 17C pressure is now 72.6 mm Hg.

17:20 to 18:20 CD Changed the filters at B6 S27 (Loc#5) and B7 S49 (Loc#9). Pressure became normal.

CD Changed the filters inside the TEOMs in both barns.

CD There are condensations seen in the walls inside the barns, especially at the cage level due to cold weather.

JN Water is seen in the northeast corners in the pits in both barns .

JN The sampling tubings inside the barns do not have condensation.

JN The blades of one stage 9 fan in B7 was seen not turning although the motor was running. The blades were frozen to the fan housi

JN A little condensation is seen in two of the sampling tubings at the outlet of raceway connected to the trailer from B6.

JN The raceway was opened and some insulation materials was added.

JN A cable hole at the bottom of the raceway was blocked by insulation material.

18:35 CD Turned on sampling locations #5 and #9.

19:00 JN/CD Fieldnotes verified. Left the trailer.

2/8/07 Thursday, February 08, 2007

8:00 Claude and Jiqin arrived.

8:30 Al Heber arrived to have a producer-project meeting

10:00 Meeting finished.

CD Condensation was still found in the junction of the B6 raceway and the trailer.

CD Insulation was added inside the raceway and more clamps are added to tie down the raceway cover.

11:00 JN Test of Environics.

13:20 JN LabVIEW restarted.

14:28 JN An error was found in the C:\IN2H\AirDAC\Program\AirDAC ini.txt

The wind direction data column was set at #30 instead of #27.

This should have introduced errors in wind D calculation when the wind D is near 306C, because the regular average method was used

Data column #30 is Outdoor RH. It was taken the last second data instead of average, but this error is insignificant.

JN AirDAC restarted after correcting re-configure the AirDAC initialization.

14:50 JN Added the Setra 260 pressure sensor for testing. Data column #61.

Connected in parallel with tubings from B6 S wall.

Wired to FP-AI-112-5 channel terminal #11.

Euro Connector Location	**Measurement**	**Wire Color**	**Old Resistor Ω**	**New Resistor Ω**
1	OFIS Static Pressure	Black	501.3	500.6
2	Weather Tower Temperature	White	502.3	500.5
3	Weather Tower RH	Green	503.7	500.9
4	GSS, Pressure	Green	502.7	500.4
5	B6 Static Pressure South	Black	500.8	500.3
6	B6 Static Pressure North	Green	501.6	500.6
7	B7 Static Pressure South	Green	502.6	500.6
8	B7 Static Pressure North	White	502.8	500.6
9	B7 Pit RH North F27	Green	502.3	500.7
10	B7 Pit Temperature North F27	Black	501.9	500.5
11	B6 Pit Temperature South F27	Black	502.7	500.6
12	B6 Pit RH South F27	Green	497.8	500.4

15:02:42 JN Shut down the DAQ board

15:32:46 JN Powered up the DAQ board

15:34 JN Started to get the signals to AirDAC.

15:58 JN Backed up the IN2H folder

16:00 JN/CD Fieldnotes verified. Left the trailer.

As shown in the above example, field notes will be entered into an electronic spreadsheet, in Microsoft Excel format. Each site will keep its own distinct field notes file. The field notes are written in third person, to avoid any potential confusion as to who is referred to in the body of the notes. Field notes are expected to contain, at minimum:

- Times of arrival and departure from the site, and names of visitors
- Descriptions of all work conducted during the visit
- Any raw data that would not otherwise be recorded
- All notes regarding instrument precision checks and/or calibrations
- Times that instrument(s) or sensor(s) are off-line or turned off.
- Any unusual observations or problems, malfunctioning or damaged instruments or sensors, and any corrective actions
- Any deviations from the SOPs or SMP that occur during work at the site
- Any items or notes that would be useful in helping the Data Analyst identify or confirm data flags

2.9.7. Data Transformation

Data transformation is the conversion of individual data points into related values (or possibly symbols) using conversion formulas (e.g., unit conversion or logarithmic conversion).

For continuously acquired data obtained using data acquisition hardware and software AirDAC, the data conversion is done real-time in AirDAC. Analog signal outputs by analyzers and sensors either in voltage or in current each have output signal ranges (e.g., from 0 to 10 VDC or from 0.004 to 0.020 A). Analyzers and sensors also have measurement ranges that correspond to these signal ranges (e.g., 0 VDC = 0 ppm and 10 VDC = 100 ppm for an NH_3 analyzer). AirDAC converts the analog signals from individual analyzers and sensors to measurement values using the following commands and equations:

If (*Abs* = false), Then

$$X = \frac{(S - S_L)\cdot(R_H - R_L)}{S_H - S_L} + R_L \tag{2.9.1}$$

Else

$$X = \left| \frac{(S - S_L)\cdot(R_H - R_L)}{S_H - S_L} + R_L \right| \tag{2.9.2}$$

Where:
Abs = A flag signaling whether to take absolute value or not
X = Converted measurement value (the units depend on the analyzer or sensor)
S = Analog output signal received by the data acquisition hardware, VDC or A
S_L = Analog signal of the instrument/sensor at low end, VDC or A

S_H = Analog signal of the instrument/sensor at high end, VDC or A

R_L = Measurement range of the instrument/sensor at low end (units depend on the instrument or sensor)

R_H = Measurement range of the instrument/sensor at high end (units depend on instrument or sensor

For thermocouple signal conversion, $S_L = 0$, $S_H = 1$, $R_L = 0$, and $R_H = 1$.

For signal conversion of activity sensors, which have an offset voltage and the sensor analog output = offset ± S, S_L = offset, S_H = offset + 1, $R_L = 0$, $R_H = 1$, and Abs = true.

For any analyzers and sensors whose converted values need correction or adjustment using a linear model (e.g., correcting analyzer outputs based on calibration coefficients of the analyzer), the following linear equation will be used to perform the adjustment in AirDAC:

$$Y = A \cdot X + B \qquad (2.9.3)$$

Where:

A = Slope

B = Intercept

The Y values will be averaged with the following equation:

$$\overline{Y} = \frac{\sum_{i=1}^{n} Y_i}{n} \qquad (2.9.4)$$

Where:

$\overline{Y}$ = Average of Y

Y_i = Calculated Y from individual samples that are taken every s (Equation 2.9.3)

n = Number of samples ($n = 15$ for the 15-s data file and $n = 60$ for the 1-min data file)

The value $\overline{Y}$ will be saved in two different data files every 15 s and 60 s, respectively.

For sensors with digital output signals, the signal value S will not be changed when it is converted to Y by setting Abs = false, $S_L = 0$, $S_H = 1$, $R_L = 0$, $R_H = 1$, $A = 1$ and $B = 0$ using Equations 2.9.1 and 2.9.3. The Y will be converted into percentage of time using Equation 2.9.4. For example, if a saved data point shows 50% of time “on” in the 1-min data file, the sensor provided signal that is 30 s “on” and 30 s “off” during the corresponding one-minute period.

For the PM samples obtained with the federal reference method, data transformation will be conducted according to the instrument instruction.

2.9.8. Data Validation

Computer-acquired raw data will be assembled and daily graphs will be plotted. Plotted graphs will be reviewed visually for any malfunctioning sensors, outliers, and missing data primarily by the PAAQL Data Analyst and secondarily by the Site PI and/or other site personnel within two business days (Refer to Section 4.1 and SOP B3). If any error is found, original data will be checked against field notes to find the cause of the error, and any inconsistencies will be reported to the site personnel. Feedback from site personnel to the Data Analyst (if required) will be provided within two business days. All original and final data will be reviewed and/or validated by technically qualified staff, and so documented in the program records. The documentation will include the dates the work was performed, the name of the reviewer(s), and the items reviewed or validated.

Operators visiting a site will record electronic field notes (see above) for the work performed, procedures followed, problems identified, and corrective measures needed. Field notes will be emailed to the site PI and the PAAQL Data Analyst at the end of each site working day and reviewed by both persons. Review of the field notes keeps the site PI and Data Analyst updated on measurement progress, and allows for planning of preventive measures to achieve QAQC objectives. It also helps with troubleshooting of the system and validation of the data (Section 2.9.9).

2.9.9. Data Flagging

Data flags indicating various reasons of data invalidity or suspicion due to special events, failure of QC limits, or contamination will be applied during data processing using CAPECAB software (SOP B6). Data flags consisting of three letters will be used for easy recognition and selection. Data flags are assigned to specific datum in the raw or processed data set. Table 2.9.2 lists the data flags that will be used in the NAEMS.

Data flags will be applied in one of three ways using CAPECAB software (SOP B6): First, for location-specific analyzers and sensors, a set of “suggested” flags will be generated and stored in an information file used by CAPECAB. These suggested flags will include flags of “EQU” for data collected at each location during the equilibrium time for the specific analyzer or sensor, and “MIS” for data missing from the original data files. The suggested flags can be accepted and assigned to the respective data points. Second, automatic flags will be generated and assigned for any datum that falls outside of the expected range of the sensor (HNR, LNR, ONR), or when the data experiences a sudden change in value (SPK, SCV). The settings for the automatic flags are stored in an information file used by CAPECAB. Third, flags can be manually assigned to data, based on information regarding calibration or instrument maintenance in the fieldnotes, or DAQ-related problems. Manually flagged data is recorded in an information file that includes the date and time the flagging was completed, the name of the person setting the flag(s), the start and end date and time of the flag(s), the flag identifier(s), and any related comments regarding the flag. Each of the three flagging methods has a data file associated with it that will be included in quarterly data result reports.

Data can be flagged in the ADPP program, but currently these flags are not transferred into the CAPECAB database for purposes of emission calculations. CAPECAB and ADPP software updates are being investigated to allow for flag information files to be shared between the two programs; however, all data corrections and flagging that affect the reported concentration and emission results will be conducted in CAPECAB.

Table 2.9.2. Data flags.

Description	Flag	Definition or additional description
Valid data	(Blank)	
Hardware related		
Data acquisition system problem	DAQ	Including system failure or malfunctioning that introduces systematic errors
System noise	NOI	Random error introduced by measurement system, usually electronic noises
Failure of instrument/sensor	FLR	Instrument/sensor not working at all
Unstable instrument/sensor	UST	Systematic error introduced
Offline of instrument/sensor	OFF	Instrument/sensor not installed, disconnected, un-powered, or removed
Pegged instrument/sensor	PEG	Out of the instrument/sensor measurement range at the higher or lower ends
Operation related		
Calibration or precision check	CAL	Also applied for data acquired at equilibrium time after calibration or precision check
Equilibrating or warming up	EQU	At switching of sampling locations (for LSAS) or start of instrument power on
Maintenance of instrument/sensor	MNT	
Condensation in sampling lines	CDN	
Insufficient sample flow	FLO	For LSAS and PM samples
Data value related		
Higher than normal range	HNR	Normal range defined and set during DAQ in AirDAC or during data processing
Lower than normal range	LNR	
Out of normal range	ONR	
Spikes	SPK	Fast, exceptional, and short duration changes in data values compared with values before and after that duration and compared with normal value change patterns
Sudden change of values (abnormal change)	SCV	Fast and evident increase or decrease in data values compared with values before that change and compared with normal value change patterns
Other flags		
Incomplete data	INC	1. Occurred in data processing, e.g. data are incomplete when calculating emission rate without air flow rate 2. Data completeness not meet DQO criteria
Missing data	MIS	Data missing from the original data file
Reserved data column	RES	Originally configured in the data files
Previous flag confirmed	PFC	Used as second or third flags

2.9.10. Data Transmittal

Data transmittal occurs when data are transferred from one person or location to another or when data are copied from one form to another. Table 2.9.3 summarizes data transmittal operations.

Table 2.9.3. Data transmittal operations.

Description of data transmittal	Originator	Recipient	QA measures applied
Electronic	Site computer	Backup device	Parity checking; transmission protocols
Continuous measurement electronic data and manually entered electronic data (via internet email)	Site computer	Site PI, Site Engineer, PAAQL administrative server	Parity checking; transmission protocols
Farm management (copy electronic files)	Farm Manager	Site PC	Parity checking; transmission protocols
Farm management (entry of hard copy data to computer by site personnel)	Farm Manager	Site PC	Review and verify all entries
Filter receiving and chain of custody	Shipping and receiving personnel	Site personnel	Review and verify all entries
Test data graphs and summaries (electronic transmittal)	Site PI or Site Engineer	PAAQL administrative server	Parity checking; transmission protocols
Quarterly and final reports (electronic transmittal)	Project SA and EPA	Report reviews and recipients	Parity checking; transmission protocols

2.9.11. Data Reduction

Data reduction involves aggregating and summarizing results so that they can be understood and interpreted. Examples of data summaries include:

- Average pollutant concentrations and other environmental variables, e.g. temperature, relative humidity, weather conditions, etc.
- Average barn ventilation rates
- Average number and weight of animals in the barns
- Average pollutant emission rates from the barns
- Accuracy, bias, and precision statistics based on the measurement data
- Data completeness

The data can be averaged over different time spans, e.g. hourly, daily, monthly, quarterly, or annually. Shorter intervals reveal variations in pollutant concentrations and emission rates (e.g. diurnal patterns).

As described above, raw data are saved in the site PC, transferred daily to PAAQL, and backed up in both the site backup system and the PAAQL administrative server. In the latter case, the timestamp imprinted on the file by Eudora when it is received from the site can be used to verify the originality of the file. Details are in SOPs B2 and B5. The equations/procedures used to calculate concentrations are described in SOP B4. Accurate working files of all documentation, including logbook entries, original data, calculations, deviations from approved procedures, data uncertainties, assumptions, QA/QC results and external performance data, audits, and review, inspection, and validation will be maintained by the respective site PI as appropriate, until they are turned over to the IMC.

All averaging functions are carried out using the CAPECAB software (SOP B6). CAPECAB has a variety of built-in features to maintain data integrity, as described further below.

2.9.12. Data Correction

Data correction will be made during data processing and by operators with administrative privilege of data access. All data correction will be carried out in CAPECAB. Typical reasons for data correction include:

- Corrections of data input due to human error
- Application of revised calibration factors
- Corrections of measurement values based on calibration/precision check results
- Addition of new or supplementary data (e.g. animal number and weight)
- Manual flagging of data as invalid or suspect.

Any correction to data that is made in CAPECAB must be done using one of two options – either a manual flag or an equation. Flags are recorded (see above), and an equation log will be implemented that will record the following information for each equation, similar to that recorded for flags:

- What equation was run, and on what data
- Identity of the person running the equation
- Date and time the equation was run
- Origin (path, filename, etc) for the equation

After correction, original entries (raw data) will always remain legible (for manual corrections) or intact (for computerized corrections). For computerized corrections, the original data and corrected data must be stored separately (i.e. as different data columns in CAPECAB). A utility program will be provided by the CAPECAB vendor that will compare the raw data files in any particular CAPECAB file with those in the original e-mailed text file from the site to verify that the raw data displayed in CAPECAB is, in all cases, the unadulterated raw data received from the site.

2.9.13. Data Analysis

Data analysis involves comparing suitably reduced data with a conceptual model. It includes computation of summary statistics. Data analysis will be performed by PAAQL personnel using data processing software CAPECAB (SOP B6). Details of the various data computations, including equations used, and data reporting are outlined in SOP B4.

2.9.14. Data Tracking

Figure 2.9.1 illustrates data flow in the project. Data are mostly originated from the measurement site and flow to the PAAQL administrative server. Once pre-processed at PAAQL, data is made available to site personnel (Site PI) and PCs. In most cases, the tracking of data and monitoring of the database are updated simultaneously. Reports of data tracking may be generated by any person with report privileges. The reports will include the following:

- Type of data
- Location and date of data origination
- Designated data distribution destination
- Planned date of data transmittal
- Fulfillment of data transmittal

The Site PI and PAAQL Data Manager are responsible for the status of data tracking.

2.9.15. Data Archival and Retrieval

All NAEMS-related files will be archived and kept for a minimum of six years after the conclusion of the project. Retrieval of the data is only for authorized people and will be made from the site computer or administration server. Project records will be maintained in a systematic, logical and appropriately indexed form, and adequately filed for rapid retrieval. Details of data archival and retrieval are described in SOP B5.

The record storage will conform to EPA records management policies (USEPA, 2005). A records management program with the following minimum requirements will be established and maintained.

- Create, receive, and maintain official records providing adequate and proper documentation and evidence of project activities.
- Manage records, in any format, in accordance with applicable statutes, regulations, and EPA policy and guidance.
- Maintain electronic records, including electronic mail records, in the enterprise-wide electronic content management system, when available, and migrate legacy systems, when feasible.
- Print and file records in a paper recordkeeping system if an enterprise-wide electronic content management system is not available.

- Maintain records according to the Agency-wide file structure allowing for timely access and retrieval.
- Secure records to protect the legal and financial rights of the project.
- Follow instructions for disposition of records as specified in the approved records schedules.

No data will be destroyed without EPA approval. At the end of the six-year period, or when appropriate, EPA will be consulted on data archives and given the opportunity to either request transfer of data archives to EPA, or agree with Purdue's assessment that data can be destroyed.

3. Assessment and Oversight

The following subsections describe assessment and oversight measures to be taken during data collection. These actions are separate from the final data validation described in Section 4.

3.1 Assessments and Response Actions

The PAAQL Data Analyst assigned to each site will be responsible for routine assessment and internal QA/QC checks of data collection, evaluation of data in accordance with validation procedures, and for initiating necessary response actions. The routine assessment will include review of data to ensure that instruments are functioning and collecting information. They will assess the data for their representativeness, completeness, comparability, accuracy and precision as outlined in Section 4. Routine assessments will also include review of the QC measures in Section 2.4.3. The Site PI will share in these duties. The PI will initiate his/her own response actions immediately upon discovery of a problem, and will respond to those initiated by the PAAQL Data Analyst, to ensure that the data meet the project DQOs.

The Science Advisor and/or Project QA Manager, with assistance of other PAAQL staff members, will conduct the audit/assessment procedures described in Table 3.1.1. The assessments include at least one field operation assessment of sampling and analysis activities at each site and at the internal and external analytical laboratories that provide analytical services to the project. Performance audit samples will be analyzed during these assessments (Section 2.4.3). The timing of these audits will be coordinated with EPA, and/or its designee, to coincide (if possible) with the external audits (see below). During field oversight, while both the PIs and site engineer are present, the Science Advisor, Project QA Manager, or other designee will visually observe sample collection and analysis to verify that the procedures outlined in this QAPP are being followed and that any corrective action initiated previously is being continued. Field documentation of samples, calibration, QC measures, staff training and corrective action will also be reviewed. In addition, the Science Advisor and/or QA Manager will conduct a review of data and record management systems. This review will verify that the data management procedures (Section 2.9 of this QAPP) and all SOPs, are being followed.

The audit of each location will be conducted and documented using forms adapted from those included in the August 1998 Quality Assurance Handbook for Air Pollution Measurement

(Appendix 15, Section 2). The NAEMS Site Audit Form (Appendix C) documents these assessments and the required response actions. All internal assessment reports will be directed to the SA, who will forward them to EPA. Any issues or anomalies identified in these reviews will be discussed with appropriate site personnel and addressed immediately, and will also be documented on the Site Audit Form. If response actions are taken, the PI will inform the SA/QA Manager of these actions and the results, and will document the actions by returning a copy of the Site Audit Form that has been annotated with his/her responses to the requested corrective actions. The Site PI will keep a copy of this annotated reply for his/her records, and will retain a copy on-site. The annotated Audit Finding Form, with the plan of action, must be delivered (electronically or otherwise) to the SA or QA Manager within 30 d of the issuance of the Site Audit Form. The Project QA Manager will review this information to verify that the QAPP is being followed, and to determine if changes to the QAPP (including the SOPs) are needed. The SA and Project QA Manager will retain copies of all Site Audit Forms and responses. Audits, and their results, will be summarized in the quarterly QA reports.

EPA or its designee will perform its own annual assessment of each site. PAAQL QA personnel will coordinate with EPA QA personnel, so that these audits can be conducted on the same day(s) as a PAAQL internal audit (described above), if this is possible. The EPA QA Assessment Report will be submitted to the SA. The Project QA Manager will send the EPA QA Assessment Report to the site PI and review the required corrective actions with the site PI. Within two weeks, the Site PI will submit a report to the Project QA Manager that outlines his/her response to the EPA assessment. Upon approval by the SA and the Project QA Manager, the Site PI’s response will be submitted to EPA by the SA. The deadline for the submittal of this report is 30 d following the on-site assessment. The Project QA Manager will ensure that these corrective actions are implemented by the Site PI.

The SA has authority to stop work. If the SA is not available or cannot be contacted, the principal investigator (PI) for the site has authority to stop work. The PI will have such authority only during an emergency, either one related to the farm operation (such as a biosecurity breach) or weather (such as tornado or heavy snow that prevents access to the farm, etc). The site PI will email the SA about the decision to stop work, and to explain the justifications for the decision.

3.2 Reports to Management

Table 3.2.1 includes the reports to management with description of frequency, originators and receivers of these reports. These reports will be directed by the project Quality Assurance Manager, to the SA, and he will forward it to EPA and AARC.

If conditions requiring corrective action are identified during a review conducted by the Project QA Manager, a brief report will be issued by the Project QA Manager to the SA and the PI; however, corrective action will be initiated immediately based on verbal discussion during the review. Each site’s PI will generate a quarterly report that contains the following information. PAAQL personnel will combine these reports into one, and will include the results of any audits that were conducted in previous months. Quarterly and final project reports will contain all valid monitoring data expressed as hourly and daily values. The reports will include the following:

1. Executive summary
2. Background and present status
3. Quality objectives for measurement data
4. Numerical and qualitative results of all QC measures for all measurement systems, including comparisons with the applicable acceptance criteria
5. Results of quality assurance assessments
6. Recommendation for further QA work, with suggestions for improving performance and fixing problems with equipment, personnel training, infrastructure needs, etc.
7. Graphical representations of the measurement locations
8. Description of any data that must be invalidated, including reasons for data invalidation and the required corrective action
9. Summary of corrective actions taken during field data collection
10. Discussion of the impact of corrective actions on data quality

Table 3.1.1. Assessment procedures, types, and frequency.

Type of Assessment: Scope	Frequency	Assessment Personnel
Field Operations: 1. Routine Operations 2. Quality Control 3. Preventive Maintenance 4. Record Keeping 5. Data Acquisition and Handling	Annually	SA or designee
Laboratory Operations: 1. Routine Operations 2. Quality Control 3. Preventative Maintenance 4. Record Keeping 5. Data Acquisition and Handling	Annually	SA or designee
Data and Record Management: 1. Data Handling 2. Software Documentation 3. Data Validation and Correction 4. Data Processing 5. Internal Reporting 6. External reporting	Quarterly	SA or designee
Quality Assurance/Quality Control: 1. Status of Quality Assurance Program 2. Audits and Audits System Traceability 3. National Performance Audit Program (NPAP) and Additional Audits 4. Documentation and Data Processing Review 5. Corrective Action System 6. Audit Result Acceptance Criteria	Annually	SA or designee

Table 3.2.1. Required reports to management.

Type of QA Report to Management	Contents	Reporting Frequency					Person responsible for:	
		AR	W	M	Q	Yr	Generating Report	Receiving Report
QA - Corrective Action Request	Description of problem; recommended action required; feedback on resolution of problem	√					**Site PI**	**QA Manager, Science Advisor (SA)**
QA - Control Chart with Summary	Repetitive field or lab activity; control limits versus time. Prepare whenever new check or calibration is done.	√		√			**Site PI**	**QA Manager, SA**
QA - Performance Audit Program Results	Summary of performance audit results					√	**QA Manager**	**SA**
QA - System Audits	Summary of system audit results; recommendations for action, as needed.					√	**QA Manager,**	**SA**
QA - Quality Assurance Report to Management	Executive summary. Precision, bias, completeness and system and performance audit results.				√	√	**QA Manager**	**SA**
Interim Reports	Executive summary. Data summary, Precision, bias, completeness and system and performance audit results				√	√	**SA, Site PIs**	**EPA, AARC**
Progress Report	Executive summary			√			**SA, Site PIs**	**EPA, AARC**

QA: Quality assurance; AR: As required; W: weekly; M: Monthly; Q: Quarterly; Yr: Yearly;

4. Data Validation and Usability

4.1 Data Review, Verification, and Validation Requirements

4.1.1. Monitoring/Sampling Design and Sample Collection

The site monitoring plan (SMP) must be reviewed and approved by EPA prior to implementation at each site. The site PIs are responsible for the proper installation of sampling and measurement equipment as specified in the SMPs and this QAPP. During the monitoring site setup and equipment installation, PAAQL personnel will visit the site to provide technical support and ensure that the sampling systems are established according to the SMP, and that the samples collected or measured are representative. Site audits will also be conducted by PAAQL personnel, as described in Section 3.1, and by an EPA subcontractor.

4.1.2. Sample Collection and Handling Verification

Standard procedures are described in the corresponding SOPs. The monitoring site PIs will ensure that the procedures are followed to ensure proper sampling and handling, and to maintain data/sample integrity. Site audits will also verify that these procedures are being properly followed. The purpose of the audits is to ensure that the monitoring, sample collection, handling and preservation are being performed following the described procedures. Following the audits, a Site Audit Form (Appendix C) will be completed and sent to the corresponding PIs and EPA. Corrective actions must be taken as soon as possible for any significant deviation noted.

4.1.3. Analytical Procedures and Quality Control

All analytical methods and procedures will be conducted according to the SOPs and the corresponding sections of this QAPP. Each site PI is responsible for ensuring that the specified methods and procedures are being followed for those analyses that are carried out on site (e.g. the gas analyzers). Proper installation and maintenance of measurement equipment, on-time sampling and calibration, and all other field and laboratory QC procedures will be ensured by site PIs. Midwest Laboratories will provide QA/QC oversight for the analyses of manure, feed, bedding, milk, and eggs. PAAQL personnel (Dr. Changhe Xiao, acting as the VOC Manager for the NAEMS) will be responsible for auditing the VOC analytical facilities at PAAQL. The audits will also validate the analytical and QC procedures, and any findings relevant to these areas will be included in the Audit Report. Acceptable precision, bias, and other criteria as specified in required measurement and sampling SOPs will be used to verify that the analytical and QC procedures are adequate. If significant deviation is found, corrective actions must be conducted and recorded in the field notes. For the affected data, the site engineer and PI, and related PAAQL personnel (at minimum, the data analyst assigned to that site) will meet to discuss and determine the validity of the data, and flag the data as invalid if that is judged to be appropriate. When flagging data as invalid, personnel must clearly record the data, reason and narrative of the flagging.

4.1.4. Calibration

The specified calibration activities and requirements must be conducted according to the frequency as specified in this QAPP and the SOPs. Verification of such activities is the responsibilities of the site PIs and will also be conducted in the site audits. Verifications include checking the proper multipoint calibration prior to measurement or sampling, proper calibration frequency, appropriate calibration points and range, and acceptable QC checks as specified in the SOPs and QAPP. Significant deviations from the calibration procedures and QAPP requirements will be noted and reported in the Site Audit Form. Corrections must be conducted and recorded in the field notes, so that the calibrations are meeting the specified frequency and requirements. The calibration and precision (zero/span) check data of gas analyzers are required information (SOPs B3 and B6) in the calculation of gas concentrations and emission rates. Thus, the validity of these checks must be verified by PAAQL data processing personnel before any gas data can be reported.

4.1.5. Data Reduction and Processing

All data generated under this QAPP will be reviewed and validated primarily by PAAQL personnel (the data analysts assigned to the particular sites), and secondarily by the PIs responsible for each individual site (Section 2.4.2.). Graphical presentation (daily figures) of the collected data will be generated according to SOP B3. An Excel graph template will be used to organize raw data, assemble one or more data files in a single day, and produce daily figures to allow the PIs and PAAQL data analysts to review data shortly after they are recorded. A custom software program, Calculation of Air Pollutant Emissions from Confined Animal Buildings (CAPECAB, SOP B6) was developed to assemble and review data, and execute the final processing of air emission measurement variables. The data “Flagging” function of the program is used to inspect and assess data validity, and flag data. All data will be initially considered invalid, but will be validated unless field notes, user-specified ranges, ventilation-stage measurements, or outliers imply a reason to flag a datum. By reviewing the figures (SOPs B3 and B6), and cross-checking the correlated variables, personnel can ensure data collected conforms to the sampling design specifications and representativeness.

Data verification will be performed by comparing the data with field notes, farm information (e.g. changes in animal numbers), and weather data to identify any possible human interferences and/or environmental changes that might affect the data. Data verification will also be done by comparing the data with those published and obtained at similar measurement campaigns. Whenever data is flagged as invalid in the data-inspection process, personnel must clearly record the reason and period in the data processing notebook (or electronic file). Also, they must record other information including analyst name, site name, and narrative of the flagging. Data will not be flagged invalid or excluded from database without adequate reason. The CAPECAB program is designed to retain all data (even when they are flagged as invalid), and the flagging can be easily reversed.

One specific case of data verification will be the use of N balances to corroborate, through a theoretical mass-balance, the measured NH_3 emissions from the barns. This is described in SOP

S5, and will be conducted annually (corresponding to the one-year storage times for manure in many of the barns).

Validation will follow these criteria:

1. Data will be invalidated if they are:

- unreasonably low or high compared with normal ranges and if there is supporting evidence that they are not correct (e.g., unresponsive relative humidity sensor inside a barn producing a reading less than 10%)
- obtained during system installation, testing, or maintenance during which uncorrectable errors might be introduced
- obtained when the sensor or instrument is proved to be pegged
- obtained when the sensor or instrument is proved to be malfunctioning (e.g., unstable)
- obtained during sensor or instrument calibration or precision check and before the sensor or instrument reaches equilibrium after calibration or precision check
- obtained when the data acquisition and control hardware and/or software is not functioning correctly

2. Data from the location-shared analyzers/sensors (LSAS), such as gas concentration analyzers and the RH/T sensor installed at the same location as the gas sampling point, will be invalidated if they were obtained when:

- the sampling pump is not operating
- the GSS sampling flow rate does not exceed the total sample flow rate drawn by all of the gas analyzers (since this would allow atmospheric air from inside the OFIS to enter the analyzer manifold of the GSS)
- condensation is present in the sampling system

3. Averaged data for any individual parameter will be invalidated to avoid errors introduced into calculated mean values due to partial-data days (e.g. only a few hours of valid data) that would result in biased time weights (SOP B4):

- Hourly averages will be invalidated if <75% of the data during that hour are valid.
- Daily means will be invalidated if <75% of the hourly average data during that day are valid.
- Monthly averages will be invalidated if <75% of the individual days during that month are valid.
- Average daily means (ADM) will be invalidated if <75% of the daily average data during all measurement days are valid.

For location-shared analyzers/sensors, the 75% valid data criterion is evaluated within individual locations, after proper zero/span data adjustment (SOPs B3 and B6), and interpolations between the valid measurement points. The interpolations are conducted to interpolate between any two or more valid measurement periods that are within 300 min (3000 min for ambient measurements, as these are collected less frequently, and are relatively constant). For example, for a monitoring site that has 12 sampling locations and a 5-min sampling period, air from each location will be sampled/analyzed every 60 min. The missing data between two measurements will be linearly interpolated based on the valid and adjusted concentrations. However, if the next valid measurement at one or more given locations was delayed (due to maintenance, zero/span checks, inlet air sampling) for more than 300 min, the interpolation will not be conducted for those locations. Also, if the gas analyzer is pegged for the first 10 min (at the first location), while the other 50 min of measurements (five other locations) are normal, only the measurement data of the first sampling location is flagged as invalid, and will not be interpolated. If the same pattern happens in enough sampling cycles during a day, so that less than 75% of the data at a specific location is valid, then the daily mean at this location is invalidated. However, the daily means of all other locations would still be valid.

4.2 Verification and Validation Methods

The purpose of verification is to ensure that conclusions can be correctly drawn from the measurement data. The purpose of validation is to determine whether the data satisfy QAPP-defined user requirements.

Verification and validation will be performed by manually checking data entries and data summaries and visually inspecting graphical data plots combined with additional data collecting information, e.g. test activity, barn data, etc. This technique will be used to verify and validate both continuously acquired data (e.g. gas concentrations, ventilation, temperatures, etc.) and manually entered discrete sample data (e.g. gravimetric PM concentration, manure analysis results, etc.). Data pre-processing and processing software ADPP (SOP B3) and CAPECAB (SOP B6) will be used to aid automatic verification and validation of the continuously acquired data by flagging, calculating statistics, and plotting.

4.2.1 Verification Methods

4.2.1.1 Verification of Procedures

Verification of data procedures, including calculating equations, parameters, and sequences, will be performed during preparation of quarterly reports by a second data analyst. A thorough review of the following will be conducted to verify whether the continuously acquired data and/or calculated data were correctly:

- Transformed during data acquisition (Section 2.9.7) and processing (SOPs B3, B4 & B6)
- Reduced during data acquisition (Section 2.9.7) and processing (SOPs B4 & B6)
- Analyzed (SOPs B4 and B6)

If any error is found in the procedures, the cause of the error will be identified. Corrections will be made that may include the following:

- Correct the data format

- Verify and correct software configuration files
- Correct equations or calculation sequences
- Repeat calculation(s) with corrected procedure

After the first quarterly verification and corrections of these procedures, the same verification method will only be applied when there has been change in the data transformation, reduction and analysis procedures.

For discrete sample data, all the calculation procedures will be verified to make sure that no errors were introduced during data reduction and analysis. If any errors were uncovered, recalculation will be conducted after the errors in the procedure are corrected.

4.2.1.2 Verification of Data

Verification of data will focus on data-entry error, outliers, data out of acceptance criteria, and data completeness. Data will be evaluated for compliance with stated objectives for representativeness, precision, and accuracy.

For discrete samples, all raw data that are hand-entered from data sheet and/or typed directly into computer data files will be double-checked against the original recording. If the number of data points is too large for this to be feasible or practical, 5% of the data will be randomly selected for verification.

Summary statistics of the data (including mean, maximum, minimum, and standard deviation) and data completeness will either be calculated manually for discrete sample data or automatically using ADPP (SOP B3) and CAPECAB (SOP B6) software for continuous measurement data.

Graphs plotting hourly, daily, and monthly summary statistics will be used to compare with each other and compare with published data and data patterns. Data outliers include those data that are out of normal range or do not fit into normal patterns. Extremely low or extremely high data will be flagged as LNR (lower than normal range) or HNR (higher than normal range), respectively. Sudden changes in data values will be flagged SPK (spike). Data marked with flags will be further verified for the cause of abnormality. A list of flags and description/definition is found in Table 2.9.2.

Special outliers that cannot be related to specific reasons are subject to further investigation. Any averaged data that do not meet the data completeness criteria (Section 4.1) will be excluded automatically from subsequent data processing by CAPECAB.

Manually or automatically (if calculated with ADPP or CAPECAB) calculated data completeness will be verified against the project measurement quality objectives (Table 1.4.1). Any suspicious completeness data will be subject to further investigation until the data completeness values are correct.

4.2.2 Validation Method

Validation of data will be performed at the measurement data level and at the summary data level. Data will be validated by using the validation criteria (Section 4.1), and by comparison with instrumental performance parameters as identified in the applicable standard operating procedure or instrument operation manual. Data validation will also be performed by comparing the recorded test activity and changes of the barn environment.

Data flagged as invalid will all be checked and verified by a second data analyst. The verification of each variable will be documented. Other flags listed in Table 2.9.2 may also be used, alone or in combination, to invalidate the raw data or summarized data. However, data generated under instrument/sensor or DAQ system with known and correctable bias will be kept valid and corrected, for example, by applying new calibration coefficients.

All invalid data will be kept, but will be excluded from the subsequent data processing and analysis. After the validation process, a summary table of the format shown in Table 4.2.1 will be completed and included in the data report. This table will include a record all flagging-related material and activity, and will therefore identify all data that were deemed to be invalid. In all cases, data deemed to be invalid by the primary PAAQL Data Analyst will be confirmed by a second Data Analyst. The identity of this person will be included for each site in the data report.

Table 4.2.1. Data validation summary.

Data type	Data range (from date to date)	Invalid	Invalidation criteria	Data validator (name, date, affiliation)	Flag Activity Verified (name, date, affiliation)

4.2.3 Authorized Personnel for Verification and Validation

The Site PI and PAAQL data management staff are authorized and responsible for data validation and verification unless an outside institution is authorized by the USEPA. They will be assigned administrative privilege to perform data flagging and correction (Table 4.2.2). Generally, the PAAQL Data Analyst (primarily) and the Site PI and/or Site Engineer (secondarily) will be responsible for data verification, and the PAAQL data management staff will be responsible for data validation. Double verification may be needed for some cases (e.g. data flags).

Table 4.2.2. Data verification and validation tasks and responsibilities.

Data type	Site PI and Engineer		PAAQL data-managers	
	Verification	Validation	Verification	Validation
Continuous measurement data	√		√	√
Discrete sample data	√			√
Manure sampling record	√			√
VOC sampling record	√			√
Farm animal and management record	√	√		
Test notes	√			√
DAQ configuration files	√	√		
Data flags			√	√
Sample chain-of-custody sheets	√			√
Receipt logs	√			√
Instrument check log	√			√
Instrument calibration sheets	√			√
Data processing configuration files			√	√

4.3 Reconciliation with Data Quality Objectives

The DQOs of the NAEMS were developed in Section 1.4. The data quality assessment (DQA) process is comprised of the following steps:

4.3.1 Step 1. Review DQAs and sampling design

Section 1.4 of this QAPP describes the development of the DQOs, and defines the primary objective of the air emission monitoring study and develops limits on the decision errors. The site monitoring plans (SMPs) (Appendix A) contain the details for the sampling design for each site, including the rationale for these designs. Any deviations from the sampling design will be indicated and their potential effect on the DQOs carefully considered throughout the entire DQA.

4.3.2 Step 2. Conduct preliminary data review

A preliminary data and data graph (including control charts) review will be performed to uncover potential limitations to using the data, to reveal outliers, to explore the basic structure of the data, and to look for anomalies in recorded data, missing values, and any deviations from standard operating procedures for all measurement variables.

Summary statistics and graphical presentations will be generated at the quarterly, annual, and biannual (final report) timeframes, and will include only valid samples. Summary statistics for each primary measurement variable (including concentration and ventilation) are numbers of samples, means, medians, standard deviations, coefficients of variation, maxima, and minima. The results will be summarized in a table or tables. Particular attention will be given to the impact on the statistics caused by the observations noted in the quality assurance review.

Graphics and summary tables will be used to show the spatial and temporal variations of the data, and will be assessed by the Site PI and PAAQL.

4.3.3 Step 3. Determine data bias, precision, and completeness

Because the objective of this NAEMS is to determine baseline emissions of different types of sites for modeling purposes, instead of emission compliance, statistical tests will not be used.

Bias, precision, and completeness will be used to evaluate the data. Bias and precision of each individual instrument/sensor are established in Section 2.6, and are determined during instrument/sensor calibrations, precision checks, and/or external audits.

For each precision check of gas analyzers using calibration gases of known concentration, bias $d_{i,}$ *w*ill be calculated using Equation 2.1 in Section 2.4.

For each $PM_{2.5}$ measurement pair, the percent relative bias d_i is calculated with Equation 2.2.

Coefficient of variation (CV), for a single check is calculated with Equation 2.3 in Section 2.4. Precision of a single instrument, *j*, during the quarter, *q*, is calculated with Equation 2.4 in Section 2.4.

Completeness is defined as the measure of the amount of valid data obtained from a measurement system, compared with the amount of data that was expected to be obtained under normal conditions. Data completeness will be expressed as the percentage of valid data obtained from the measurement system. For data to be considered valid, they must meet all the acceptance criteria. Calculations of data completeness are made during data processing.

The following formula will be used to calculate completeness:

$$C = \frac{V}{n} \times 100\% \qquad (4.1)$$

Where,

C = completeness, %.
V = number of measurements judged valid
n = total possible number of measurements.

Results of precision, bias, and completeness calculations will be recorded in the data summary table, and included in quarterly, annual, and final reports.

4.3.4 Step 4. Verify data bias, precision, and completeness

Bias in pollutant concentration measurements and the adjustment of measurement data using precision check data to reduce the bias will be evaluated. Bias is established within ±10%.

Measurement precision is established at a 10% coefficient of variation (CV). Data completeness is established at 75%. For each pollutant measurement instrument, the site PI and the PAAQL data analysts will review the CV and completeness calculated in Step 3 (Section 4.3.3).

Table 4.1 will be completed during each DQA. A check will be placed in each of the row/column combinations that apply. If any of the DQO assumptions are violated, then the site PI and PAAQL will need to reevaluate the DQOs.

Table 4.3.1. Summary of bias, precision, and completeness.

Instrument	Bias <±10%?	Precision <10%?	Completeness >75%?
Analyzer 1			
Analyzer 2			
…			
TEOM 1			
TEOM 2			
…			

4.3.5 Step 5. Draw conclusions about the data quality

If any of the established bias, precision, and completeness assessed in Step 4 is not met, then the test is suspect and will require further investigation.

4.3.6 Action plan based on conclusion from the DQA

All five steps of the process will be completed and Table 4.3.1 will be generated on a quarterly basis. If all answers are "yes" (DQI's are within limits), then the Site PI and PAAQL will assume that the DQO's have been met. If this is not the case, the Site PI and PAAQL will take one of the following possible actions:

4.3.6.1 Re-examine the Measurement Equipment, Material, or Procedures

If the process reveals that the problem is related to the equipment, materials (including calibration gases), or operation procedure (including calibration or precision check procedures), PAAQL will re-examine the selected measurement equipment, verify the accuracy and stability of the calibration gases, and evaluate the standard operating procedures to identify the real cause of the errors. Measures, including changing equipment, re-certifying calibration gases, or modifying SOPs will be taken as necessary. Modification of the procedure or stricter quality control will be implemented.

4.3.6.2 Reducing the QA Requirement

QC is integral to any site monitoring and is particularly important to the project. However, once it is demonstrated that the data collected from the sites are not within tolerable levels of error, PAAQL may consider and request a reduction of QA requirements.

4.3.6.3 Extensive Review of Quarterly Data until DQOs are Achieved

The Site PI and PAAQL will continue to review the quarterly QA reports and the QC summaries until the bias, precision, and completeness limits are attained.

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APPENDIX A –NAEMS Site Monitoring Plans

Barn SMPs are contained in Appendix A. Area-source SMPs are contained in the companion QAPP (the NAEMS Open-Source Component).

SMP	Type	Title
CA1B	Barn	Broiler Ranch in California
CA2B	Barn	Layer Site in California
IN2B	Barn	Layer Site in Indiana
NC2B	Barn	Layer Site in North Carolina
IN3B	Barn	Finisher Swine Farm in Indiana
NC3B	Barn	Finisher Swine Farm in North Carolina
IA4B	Barn	Sow Farm in Iowa
NC4B	Barn	Sow Farm in North Carolina (Barn Component)
OK4B	Barn	Sow Farm in Oklahoma (Barn Component)
CA5B	Barn	Dairy Farm in California
IN5B	Barn	Dairy Farm in Indiana
NY5B	Barn	Dairy Farm in New York State
WA5B	Barn	Dairy Farm in Washington State (Barn Component)
WI5B	Barn	Dairy Farm in Wisconsin (Barn Component)
IA3A	Area	Finisher Swine Basin in Iowa
NC3A	Area	Finisher Swine Lagoon in North Carolina
OK3A	Area	Finisher Swine Lagoon Site in Oklahoma
IN4A	Area	Sow Lagoon in Indiana
NC4A	Area	Sow Farm in North Carolina (Lagoon Component)
OK4A	Area	Sow Farm in Oklahoma (Lagoon Component)
IN5A	Area	Dairy Lagoon in Indiana
TX5A	Area	Dairy Corral Site in Texas
WA5A	Area	Dairy Farm in Washington State (Lagoon Component)
WI5A	Area	Dairy Farm in Wisconsin (Lagoon Component)

APPENDIX B – NAEMS Standard Operating Procedures for Barn Source Measurements

SOP	Title
A1	Laboratory Testing of Ventilation Fan Performance
A2	Measurement of Ventilation Fan Flow Rate Using the Fan Assessment Numeration System (FANS)
A3	Ventilation Fan Air Velocity Measurements Using Open Impeller Anemometry
A4	Fan Airflow Rate Estimation
A5	Measurement of Fan Static Pressure in Livestock Buildings with Setra Model 260 Differential Pressure Transducer
A6	Ultrasonic Anemometer for Non-Ventilated Barns
A7	Fan Status Monitoring Using Vibration Sensors
A8	Ventilation Fan Airflow Measurements Using the Air Velocity Transverse Method
A9	Measurement of Airflow Rate or Calibration of Air Sampling Instruments with Gilibrator 2 Calibration Systems
A10	Calculation of Airflow in Naturally Ventilated Barns
A11	Fan Status Monitoring Using RPM Sensors
B1	Data Acquisition and Control Hardware
B2	Data Acquisition and Control Software (AirDAC)
B3	Air Data Pre-Processing Software
B4	Calculation and Reporting of Air Emissions from Barns
B5	Data Management for Barns
B6	Data Processing Software (CAPECAB)
E1	Temperature Measurement Using Thermocouples
E2	Measurement of Relative Humidity (RH) and Temperature with the Omni RHT-WM Humidity Transmitter
E3	The Measurement of Solar Radiation with the Licor Model 200SL or 200SZ Silicon Pyranometer
E4	Wind Speed and Direction Measurements Using the R.M. Young Model 03002VM Wind Sentry
E5	Roof-mounted Weather Station Tower
G1	The PAAQL Gas Sampling System
G2	Compressed Gas Cylinders
G3	Measurement of Carbon Dioxide (CO_2) with the MSA Model 3600 Infrared Gas Monitor
G4	Measurement of Ammonia (NH_3) Using the TEI Model 17C Chemiluminescence Analyzer
G5	Measurement of Hydrogen Sulfide (H_2S) with the Thermo Electron Corporation Model 450I Pulsed-Fluorescence Analyzer
G6	Measurement of Methane and Non-Methane Hydrocarbons with the Thermo Electron Corporation Model 55C Analyzer
G7	Use of the INNOVA 1412 Photoacoustic Multi-Gas Monitor
G8	Multi-Point Calibration of Gas Analyzers
G9	Precision Checks of Gas Analyzers
G11	Operation of the Environics® Computerized Gas Dilution System

G12	FTIR Verification of Gas Cylinder Concentration
M1	Manure Sampling
M2	Conducting pH Measurements on Manure Samples
M3	Determining Solids Content of Manure Samples
M4	Determining Total (Kjeldahl) Nitrogen Content of Manure Samples
M5	Determining Ammonia Content of Manure Samples
P1	Measurement of Ambient Atmospheric Particulate Matter Using the Thermo Electron Corporation TEOM Series 1400A Monitor
P2	Measurement of Barn Exhaust Total Suspended Particulate Concentrations Using an Isokinetic Multipoint Gravimetric Method
P3	Measurement of $PM_{2.5}$ with the Thermo Electron Corporation Partisol Model 2000 Air Sampler
P4	Continuous Measurement of PM_{10} Particulate Matter Using the Thermo Electron Series FH 62C14 (Beta) Sampler
Q1	Use of Control Charts for Performance Monitoring of Gas Analyzers and Analytical Instruments
S1	Producer Collaborations at Barn Monitoring Sites
S2	Recording and Tracking Animal Inventory at Livestock Barns
S3	Activity Measurements
S4	Process Relay Monitoring
S5	Nutrient Balance
S6	Determining Total Kjeldahl Nitrogen (TKN) Contents of Feed, Bedding, Milk and Eggs
U1	On-farm Instrument Shelters for Barn Sources
U2	Installation of Barn Measurements
U3	Heated Raceway
U6	The Powerware 9125 Uninterruptible Power Supply
V1	Sampling of Volatile Organic Compounds (VOCs) in Air Samples through Use of Sorbent Tubes
V2	VOC Sampling Using Canisters
V3	Collection of Amines in Air Samples Through Use of Sulfuric Acid-Containing Bubblers
V4	Thermodesorption and GC/MS Analysis of VOCs collected on Sorbent Tubes
V5	Analyzing and Quantitating Amines By Ion Chromatography
V6	GC/MS Analysis of VOCs Collected in Sampling Canisters
V7	Cleaning, Certification and Pre-sampling Preparation of Sampling Canisters

APPENDIX C – Site audit forms for NAEMS

NAEMS Site Audit Form

Date:
Site:
Auditor(s):
Researchers present during visit:

Project Management:

Start date:
Frequency of online data observation:

Analyst(s) training:

Internal supervisory audits:
Data available at site for inspection?
Initial meeting with producer?
Is data being inspected following business day?
Are electronic field notes being maintained?
Is manual entry log book being maintained?

Characteristics of producer collaboration and cooperation:
Is producer providing the following data?
Mortalities:
Animal inventory and weight:
Production (e.g. eggs, milk):
Water and nutrient consumption:

Occurrence of special activities, e.g., generator tests, manure removals or agitation, change in diet and animal health, temperature set points, ventilation interventions, building cleaning, power failures, etc.:

Data Management

All files under one folder in the PC?
Data and files backed up in case of hard drive failure?
Are data files emailed to campus daily?
Are important project files (hard copy and electronic files, including data, program, field notes, emails, etc.) backed up and stored away from instrument shelter (e.g. on campus)?

Instrument Shelter

Describe the electrical grounding system.
Describe the grounding of the trailer, weather tower, feed bins, barns, etc.
Cleanliness and orderliness:
SOPs displayed near instrument?.
Security?

Utilities:
Environmental control:
Electrical power protection:

Gas Sampling System:

Date of last leak test:
Visual appearance:
Pressure =
Flow rate (minimum = 4.0 L/min) =
Is the manual sampling port bled to exhaust?
What is the ambient sampling period?
Has response time been tested?

Number of gas sampling locations?

Description of gas calibration system:

Using mixing manifolds?

How are gas and vacuum sampling lines heated, 3°C above sampled air, etc.:

Control charts available for gas analyzers? .
Calibration records available in shelter?
Log of calibration times?
Are all gas cylinders unexpired?

Calibration Records:

Instrument	Calib.* interval, d		Most recent	Loc	n	r	Notes
	QAPP	Actual					
H_2S							
CO_2							
NH_3							
CH_4							
THC (propane)							
Ethanol							
Methanol							
Bag test							
dP zero check							
dP span check							
TC							
RH/Temp							
GSS MFM							
TEOM vs FRM							
TEOM mass ver							
TEOM airflow							
TEOM leak test							
TEOM barometer							
BG Calibration							
Open anemometer							
Mixing manifolds							

B/A = before and after the test. S/W = once in summer once in winter. FC = at every filter change; Loc = location; n= number of points; r = replications.

Barn Inspection:

Check location of sensors for representativeness:

Vulnerability of sampling lines to condensation:

Equipment protection (from animals, workers):

Are the activity sensors placed to monitor both animal and worker activity?
Inspection of vane anemometer positioning.

What operational data is being gathered?

Maintenance:

	Interval, d (QAPP)	Most recent	Notes
Clean TEOM air inlet			
Clean PM_{10} head			
Replace TEOM filter			
Replace in-line filter			
Replace gas membrane filters			

Weather data:

Temperature: Yes ____ No ______
Humidity: Yes ___ No ______
Wind velocity: Yes ____ No ______
Wind direction: Yes ____ No ______
Solar radiation: Yes ____ No ______
Height of wind sensor:

Fan airflow measurements:

Description of fan monitoring method:

Speed/airflow of variable speed fans:

Which fans have the anemometers?

Have the rpm sensors been checked with optical meters?

Connections verified?

FANS measurements of fan curves:
Date(s):
Replications each point:
Number of static pressures
Number of fans tested:
Notes:

What calibrations or checks were done during this audit?

Appendix D. NAEMS Sample Chain-of-Custody (COC) Form

CHAIN OF CUSTODY SHEET

NATIONAL AIR EMISSION MONITORING STUDY (NAEMS)

(Please print clearly in ink)

Name: ____ Phone: __________________
Site Location: ____ Email Address: __________________________________
Method of Delivery:_____________________________________ Tracking Number:________________________________
Sample Set ID (Lab Use Only):_______________

Sample #	Sample Description or Location	Date Sample Taken	Type of Sample*	Collected by (Initials)	Remarks	Condition (Circle one)** (Lab use only)	
						Acceptable	Unacceptable
						Acceptable	Unacceptable
						Acceptable	Unacceptable
						Acceptable	Unacceptable
						Acceptable	Unacceptable
						Acceptable	Unacceptable
						Acceptable	Unacceptable
						Acceptable	Unacceptable
						Acceptable	Unacceptable

* e.g. Manure, feed, VOC sorbent tube, VOC canister, VOC bubbler, etc.
** If judged “unacceptable”, note reason in the space provided in the column

Released by: ____ Date: _____/_____/_____
(Signature or client)

Received by:______________________________ **PAAQL** **Midwest Laboratories** (Circle One) Date: _____/_____/_____

Southeastern Broiler Gaseous and Particulate Matter Emission Monitoring Quality Assurance Project Plan

Southeastern Broiler Gaseous and Particulate Matter Emission Monitoring Quality Assurance Project Plan

Prepared by
Iowa State University
and the University of Kentucky

Foreword

In January 2005, the United States Environmental Protection Agency (EPA) announced a plan, after negotiating with representatives of the animal agricultural industry, to collect scientifically credible data concerning air emissions from livestock and poultry facilities. This effort is titled the Air Compliance Agreement (ACA). Monitoring work performed as part of the ACA will have regulatory significance to future enforcements and decisions made by the EPA in regards to air emissions from animal agriculture. As such, projects within the ACA are required to operate with a Category 1 Quality Assurance Project Plan (QAPP).

The QAPP is defined by the EPA as a tool for project managers and planners to define the type and quality of data needed for environmental decisions, and to describe the methods for collecting and assessing the data. The QAPP integrates technical and quality control aspects regarding planning, implementation, and assessment for a project. The goal is to ensure that the results of a project are of the type and quality needed and expected by the EPA. The four components of the plan are Project Management, Data Generation and Acquisition, Assessment and Oversight, and Data Validation and Usability.

In the fall of 2005, Iowa State University and the University of Kentucky began the implementation of the monitoring system at the sites proposed for use in the ACA study for southeastern broiler operations. This segment of the study will monitor air emissions from two mechanically ventilated commercial broiler houses in western Kentucky. The aerial emissions monitored include ammonia (NH_3), carbon dioxide (CO_2), hydrogen sulfide (H_2S), non-methane hydrocarbons (NMHC), total suspended particulates (TSP), particulate matter of ≤ 10 µm diameter (PM_{10}) and particulate matter of ≤ 2.5 µm diameter ($PM_{2.5}$). The following sections describe the development and implementation of key quality assurance and control components for the project's Category 1 QAPP as required by the EPA.

Acronyms and Abbreviations

ΔP – change in pressure
µg – microgram
A/O – Analog output
AC relay – Alternating Current relay
ACA – Air Compliance Agreement
ADM – Average daily means
AFO – Animal Feeding Operation
API – Advanced Pollution Instrumentation
ARS – Agricultural Research Service
ASCII- American Standard Code for Information Interchange
ASTM – American Society for Testing and Materials Standards
Atm – atmosphere
Atm – atmospheric pressure unit
Bar – a measurement unit of pressure
BESS – Bioenvironmental Structural Systems
Btu – British thermal unit
C – Celsius
c – critical
Cal-gas – calibration gas
CD – Compact Disc
CDD – Complete-data days
CH_4 – methane
CMOS – Complementary Metal Oxide Semiconductor
CO_2 – Carbon Dioxide
CPU – central processing unit
CS – Current Switch
CV – Coefficient of Variation
DAC/DAQ – Data Acquisition
DC – Direct Current
DHCP – dynamic host configuration protocol
DQO – data quality objectives
EH&S – Environmental Health and Safety
EPA – Environmental Protection Agency
ER – Emission Rate
F – Fahrenheit
FANS – Fan Assessment Numeration System
FEP (tubes) – Fluorinated Ethylene Propylene
FID – Flame Ionization Detector
FS – full scale
GC – Gas Calibration
g – gram
GSS – Gas Sampling System
H_2S – Hydrogen Sulfide
HD – hard drive
Hg – Mercury
hv – App. K wavelength
I/O – input/output
IFAFS – Initiative for Future Agriculture and Food System
WC – water column
IP – Internet Protocol
ISU – Iowa State University
kPa – kilopascals
L – Liter
LED – light emitting diode
LPM – Liters per minute
mA – miliAmps
MAEMU – Mobile Air Emissions Monitoring Unit
mBar – 10^{-3} atmosphere
MC – mass concentration
mL – milliliters
MR – Mass rate
MS – Microsoft
MSDS – material safety data sheet
mV – miliVolts
NA – Not applicable
NAEMS – National Air Emissions Monitoring Study
NAS – National Academy of Science
NH_3 – Ammonia

NI – National Instruments
NIST – National Institute of Standards and Technology
nm – nanometers
NMHC – Non-Methane Hydrocarbons
NPB – National Pork Board
NPT – National Pipe Tapered
NRI – National Research Initiative
NSRIC – National Swine Research and Information Center
OD – Outside Diameter
P – probability of Type 1 error
Pa – Pascals
PC – Personal Computer
PFA (Teflon)
pH – acidity scale
PI – Principle Investigator
PM – Particulate Matter
Ppb – parts per billion
Ppm – parts per million
PSF – pounds per square foot
PSI – pounds per square inch
PTFE (Teflon)
PVC (pipes)
QA – Quality Assurance
QAPP – Quality Assurance Project Plan
QC – Quality Control
R&P – Rupprecht & Patashnick, Co., Inc.
RH – Relative Humidity
RL – relative load
RS (232 mode)
RSC – Rotem Serial Cable
SIT – Sample Integration Times
SN# - serial number
SOP – Standard Operating Procedures
SP – Static Pressure
SP – Static Pressure
SP (control person)
STP – Standard Temperature and Pressure
SW – Sidewall
T – Absolute Temperature
TC – Thermocouple
TE – Tunnel End
TEMP. DIFF. – Temperature Differential
TEOM – Tapered Element Oscillating Microbalance
TF – Tunnel Fan
THAM – Tris hydroxymethyl aminomethance
THC – Total Hydrocarbons
THC (propane)
TM (computation)
TS – total solids
TSP – Total Suspended Particulate
UPS – Uninterruptable Power Supply
USB – universal serial bus
USDA – United States Department of Agriculture
UV – ultraviolet
V – Volt
VAC – Voltage Alternating Current
VDC – Voltage Direct Current
VI – virtual interface
VOC – Volatile Organic Compounds
Ω – Ohms

Table of Tables

Table of Figures

1.0 QA Project Plan Identification and Approval

Title: *Southeastern Broiler Gaseous and Particulate Matter Emission Monitoring*
Funding Agency: *Tyson Foods, Inc.*

The attached **Category 1** QAPP for the above titled study is hereby recommended for approval and commits Iowa State University and the University of Kentucky to follow the elements described within. Funding for this project is provided by a grant from Tyson Foods, Inc.

Robert T. Burns, Project Leader, Iowa State University Date

Hongwei Xin, Project Leader, Iowa State University Date

Richard S. Gates, Project Leader, University of Kentucky Date

Steve Hoff, Project Leader, Iowa State University Date

EPA APPROVALS

Sharon Nizich, EPA Project Manager Date

Joe Elkins, EPA QA Officer Date

2.0 Table of Contents

3.0 QAPP Distribution List

Individuals listed here will receive original and updated copies of the QAPP.

Robert Burns	Iowa State University
Hongwei Xin	Iowa State University
Hong Li	Iowa State University
Lara Moody	Iowa State University
Steve Hoff	Iowa State University
Richard Gates	University of Kentucky
Doug Overhults	University of Kentucky
John Earnest, Jr.	University of Kentucky
Steve Patrick	Tyson Foods
Kevin Igli	Tyson Foods
Steve Key	Tyson Foods
Sharon Nizich	EPA
Joe Elkins	EPA

The final approved QAPP will be available to all members of the project team. A bound copy of the document will be placed at both sites inside the Mobile Air Emissions Monitoring Unit (MAEMU). An electronic copy will be placed on the Internet for download by team members. The project team will be alerted of QAPP updates via an email indicating when and where they can obtain a revised version.

4.0 Project/Task Organization

4.1 Roles and Responsibilities

Principle Data Users
The United States EPA will be the principle users of data resulting from this project. As such, the project is following a Category 1 QAPP.

EPA Participants
Sharon Nizich is the EPA Project Manager for this study. Her role is to ensure that EPA's goals for the project are met and that proper steps and procedures are followed to provide high quality project data.

Joe Elkins is the EPA Quality Assurance (QA) Officer for this study. His role is to ensure that the project meets the QA requirements set forth in this document.

Tyson Participants (funding organization)
Steve Patrick is a contact between the project personnel and Tyson Foods. He will coordinate preparation of the sites, for example, the introduction/installation of power supply and high-speed Internet service for the MAEMU.

Kevin Igli is a contact between the project personnel and Tyson Foods. He is the primary coordinator between EPA and Tyson Foods. He is also the major decision maker on project funding.

Steve Key is the broiler service technician for the sites and assists the project team with production related issues, for example, providing the standard operation procedures of the broiler houses, and data concerning flock production conditions and performance.

Iowa State University and the University of Kentucky (research organizations)
Project Leaders Robert Burns, Hongwei Xin, Richard Gates and Steve Hoff are responsible for directing various actions occurring within the project, reviewing and approving the QAPP, and reviewing, analyzing and reporting the collected data.

Robert Burns is the lead Principle Investigator (PI) for the project. He is responsible for technical decisions made for the project, directing the project team, providing technical expertise, and submitting progress and final reports. He is also responsible for interacting with any media inquiries.

Hongwei Xin is responsible for providing technical expertise, assisting with the selection of monitoring equipment, and assisting with data review, analysis and reporting.

Richard Gates is responsible for coordinating scheduled daily and weekly operational and maintenance activities at the sites in Kentucky, maintaining a response team for flagged data excursions, overseeing regular fan calibration assessment using the Fans Assessment Numeration System (FANS) testing, and providing general logistical and technical expertise.

Steve Hoff is responsible for providing overall technical expertise and technical guidance on particulate sampling, and for assisting with data review, analysis, and reporting.

Hong Li is a research associate working on the project and is responsible for instrument testing and monitoring, data collection and analysis, and data reporting. Li remotely monitors the data collection system inside the MAEMU and performs the data reviews. He works closely with individuals performing the on-site monitoring in Kentucky. He is responsible for documenting the completion of between flock QAPP requirements.

Lara Moody is an extension program specialist. She is the Iowa State University (ISU) QA Manager. She prepares and maintains the QAPP, performs internal audits, and ensures that the QA procedures outlined in this document are performed accordingly.

Raj Raman is an associate professor in the Department of Agricultural and Biosystems Engineering at Iowa State University. He will serve as the supervisor for Lara Moody for matters related to this project and will review the QA Project Reports that she submits.

Doug Overhults is an associate extension professor stationed within 0.5 hour driving distance from the monitoring sites at the Western Kentucky Experiment Station in Princeton, Kentucky. He is responsible for directing regular on-site visits and for assisting with system installation and maintenance. He assists with QAPP documentation and site requirements during periods when animals are in the house and sampling is occurring.

John Earnest, Jr. is an agricultural engineering technician stationed within 0.5 hour driving distance from the monitoring sites at the Western Kentucky Experiment Station in Princeton, Kentucky. He is responsible for ensuring proper operation, regular calibration and maintenance of the measurement instrumentation. Earnest conducts regular site visits (at least once a week) and also assists in system installation. During the time between flocks, Earnest is responsible for litter sample collection. He assists with QAPP documentation and site requirements during periods when animals are in the house and sampling is occurring.

The project organization chart is shown in Figure 4.1.

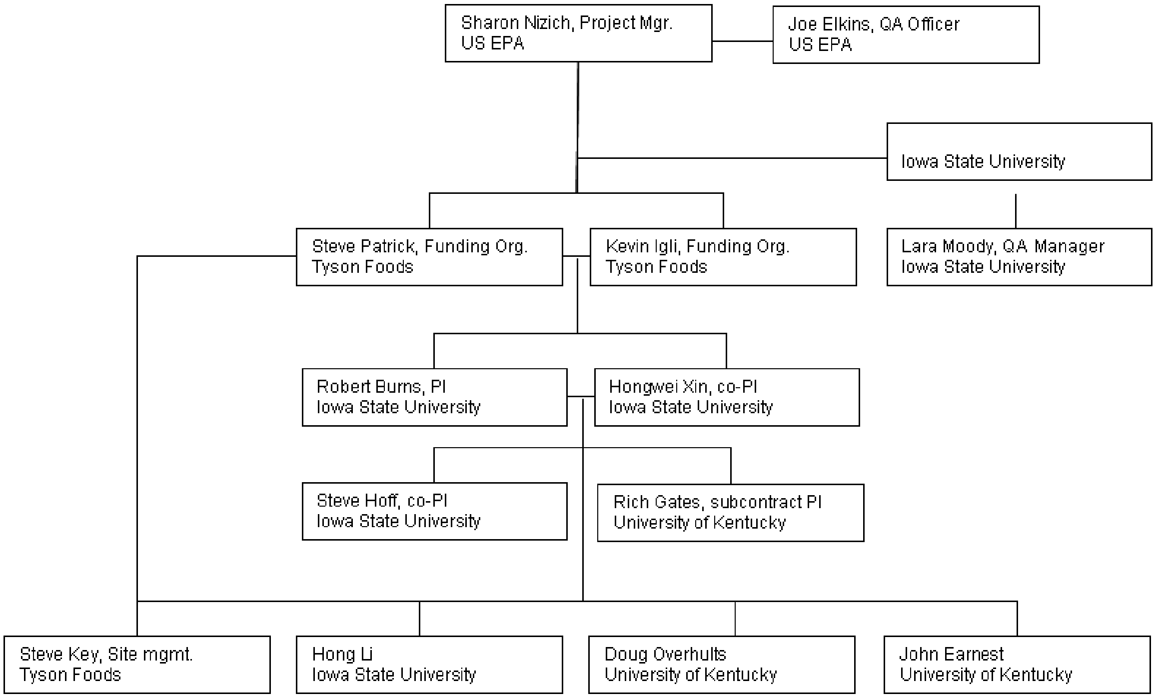


Figure 4.1. Project organization chart.

4.2 Participant Contact Information

Name	**Affiliation**	**Phone**	**E-mail**
Sharon Nizich	EPA	919-541-3078	nizich.sharon@epa.gov
Joe Elkins	EPA	919-541-5653	elkins.joe@epa.gov
Robert Burns	Iowa State University	515-294-4203	rburns@iastate.edu
Hongwei Xin	Iowa State University	515-294-4240	hxin@iastate.edu
Steve Hoff	Iowa State University	515-294-6180	hoffer@iastate.edu
Hong Li	Iowa State University	515-294-8633	lwblue@iastate.edu
Lara Moody	Iowa State University	515-294-7355	lmoody@iastate.edu
Raj Raman	Iowa State University	515-294-0465	rajraman@iastate.edu
Richard Gates	University of Kentucky	859-257-3000 x 127	gates@bae.uky.edu
Doug Overhults	University of Kentucky	270-365-7541 x 237	doverhul@uky.edu
John W. Earnest, Jr.	University of Kentucky	270-365-7541 x 237	jearnest@uky.edu
Steve Patrick	Tyson Foods	479-290-7541	steve.patrick@tyson.com
Kevin Igli	Tyson Foods	479-290-4055	kevin.igli@tyson.com
Steve Key	Tyson Foods	270-521-3038	steve.keys@tyson.com

4.3 Project Investigator and Team Member Qualifications

Resumes for the individuals carrying out the research are included in Appendix V. Below is a summary of the teams qualifications and experience; experience is shown as “barn months”. A "barn month" is calculated as the number of months spent monitoring a particular barn (for example, two broiler houses monitored for three months equals six barn months).

Robert Burns has fourteen years of experience working as an environmental engineer with air quality issues. In addition, he has worked closely with livestock and poultry production systems for the last eleven years. He has a unique combination of knowledge of both air quality issues and animal production systems. Dr. Burns holds a B.S. in Agricultural Engineering, an M.S. in Environmental Engineering and a Ph.D. in Civil Engineering (Environmental Engineering specialization) from the University of Tennessee. He is a licensed Professional Engineer (P.E.) and Certified Crop Advisor (CCA). Robert specialized in Air Pollution Control in both his Masters and Doctoral degrees. During his Masters degree he led the development of stationary and mobile source emissions inventories for volatile organic compounds and nitrous oxides for the State of Tennessee. Burns's Ph.D. focused on the finite difference modeling of photo-chemical formation of tropospheric ozone in the Southeastern United States. During his professional career Burns has published over 75 technical publications dealing with animal waste and air quality management, served as PI or Co-PI on 34 funded grants totaling $3,563,176 and served as a major or co-major professor to 16 engineering masters and doctoral students. In his current position, Burns' research focuses on animal waste management and includes work on measurement and mitigation of air emissions from animal feeding operations, phosphorus recovery, anaerobic digestion and solids separation. Burns's current research team is comprised of fifteen members and is currently working on projects involving the measurement or mitigation of air emissions from poultry broiler, layer and turkey production systems. Burns has a total of 114 barn months of agricultural air monitoring experience, all in broiler production.

Hongwei Xin has nearly 25 years of training and experience in animal environmental engineering research. The commencement of his field experience in monitoring the environment and quantifying aerial emissions for animal feeding operations dated back 17 years when he was a post-doc research associate at the University of Arkansas (1990-1993). At the University of Arkansas he conducted an extensive, automated 3.5-year monitoring of the housing environment, energy use, and production performance of four commercial-scale broiler houses owned by the University of Arkansas and two broiler houses owned by the cooperative producers. Since joining Iowa State University in December 1993, Xin and his associates (graduate students and post-docs) have independently and collaboratively conducted field monitoring on the following animal feeding operations: broilers (USDA-IFAFS project, in collaboration with colleagues at University of Kentucky and Penn State University), swine (farrowing and growing-finishing), pullets and laying hens, and growing turkeys. To date, Xin has totaled approximately 604 barn months of field monitoring for these species, of which 368 barn months were for the measurement of broiler housing air emissions. In addition, Xin has been collaborating with scientists in Brazil and China in monitoring and mitigating emissions of greenhouse gases (CH_4, CO_2, N_2O) and noxious gases (NH_3, H_2S) from animal feeding operations under some conditions that are unique to the respective countries. Since 2004 Xin has been serving as the Chair of the United Egg Producers Environmental Scientific Panel that has the mission to serve as a clearinghouse for the egg industry on the state of air emissions research and as an advisory body to the industry toward seeking practical means to mitigate air emissions from egg operations.

Richard Gates has nearly 15 years of experience monitoring and quantifying gaseous emissions from animal feeding operations. He has over 30 years of experience with broiler, layer, hog (grow-finish) and greenhouse operations, including designing systems for use in the United States, Japan, South Africa and Brazil. He has 216 barn months of experience monitoring broiler operations in Kentucky and Pennsylvania; 4 barn months monitoring layer operations in Iowa, and 12 barn months monitoring slurry from a hog grow-finish operation in Kentucky. He was PI on a recent USDA-IFAFS grant (with ISU and Penn State colleagues) to quantify ammonia emissions from U.S. poultry (layer and broiler) farms.

Steve Hoff has been involved with air quality issues associated with animal agriculture for the past 15 years, with the past 6 years devoted to odor transport; odor modeling; gas, virus and PM emissions; and gas and odor mitigation, all primarily from swine production systems. He has worked continuously on several air quality monitoring projects over the past six years. These in total comprise the following:
PSF Monitoring: 2 lagoon-barn combinations/month x 24 months = 48 barn months
IFAFS Monitoring: 2 barns/month x 20 months = 40 barn months
USDA-NRI A: 1 barn/month x 10 months = 10 barn months
USDA-NRI B: 2 barns/month x 8 months = 16 barn months
USDA-Special Grant: 2 barns/month x 18 months = 36 barn months
NPB: 2 barns/month x 9 months = 18 barn months

Hong Li has 4 years of experience monitoring and quantifying gaseous emissions from animal feeding operations. He has over 8 years of experience in agricultural environmental control. His research area is in environmental controls, air quality, and manure management systems. He has 30 barn months of experience monitoring layer operations in Iowa (USDA-IFAFS project).

Lara Moody has 7 years of experience working as an agricultural engineer in the area of animal waste management. She has 5 years of experience directing waste management laboratory operations and acting as a project coordinator on multiple projects. Research she has participated in focuses on animal waste management and includes work on waste treatment, nutrient management, phosphorus recovery, anaerobic digestion and solids separation at animal feeding operations.

Doug Overhults has over 25 years experience providing statewide Extension education programs related to the design and operation of facilities for swine and broiler production. His primary area of expertise is planning, analysis, and engineering design of efficient animal production facilities, environmental controls, structures, and manure management systems. He has worked extensively with mechanical ventilation systems, cooling systems, and control systems in both swine and broiler facilities. Dr. Overhults has 84 barn months experience in monitoring energy use and the performance of an integrated environmental controller in a broiler facility in Kentucky.

John Earnest has nearly 15 years of experience in utilization, application and design/fabrication of specialized agricultural equipment including energy monitoring equipment, power distribution, chemical application equipment, Global Positioning Systems, and specialized electrical and motor control systems. He had primary responsibility for on-site operation and maintenance of instrumentation and data collection systems for an extensive interior environment and energy use study at a broiler production site over a period of 72 barn months. He also has extensive experience with information technology including data collection and control software, AutoCAD, and ArcView and other Geographic Information System-related software.

5.0 Problem Definition/Background

A comprehensive review by the National Academy of Science (NAS) in 2002 regarding air emissions data pertaining to the U.S. animal feeding operations (AFOs) concluded that such data is lacking under U.S. animal production conditions. The review called for collection of baseline emission data and development of process-based models to predict such air emissions. In response to NAS recommendations, the United States Department of Agriculture (USDA) has made quantification of air emissions from AFOs one of the top priorities in its Initiative for Future Agriculture and Food System (IFAFS) Program and subsequently the National Research Initiative (NRI) Program. As a result, since 2002 great strides have been made toward collection of baseline air emissions from U.S. AFO facilities. Noticeable among the funded studies was the six-state (IA, IN, IL, MN, NC, TX) project on air emissions from cattle, swine and poultry facilities, and the three-state (IA, KY and PA) project on ammonia (NH_3) emissions from layers (in Iowa and Pennsylvania; Liang et al., 2005) and broilers (in Kentucky and Pennsylvania; Wheeler et al., 2006). Due to the unfortunate passing of the key project personnel for the broiler part of the six-state project at North Carolina, data on air emissions from broiler houses experienced difficulties. Hence, there is a lack of air emissions (except for ammonia) data for broiler housing systems. During this time period, more research findings on ammonia emissions from European broiler houses have been reported (Nicholson et al., 2004). However, information regarding emission rates of particulate matter (PM), hydrogen sulfide (H_2S) and hydrocarbons from broiler houses remains meager.

This study will be an integral part of the national air emissions monitoring study (NAEMS) resulting from the ACA that has been reached between the U.S. EPA and certain sectors of the animal industry. It will represent the southeastern broilers air emissions study. The aerial pollutants quantified in this monitoring study include ammonia (NH_3), carbon dioxide (CO_2), total suspended particulates (TSP), particulate matter 10 microns or less in aerodynamic diameter (PM_{10}), $PM_{2.5}$, hydrogen sulfide (H_2S) and non-methane hydrocarbons (NMHC).

The emissions data from this monitoring study is expected to be used primarily by, but not limited to, a) the U.S. EPA for development of emission estimation methodologies or emission factors for southeastern broiler operations; b) governmental agencies for improvement of national air emission inventories, c) the scientific community for development and/or verification of process-based emission models; d) the broiler industry as they continue to strive for lower air emissions through practical mitigation strategies.

There were two possible approaches considered for quantifying emissions from broiler houses. One approach was to monitor one broiler site for two years with a single monitoring system, as outlined in the ACA study. The other approach considered was to monitor two broiler sites with two sets of the monitoring system. The former approach requires less capital investment for the monitoring equipment and setup (since only one set of the monitoring system would be involved). The latter provides a wider spectrum and thus, more representativeness of the data in terms of farm-to-farm variations in flock management, daily operation styles, and bird performance. Statistically, it provides a farm replication. This latter approach also allows collection of twice the emission data of the first approach considered. Hence, we elected to use the latter approach (two barns on two separate sites) in this study.

6.0 Project/Task Description

6.1 Project Objectives

The objective of this study is to determine and report emissions of NH_3, CO_2, TSP, PM_{10}, $PM_{2.5}$, H_2S and NMHC based on semi-continuous pollutant concentrations (measured on 120-second intervals) and fan flow data (measured on 1-second intervals) over a one year period from two broiler houses representative of commercial broiler production in the southeastern United States. It is anticipated that this data will be used to represent southeastern broilers in conjunction with the National Air Emissions Studies.

6.2 Project Description

Two broiler houses associated with Tyson Foods broiler operations in western Kentucky are being monitored in this extensive field monitoring study. The location of the monitored facilities in Kentucky is shown in Figure 6.1, and the location of the specific houses at each site is shown in aerial photos in Figure 6.2. The monitored broiler production houses use tunnel ventilation and box air inlets along the sidewalls (see Figure 6.3), which is representative of the typical production practices in terms of housing style (e.g., tunnel ventilated) and environmental control strategy (e.g., pancake brooder along with space heaters), bird management (e.g., half-house brooding), and typical litter management and handling schemes (e.g., de-caking houses between flocks).

Each broiler house has its own Mobile Air Emissions Monitoring Unit (MAEMU) that houses air pollutant and fan flow monitoring systems and provides an environment-controlled instrument area as shown in Figure 6.4. Air samples from the broiler house sampling points (representing the exhaust air streams) to the instrument trailer/analyzers are protected against in-line moisture condensation with insulation and temperature-controlled resistive heating cable. Fan operational status and building static pressure are both continuously (on 1-second intervals) monitored. This data is used in conjunction with individual fan operation curves to calculate the flow rate exhausted by each fan during operation. A real-time data acquisition system (DAQ) program developed using LabView 7 software (National Instruments, Corporation, Austin, TX) is used to acquire data, automate sampling location control, display real-time data, and deliver data and system operation status as shown in Figures 6.5 and 6.6.

Each MAEMU houses a gas sampling system, gas analyzers, environmental instrumentation, a computer, data acquisition system, and other equipment needed for the study. Each building will be sampled continuously for 12 months. Gaseous and particulate matter sampling occurs when the house ventilation system is in operation. Gaseous samples are continuously collected and analyzed every 30 seconds, with every fourth concentration value used to calculate emissions. Using this approach gaseous emissions are sampled continuously on a 120-second interval. All three types of particulate matter (TSP, PM_{10}, $PM_{2.5}$) concentration are being sampled continuously with concentrations recorded on a 1-second interval. The 12-month duration assures this project will meet the objectives of characterizing long-term emissions and to respond accurately to the need for annual emission factors from animal facilities by regulatory agencies and others. Long-term measurements allow the recording of variations in emissions due to seasonal effects, animal growth cycles, and diurnal variations.

6.3 Project Personnel Requirements

The personnel required to sucessfully collect the emissions data at the level of quality that meets the Category 1 QAPP criteria include various professionals/individuals with specific skills. Namely, the project personnel have a strong working knowledge of southeastern broiler production systems, knowledge and experience to design, manufacture, and install the emissions sampling and data collection systems, training in the operation and maintenance of the emissions data collection systems, and knowledge and experience in data analysis and quality assurance. Our project team includes eleven senior project personnel including project investigators, post-doctoral research associates, masters level research associates, a QAQC coordinator and a number of undergraduate students who provide hourly assistance during installation of the air sampling and data collection systems in/for the broiler houses. Section 4.0 of this document provides a detailed explanation of the roles and responsibilities of all the regular project members. Table 6.1 provides a brief listing of the primary personnel requirements associated with each of the major pieces of monitoring equipment used in the project. More detailed descriptions of personnel resonsibilities are provided in Section 4.0.

6.4 Project Equipment Requirements

The primary pieces of equipment utilized in the monitoring study are listed in Table 6.1. In order to collect air emissions data on a continuous basis, all selected monitoring equipment feature automatic operation. This allows for continuous collection of air samples and continuous analysis of sample concentrations. Monitoring of fan operational status and building static pressure is also automatic to facilitate continuous calculation of individual fan airflow. As indicated in Table 6.1, all emissions monitoring data is transferred as a digital signal with the exception of the on/off status of each fan, which is indicated as an analog signal. Detailed descriptions of each piece of equipment selected for this study can be found in Section 12.0 – Sampling Methods Requirements.

Table 6.1. Project measurement equipment and personnel requirements.

Project Measurements*	**Method**	**Data Type**	**Equipment Requirement****	**Personnel Requirement**
NH_3	Automated	Digital	INNOVA 1412	Unit Calibration & Maintenance, Data Transfer, & Data Review
CO_2	Automated	Digital	INNOVA 1412	Unit Calibration & Maintenance, Data Transfer, & Data Review
TSP	Automated	Digital	TEOM 1400	Unit Calibration & Maintenance, Mid-Flock Unit Move, Data Transfer, & Data Review
PM_{10}	Automated	Digital	TEOM 1400	Unit Calibration & Maintenance, Mid-Flock Unit Move, Data Transfer, & Data Review
$PM_{2.5}$	Automated	Digital	TEOM 1400	Unit Calibration & Maintenance, Mid-Flock Unit Move, Data Transfer, & Data Review
H_2S	Automated	Digital	API 101 E	Unit Calibration & Maintenance, Data Transfer, & Data Review
NMHC	Automated	Digital	VIG 200	Unit Calibration & Maintenance, Data Transfer, & Data Review
Barometric Pressure	Automated	Digital	WE 100	Unit Calibration, Data Transfer, & Data Review
Temperature	Automated	Digital	Type T Thermocouple	Unit Calibration, Data Transfer, & Data Review
Static Pressure	Automated	Digital	Setra 264	Unit Calibration, Data Transfer, & Data Review
Ventilation Fan Operation	Automated	Analog Signal	Current Switch	Data Transfer, & Data Review
Relative Humidity	Automated	Digital	HMW 61U	Unit Calibration, Data Transfer, & Data Review
Litter N Content	Manual	Numeric	Rapid Still II and Digester	Sample Collection & Laboratory Analysis

* For detailed information about these measurements, see Section 12.

**For specific information about the required equipment, see Appendix U.

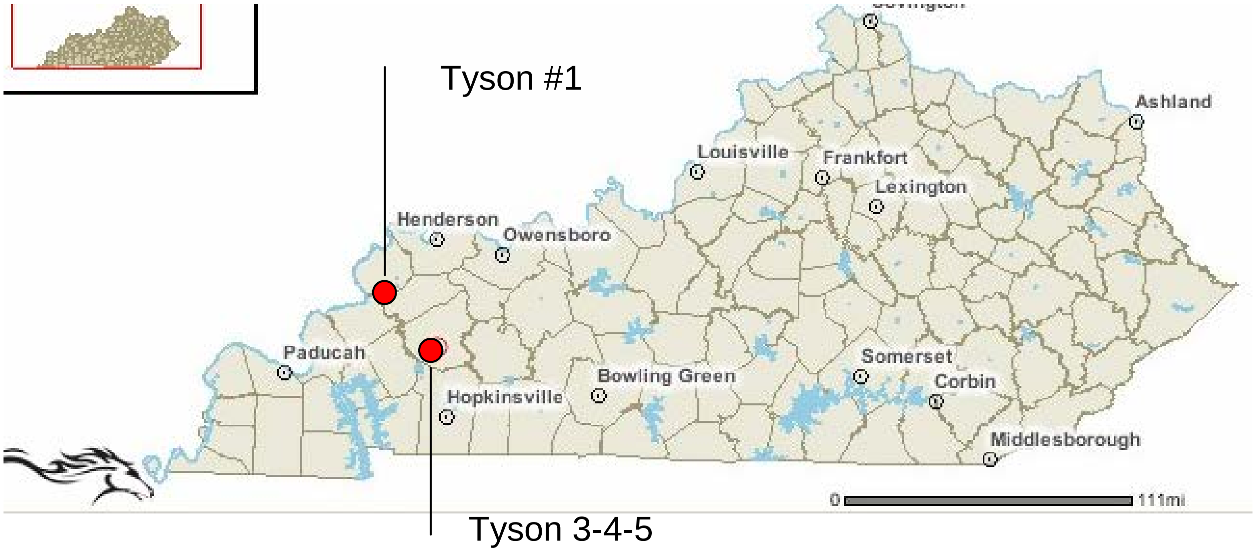


Figure 6.1. Locations of measurement sites in Kentucky.

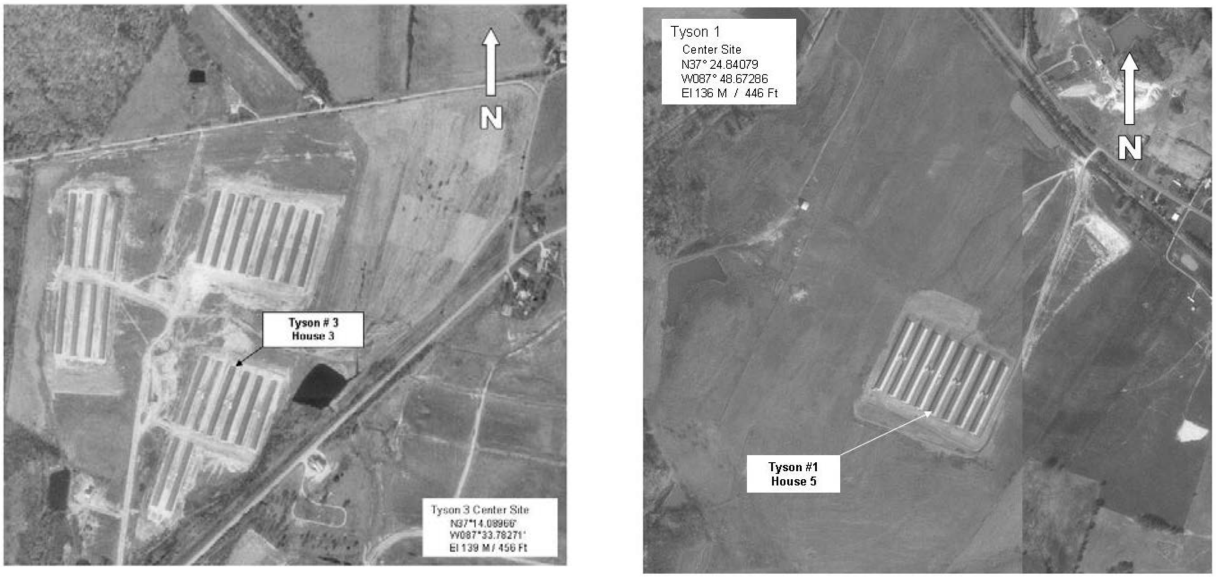
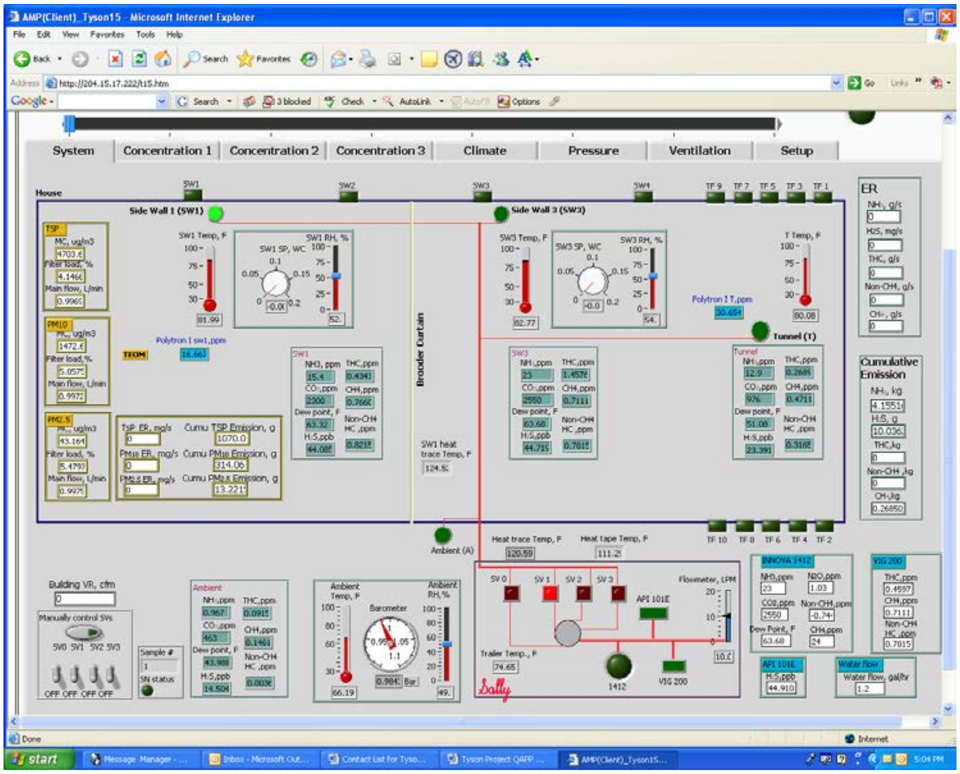


Figure 6.2. Aerial pictures indicating the locations of each monitored broiler house.

Figure 6.3. Tunnel fans and box air inlets representative of typical southeastern broiler facilities.

Figure 6.4. Environmentally controlled Mobile Air Emissions Monitoring Units (MAEMU).



TSP
MC, ug/m3: 4703.6
Filter load, %: 4.146
Main flow, L/min: 0.9965

PM10
MC, ug/m3: 1472.6
Filter load, %: 5.0575
Main flow, L/min: 0.9972

PM2.5
MC, ug/m3: 43.164
Filter load, %: 5.4790
Main flow, L/min: 0.9975

TSP ER, mg/s: 0
Cumu TSP Emission, g: 1070.0
PM10 ER, mg/s: 0
Cumu PM10 Emission, g: 314.06
PM2.5 ER, mg/s: 0
Cumu PM2.5 Emission, g: 13.221

SW1 Temp, F: 81.99
SW1 SP, WC: -0.0
SW1 RH, %: 52.
Polytron I sw1,ppm: 16.66

SW1
NH3, ppm: 15.4
THC,ppm: 0.434
CO2,ppm: 2300
CH4,ppm: 0.766
Dew point, F: 63.32
Non-CH4 HC ,ppm: 0.821
H2S,ppb: 44.08

SW1 heat trace Temp, F: 124.5

SW3 Temp, F: 82.77
SW3 SP, WC: -0.0
SW3 RH, %: 54.

SW3
NH3,ppm: 23
THC,ppm: 1.457
CO2,ppm: 2550
CH4,ppm: 0.7111
Dew point, F: 63.68
Non-CH4 HC ,ppm: 0.7815
H2S,ppb: 44.719

Polytron I T,ppm: 30.654
T Temp, F: 80.08

Tunnel
NH3,ppm: 12.9
THC,ppm: 0.268
CO2,ppm: 976
CH4,ppm: 0.4711
Dew point, F: 51.08
Non-CH4 HC ,ppm: 0.316
H2S,ppb: 23.391

ER
NH3, g/s: 0
H2S, mg/s: 0
THC, g/s: 0
Non-CH4, g/s: 0
CH4, g/s: 0

Cumulative Emission
NH3, kg: 4.1551
H2S, g: 10.036
THC,kg: 0
Non-CH4 ,kg: 0
CH4,kg: 0.26850

Heat trace Temp, F: 120.59
Heat tape Temp, F: 111.2

Building VR, cfm: 0
Manually control SVs
SV0 SV1 SV2 SV3
OFF OFF OFF OFF
Sample #: 1
SN status

Ambient
NH3,ppm: 0.967
THC,ppm: 0.091
CO2,ppm: 463
CH4,ppm: 0.1461
Dew point, F: 43.988
Non-CH4 HC ,ppm: 0.003
H2S,ppb: 14.504

Ambient Temp, F: 66.19
Barometer: 0.984 Bar
Ambient RH,%: 49.

SV 0 SV 1 SV 2 SV 3
Flowmeter, LPM: 10.0
Trailer Temp., F: 74.65

INNOVA 1412
NH3,ppm: 23
N2O,ppm: 1.03
CO2,ppm: 2550
Non-CH4,ppm: -0.74
Dew Point, F: 63.68
CH4,ppm: 24

VIG 200
THC,ppm: 0.4597
CH4,ppm: 0.7111
Non-CH4 HC ,ppm: 0.7815

API 101E
H2S,ppb: 44.910

Water flow
Water flow, gal/hr: 1.2

Figure 6.5. Screen display of the broiler emissions monitoring program developed in LabView 7.

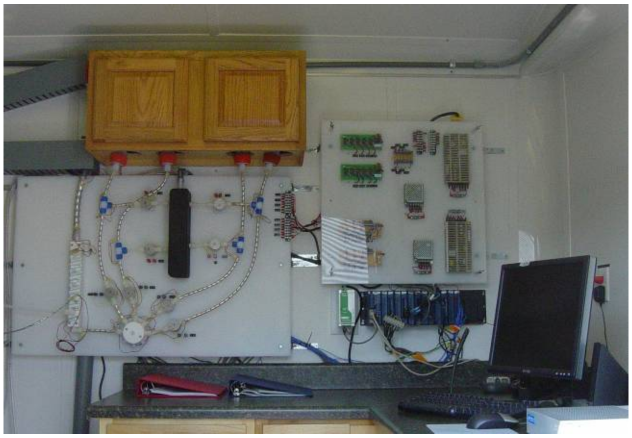


Figure 6.6. View of hardware required to run pollutant sampling system.

6.5 Project Schedule and Milestones (March 2005 to October 2007)

Table 6.2 provides the schedule for this project. Because this project is tied to a broiler NH_3 emissions study that began in the 2^{nd} quarter of 2005, the project schedule outlined in Table 6.2 had to be implemented in order to ensure that the planned monitoring could be completed with the available funding. The original NH_3 monitoring study that began in 2nd quarter of 2005 was expanded in the 4th quarter of 2005 to include CO_2, TSP, PM_{10}, $PM_{2.5}$, H_2S and NMHC as well as NH_3. Monitors for all pollutants were successfully installed at the sites in January 2006. A series of performance tests were conducted in January and February 2006 to confirm that the monitoring systems were working as designed and to determine representative locations for air sampling points and TEOM placement. Study data collection for all pollutants of interest formally began on February 20, 2006 with the placement of a new flock of birds in the houses. Emissions data for all pollutants will be collected through February 2007, or until the flocks of broilers in the houses on that date, have completed the production cycle. In effect, emissions monitoring will be continued until the flocks in the houses on February 20, 2007 have been removed from the houses to ensure that emissions from more than one full year (five to seven flocks) of production is monitored at each of the two broiler houses.

Table 6.2. Project Schedule

	2005	2006				2007		
	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	1st Qtr.	2nd Qtr.	3rd Qtr.
Purchase Monitoring Equipment	X							
Prepare QAPP	X	X						
EPA Review of QAPP		X	X					
QAPP Revisions			X	X				
Prepare Monitoring Trailers	X	X						
On-site Equipment Installation	X	X						
Monitoring System Testing		X						
Collect Data		X	X	X	X	X		
Analyze Data			X	X	X	X	X	X
Mid-Term Progress Report				X			X	
Final Emissions Report								X

Major project milestones are provided in Table 6.3. In addition those milestones that have been completed to date are so noted along with their date of completion.

Table 6.3 Project Milestones

Project Milestone	**Status**	**Completed Date**
Submit QAPP to EPA	Completed	3/01/06
Install all emissions monitoring equipment	Completed	1/06/06
Performance testing of emissions monitoring system	Completed	2/10/06
Begin Collection of Study Data	Completed	3/20/06
Receive QAPP comments from EPA	Completed	4/12/06
Revised QAPP Submitted	Completed	8/03/06
Revised QAPP Approved by EPA		
Mid-Term Progress Report		Due 3rd Quarter 2006
Late-Term Progress Report		Due 2nd Quarter 2007
Final Emissions Report		Due 3rd Quarter 2007

7.0 Quality Objectives and Criteria for Measurement Data

7.1 Data Quality Objectives

Background

The overall objective of this data acquisition project is to generate data of sufficient quality to satisfy the research objectives of the project stated above. Data will undergo quality assurance review, which will assess, among other things, data representativeness, data completeness, comparability, and accuracy (U.S. EPA document QA/G-5).

The intended use of the collected data is to provide an estimation of daily emissions of gases and particulates (emissions of NH_3, TSP, PM_{10}, $PM_{2.5}$, H_2S and NMHC) from commercial broiler production houses in the southeastern U.S. The collected data will provide insight into temporal variability (as birds age, seasonal effects, and other temporal effects) and spatial variability (two houses on two separate sites are monitored). This variability has been previously estimated in earlier studies in Kentucky and Pennsylvania broiler houses (Wheeler et al., 2006) and bird age was found to be the predominant factor in variation over time. Variation between houses (eight houses on two sites in Kentucky, and four houses on two sites in Pennsylvania) was found to be relatively small when other factors were held constant (e.g., bird age).

Data Quality

Data representativeness is ensured by the overall sampling design, which includes high frequency sampling over a 12-month measurement period at two similar broiler operations at different locations. This is described in detail in Section 11 – Sampling Process Design. Underlying theoretical considerations that impact the representativeness of data by direct or component determination are outlined in this section.

“Data completeness is a measure of the amount of valid data obtained from a measurement system, expressed as a percentage of the number of valid measurements that should have been collected” (USEPA. 1998. *EPA Guidance for Quality Assurance Project Plans*. EPA QA/G-5). Data completeness is achieved by ensuring that valid building emission data obtained from the measurement system is no less than 75% of the scheduled sampling. A greater percentage does not seem reasonable with potential lightning strikes, equipment breakdowns, university and broiler integrator schedules, and farm related problems. Using total daily emissions as the primary Data Quality Objectives (DQOs), we thus require a minimum of eighteen hours of sampling for daily emission to be used. Data completeness is ensured by 1) using properly maintained and reliable instrumentation, 2) maintaining a ready supply of spare parts, 3) installing electrical backups such as uninterruptible power supplies, 4) regular calibration checks, 5) frequent remote access to the DAQ computer, and 6) local broiler production management collaboration and cooperation.

Data comparability is maintained by 1) employing equivalent analytical methods (where appropriate and available methods exist), and a sampling protocol used in recent emission studies in confined livestock and poultry facilities, 2) comparison of measurements with previous mass balance and emissions rate measurements reported for poultry buildings, and 3) through the use of common equipment and protocols at both sites.

7.2 Measurement Performance Criteria

According to EPA QA/G-5, p 27:

> "Measurement performance criteria for new data collection efforts are stated in terms of the desired (assumed) level of uncertainty in data that will be used to address the study question or support the decision. When possible, it is desirable to state measurement performance criteria in quantitative terms, such as limits on analytical imprecision, bias and method detection limits, and limits on the overall variance of study results (to include spatial and temporal variability)."

Thus, in the remainder of this section we provide background on the DQO to justify and document our selection of acceptable limits on uncertainty in the emissions data, denoted as ER (Emission Rate), and expressed on a mass of constituent emitted from the building in a consecutive 24-hour period normalized to a per-bird basis. For example, ammonia ER is expressed in kg NH_3 bird^{-1} day^{-1}. This unit is selected so that ER from broiler houses with different numbers of birds can be compared and provide information regarding spatial variability in the data.

Accuracy is a two-part quality indicator and includes both bias (systematic error) and precision (random error). **Accuracy** is a measure of the closeness of an individual measurement or the average of a number of measurements to the true value (EPA QA/G5). Accuracy of the measured value will be expressed in terms of the percentage decrease or increase from the known value and in terms of the absolute difference between the measured and known value. **Precision** is a measure of agreement among replicate measurements of the same property, under prescribed similar conditions (same source). Precision is defined as the standard deviation of replicate measurements of the concentration of a known pollutant expressed as a percentage difference from the known value. Concentration measurement accuracy (bias and precision) is maintained by regular calibration of the instruments that involves challenging the measurement system to perform replicate analyses of samples with known concentrations. Ventilation rate measurement accuracy is maintained by regular testing of fans at the start and end of the study, and a select subset of fans after each flock is completed. In all cases, a clear schedule of calibration is documented and adhered to.

Static Calibration is a formalized methodology for removing measurement bias and quantifying measurement precision (Doeblin, 1990). A static calibration in which measurements are regressed against "true" or standard values with equivalent units, allows for direct quantification of precision from the standard error of the regression, and a hypothesis test regarding whether bias exists (e.g., non-unity slope). If bias exists, it is removed by inversion of the calibration regression, and the standard error of regression is adjusted by dividing by the (non-unity) slope of regression. This standard error (s) can then be utilized to make meaningful statistical bounds on the uncertainty of a measurement post-calibration, for example, by the use of 2-s limits and assuming normally distributed random errors, the point estimate from the instrument is within 2-s limits or ±2.5% of the "true" value. This also assumes that the value(s) for the standard used in the calibration is of much greater absolute accuracy, somewhat problematic for example with calibration gases that are at best 2-3% of stated value.

For example, the FANS system used to calibrate individual ventilation fans has been demonstrated to exhibit an imprecision of 139 $m^3 h^{-1}$ (83 cfm) (Gates et al., 2004) as represented by the (adjusted) standard error of regression for 10 FANS units calibrated at the University of Illinois BioEnvironmental and Structural Systems (BESS) Laboratory. Three sigma (3s) limits (which comprise 99.7% of expected error) on the precision of fan ventilation rate are thus on the order of 417 $m^3 h^{-1}$ (237 cfm), remarkably accurate for fans that nominally run at 17,000 to 34,000 $m^3 h^{-1}$. To state the FANS accuracy in terms of precision as is defined in EPA QA/G5, requires knowledge of the actual flow rate, since accuracy is expressed on a percentage basis. For example, this 417 $m^3 h^{-1}$ accuracy translates to a 2.4% error for a single sidewall fan at a nominal 17,000 $m^3 h^{-1}$ flow; but 1.2% error for a 48-inch tunnel fan with a nominal 34,000 $m^3 h^{-1}$. As a consequence, while it may be considered convenient to express the DQOs in terms of percent imprecision, it is important to recognize that small absolute errors in measurement may be expressed as large relative errors on a percentage basis. For example, the same 3s limit applied to a 1,700 $m^3 h^{-1}$ flow rate yields an "imprecision" of 24% using the G5 definition (see Gates et al., 2004, for additional analysis and discussion). A similar statement may be made for each of the concentration measurements in this study.

Because of the continuous nature of our concentration measurements, static calibration is critical, and especially important to remove bias and to reduce the measurement uncertainty to that of the instruments' effective random errors. This can be understood by considering the cumulative effect that a biased concentration reading would have on estimation of daily ER. For sake of brevity, assume constant concentration and constant ventilation rate over a 24-h period, and assume a 10% positive bias in the concentration reading. We would then see a 10% under-prediction of ER for the 24-h period. If instead the measurement error in concentration was 10% of reading, but it was completely random and centered about zero, then we would expect an error in ER of ±5% or less.

Dynamic response of instruments is important for proper sampling frequency for locations within a site. In this study, a single instrument is used to sample gas concentration data from two to four locations on a site (one outside measurement for background and up to three locations within each broiler house). Each instrument may exhibit different transient response characteristics when multiplexed across multiple locations, and to measure different gases. A sufficient number of samples at one location must be taken to ensure that the instrument's settling time is exceeded. **Settling time** is defined as the time required by an instrument to achieve and remain within a specified tolerance band around the assumed constant final value. For example, a 5% settling time means the time required for an instrument to achieve and remain within 95 to 105% of the final value. Our research suggests that the critical gas measurement (with maximum settling time) in this study is ammonia. Figure 7.1 illustrates that a 4% settling time equates to nearly 2 min (Moody et al., 2006). Thus, to ensure that an accurate sample is acquired, repeated sampling at a location should occur for 120 s before multiplexing to another location.

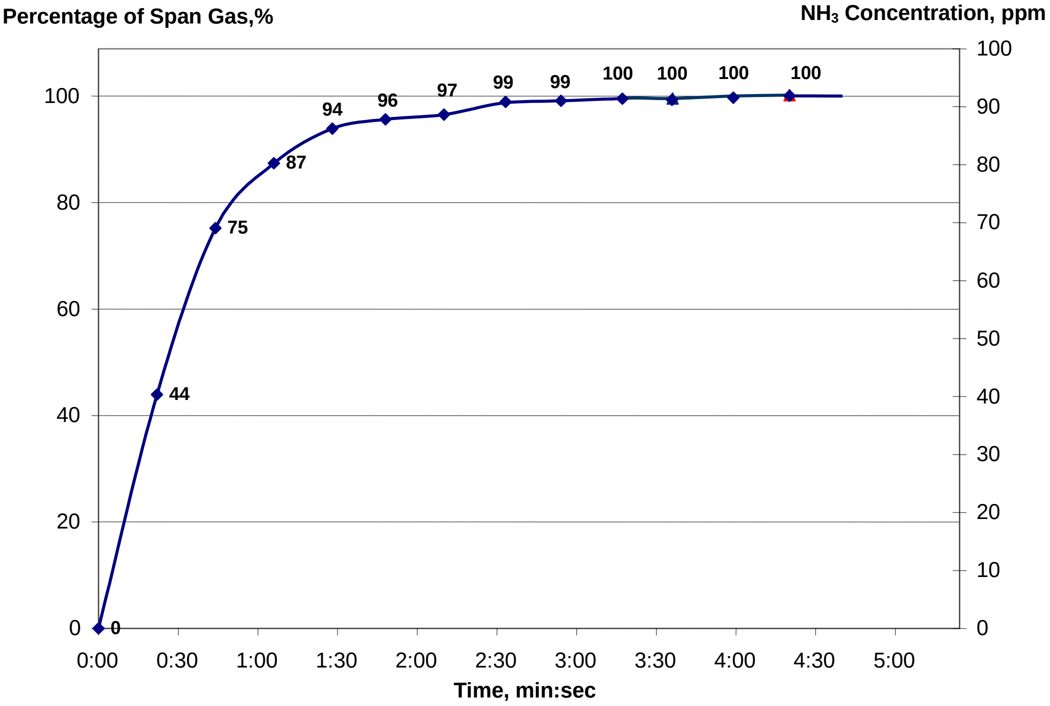


Figure 7.1. INNOVA analyzer dynamic response to step change in ammonia. The settling time is approximately 120 s to better than 96% of true span (100% = 100 ppm).

The dynamic response characteristic exhibited in Figure 7.1 is typical of a first order measurement system (Doeblin, 1990). For first order instruments, a 5% settling time corresponds to 2 time-constants (2τ), which indicates that the time constant for the Innova 1412 is about 65 s when measuring ammonia.

7.3 Component Error Analysis

Component Error Analysis is is a necessary tool to quantify uncertainty when a quantity such as daily emission rate is calculated from multiple measurements, each with its own degree of accuracy. A component error analysis (Doeblin, 1990) is a useful means for providing statistical meaning to a statement on the magnitude of error in the calculation of daily emission rate. This analysis has been performed for an earlier project that measured broiler house ammonia emissions and documented in a Ph.D. dissertation (Casey, 2005). Key assumptions included 2% accuracy on ammonia calibration gas, accuracy on ventilation rate as described above using

FANS and protocol, and either 1% or 3 ppm accuracy on ammonia measurement (to compare effect of electrochemical sensors versus photo-acoustic analyzers). For purposes of this DQO, only the 1% accuracy on gas concentration is of interest since that corresponds to the previously selected gas concentration measurement instrumentation.

A manuscript (in preparation) on this topic, for broiler house ammonia emissions, was used in the following description (Casey et al., 2006). In general, since ER is computed as the sum of multiple ER values obtained from measurements over the course of the day, with each ER computed from the product of ventilation rate and concentration difference, the two key measurements affecting the uncertainty of daily ER are the uncertainties associated with these key measurements. As has been previously discussed, the uncertainty on individual fan ventilation rate is under 3% when using 3-s limits. However, it is likely that uncontrolled factors between calibrations can increase this uncertainty to 10%, and it is likely that the error in ventilation rate will tend to be biased towards over-estimation, i.e., as fans become dirty their performance degrades yet the calibration curves are for clean fans, with resultant over-estimation in emission rate. Concentration data for the various gas and dust constituents in this study are 1% or better (Table 7.1), with a 5% limit for required recalibration.

Table 7.1. Sampling parameter and equipment quality control objectives.

Parameter	Sample Matrix	Analyzer Matrix	Detection Limit	Quantitation Limit	Estimated Precision	QC Check	QC limit	Action
NH_3	Air	INNOVA 1412	0.2 ppm	2000 ppm	±1%	weekly	5%	Calibrate
CO_2	Air	INNOVA 1412	3.4 ppm	34,000 ppm	±1%	weekly	5%	Calibrate
CH_4	Air	INNOVA 1412	0.4 ppm	4000 ppm	±1%	weekly	5%	Calibrate
Non-CH_4	Air	INNOVA 1412	0.02 ppm	200 ppm	±1%	weekly	5%	Calibrate
H_2S	Air	API 101E	0.4 ppb	20000 ppb	±0.5%	weekly	5%	Calibrate
CH_4	Air	VIG 200	0.1 ppm	100	±1%	weekly	5%	Calibrate
Non-CH_4	Air	VIG 200	0.01 ppm	10	±1%	weekly	5%	Calibrate
Temperature	Air	Type T Thermocouple	-40ºC	50ºC	0.5ºC	Every flock	0.5 ^oC	Calibrate
RH	Air	HMW 61U	2%	95%	2%	Six months	5%	Calibrate
S. Pressure	Air	Setra 264	2 Pa	125 Pa	±1%	Six months	5%	Calibrate
Barometric pressure	Air	WE100	0.8 bar	1.1 bar	±1%	Six months	5%	Calibrate
TSP	Air	TEOM 1400	0.01 ug/m^3		±5 ug/m^3	Yearly	5%	Calibrate
PM10	Air	TEOM 1400	0.01 ug/m^3		±5 ug/m^3	Yearly	5%	Calibrate
PM2.5	Air	TEOM 1400	0.01 ug/m^3		±5 ug/m^3	Yearly	5%	Calibrate
Fan flow rate	Air				200 m^3h^{-1}	Every flock	10%	Calibrate
Fan run time	Air	Current Switch	1.0 Aac	100 Aac		Every flock		Replace on failure

A component error analysis (Casey, 2005; Casey et al., 2006) suggests that if 3-s limits on ventilation rate and 1% accuracy on ammonia can be maintained (this is the standard DQO for this project) then the uncertainty in ER is 2-3%. Uncertainty decreases as the number of fans being used increases, and is largely unaffected by ammonia concentration in the building over the range of 10 to 100 ppm. Increasing both ventilation uncertainty (to 10% of reading) and ammonia concentration uncertainty (to 3 ppm) causes substantially greater uncertainty in ER, with a range from 4.9% (8 fans, 100 ppm) to 19% (1 fan, 10 ppm).

While this analysis was carried out specifically for ammonia, it applies equally to all gaseous contaminants being measured in this study, which have stated accuracies of 1% or better. For particulates the analysis also applies, but since the particulate accuracy is represented in terms of an absolute mass concentration (5 ug/m^3), it is directly applicable to concentrations greater than 500 ug/m^3.

From this component error analysis, it is clear that careful control of ventilation rate uncertainty is critical for controlling ER uncertainty, and has probably contributed to the majority of error in such measurements prior to the implementation of the FANS methodology with regular calibration of individual fans. For this project, uncertainty in ER should be maintained at less than 10% using the instrumentation listed in Table 7.1 and the methodology outlined in the QAPP. Typical uncertainty in ER, based on 2-or 3-s limits, is expected to be under 3%.

7.4 Effect of Background Concentration and Air Density Effects on ER

The component error analysis cited (Casey, 2005; Casey et al., 2006) neglected background ammonia concentration. Other studies have incorporated background concentration but have performed a pseudo-mass balance that neglects effects of differing air densities between outside and inside air. This section outlines the error associated with these two omissions. In general, the impact of these omissions on ER for the methods proposed in this study, are inconsequential. However the ER methodology employed in this study properly accounts for both background concentrations and differences in air density. This analysis is provided to demonstrate the order of errors involved in prior analyses in which they were neglected when quantifying ER errors.

Building emission rate of any substance, ER, is given by:

$$ER_{[g]} = Q_e\left(\frac{[G]_e}{T_e} - \frac{\upsilon_i}{\upsilon_e} \times \frac{[G]_i}{T_i}\right) \times 10^{-6} \times T_{std} \times \frac{P_a}{P_{std}} \times \frac{w_m}{V_m}$$

where:

$ER_{[g]}$ = Gas emission rate for the house, g hr^{-1} house^{-1}

Q_e = Exhaust ventilation rate of the house at field temperature and barometric pressure, m^3 hr^{-1} house^{-1}

$[G]_i$, $[G]_e$ = Gas concentration of incoming and exhaust house ventilation air, respectively, parts per million by volume (ppm$_v$)

w_m = molar weight of the gas, g mole^{-1} (17.031 for NH_3)

V_m = molar volume of gas at standard temperature (0°C) and pressure (101.325 kPa) or STP, 0.022414 m^3 mole^{-1}

T_{std} = standard temperature, 273.15 °K

T_i, T_e = absolute temperature of incoming and exhaust air, respectively, °K

P_{std} = standard barometric pressure, 101.325 kPa

P_a = atmospheric barometric pressure at the monitoring site, kPa

ν_i , ν_e = specific volume of incoming and exhaust air, respectively, m^3 moist air per kg dry air, calculated from air temperature and RH

Specific volume of moist air at (T, P_a) is computed from:

$$\nu = \frac{R_{da}T(1+1.6078W)}{P_a}$$

where:

R_{da} = dry air universal gas constant, 287.055 J kg^{-1} K^{-1}

W = humidity ratio, kg water vapor kg^{-1} dry air

Humidity ratio at a given temperature and relative humidity obtained from:

$$W = \frac{0.62198\,P_w}{P_a - P_w}$$

$$P_w = \phi\, P_{ws}$$

$$\ln(P_{ws}) = C_1/T + C_2 + C_3T + C_4T^2 + C_5T^3 + C_6T^4 + C_7\ln(T)\,; \quad -100 < t < 0\ ^{o}C$$

$$\ln(P_{ws}) = C_8/T + C_9 + C_{10}T + C_{11}T^2 + C_{12}T^3 + C_{13}\ln(T)\,; \quad 0 < t < 200\ ^{o}C$$

where:

ø = relative humidity, decimal

P_w = water vapor partial pressure, Pa

P_{ws} = water vapor saturation pressure, Pa

$C_1..C_{13}$ = given e.g. ASHRAE HOF (2005) page 6.2 equations 5 and 6

The specific volume ratio ν_i/ν_e, is:

$$\frac{\nu_i}{\nu_e} = \frac{T_i(1+1.6078W_i)(1+W_e)}{T_e(1+1.6078W_e)(1+W_i)}$$

Substitution into the equation for ER gives:

$$ER_{[g]} = \frac{Q_e}{T_e}\left\{[G]_e - [G]_i\,\frac{(1+1.6078W_i)(1+W_e)}{(1+1.6078W_e)(1+W_i)}\right\}\times 10^{-6}\times T_{std}\times\frac{P_a}{P_{std}}\times\frac{w_m}{V_m}$$

The effect on $ER_{[g]}$of neglecting background concentration $[G]_I$ is quantified in the following table for a broad range in expected indoor and outdoor temperature and humidity ratios. The following points can be made:

1. Neglecting a positive, non-zero background concentration can over-predict ER
2. The specific volume ratio ν_i/ν_e provides a multiplier of 103% to 115% to the background concentration, resulting in potential further over-prediction
3. The greatest over-prediction will occur during the coldest and driest outside conditions coupled with the warmest and most humid interior conditions, and is about 15% for typical Kentucky winter time brooding conditions.
4. Note that the adjustment in the table below is applied to the background gas concentration, not the ER. Thus, the error in ER from neglecting density effects is less than 15% of the back-ground concentration; the error in ER from neglecting background concentration depends on the magnitude of $[G]_e$ and $[G]_i$.

Table 7.2. Temperature and Humidity adjustment ratio of air emissions.

Comment	Humidity Ratio, (kg H_2O/kg dry air)		Air Temperature (K)		Adjustment
	Inlet **W_i**	Exhaust **W_e**	Inlet **T_i**	Exhaust **T_e**	**ratio***
winter brooding	0.000	0.020	263	306	115.0%
winter growout	0.002	0.012	263	293	110.7%
fall/spring brooding	0.004	0.020	273	306	111.0%
fall/spring dry interior	0.004	0.010	273	306	111.7%
fall/spring growout	0.004	0.010	283	293	103.2%
summer brooding	0.010	0.020	293	306	103.8%
summer growout	0.010	0.012	283	293	103.4%

* multiply background [ppm] by "ratio" to get adjustment for air density differences

7.5 Summary

In summary, the **Measurement Performance Criterion for daily ER** obtained in this project has been selected to be better than 10%. To achieve this performance, individual instrumentation performances must be appreciably better so that the combined errors, as described above, result in daily ER estimates with this level of certainty.

8.0 Special Training/Certification

8.1 Field Activities

All individuals involved in data collection are instructed on use of the monitoring equipment and the use of the remote access software to view the current status of the DAQ system in real-time. A set of standard operating procedures (SOPs) were written for individuals involved in the project and they are included in the Appendices of this document. The following is a list of the included SOPs:

1. Appendix B: SOP of Gas Sampling System
2. Appendix C: SOP of Field Estimation of Ventilation Capacity using FANS
3. Appendix D: SOP of INNOVA 1412 Photoacoustic Multi-gas Monitor
4. Appendix E: SOP of Temperature and Humidity Measurement
5. Appendix F: SOP of Differential Static Pressure Transducers
6. Appendix G: SOP of Compact Fieldpoint Modules
7. Appendix H: SOP of Using Remote Panel of Southeast Broiler Emission Monitoring Program
8. Appendix I: SOP of Data Management at ISU
9. Appendix J: SOP of Reporting and Calculation of Containment Concentration, Ventilation, and Emissions
10. Appendix K: SOP of Model 101EUV Fluorescence H_2S Analyzers, API 101E
11. Appendix L: SOP of VIG Model 200 Hydrocarbon Analyzer
12. Appendix M: SOP of Tapered Element Oscillating Microbalance (TEOMs) for TSP
13. Appendix N: SOP of Tapered Element Oscillating Microbalance (TEOMs) for PM_{10}
14. Appendix O: SOP of Tapered Element Oscillating Microbalance (TEOMs) for $PM_{2.5}$
15. Appendix P: SOP of Barometric Pressure Sensor
16. Appendix Q: SOP for use of Rotem RSC-2 Scale System
17. Appendix R: SOP for Fan Current Switch Application

University of Kentucky personnel (John Earnest and Doug Overhults), making one or more monitoring site visits weekly, were trained in the use, maintenance and calibration of all monitoring instruments (gas sampling system, TEOMs, and the overall use and operation of the MAEMU) by ISU project personnel (Hong Li, Robert Burns and Hongwei Xin).

The live production managers and facility managers at each site are trained by project team members Robert Burns and John Earnest, concerning how the in-house components of the monitoring system function. Production managers and facility managers are provided with contact information for project personnel and a list of responsibilities (Figure 8.1).

Dates of the trainings, a list of participants, and the topics included are recorded and filed by the QA Manager each time a session occurs. Because there is a high turnover rate for production facility managers, training sessions are held and recorded on an as-needed basis.

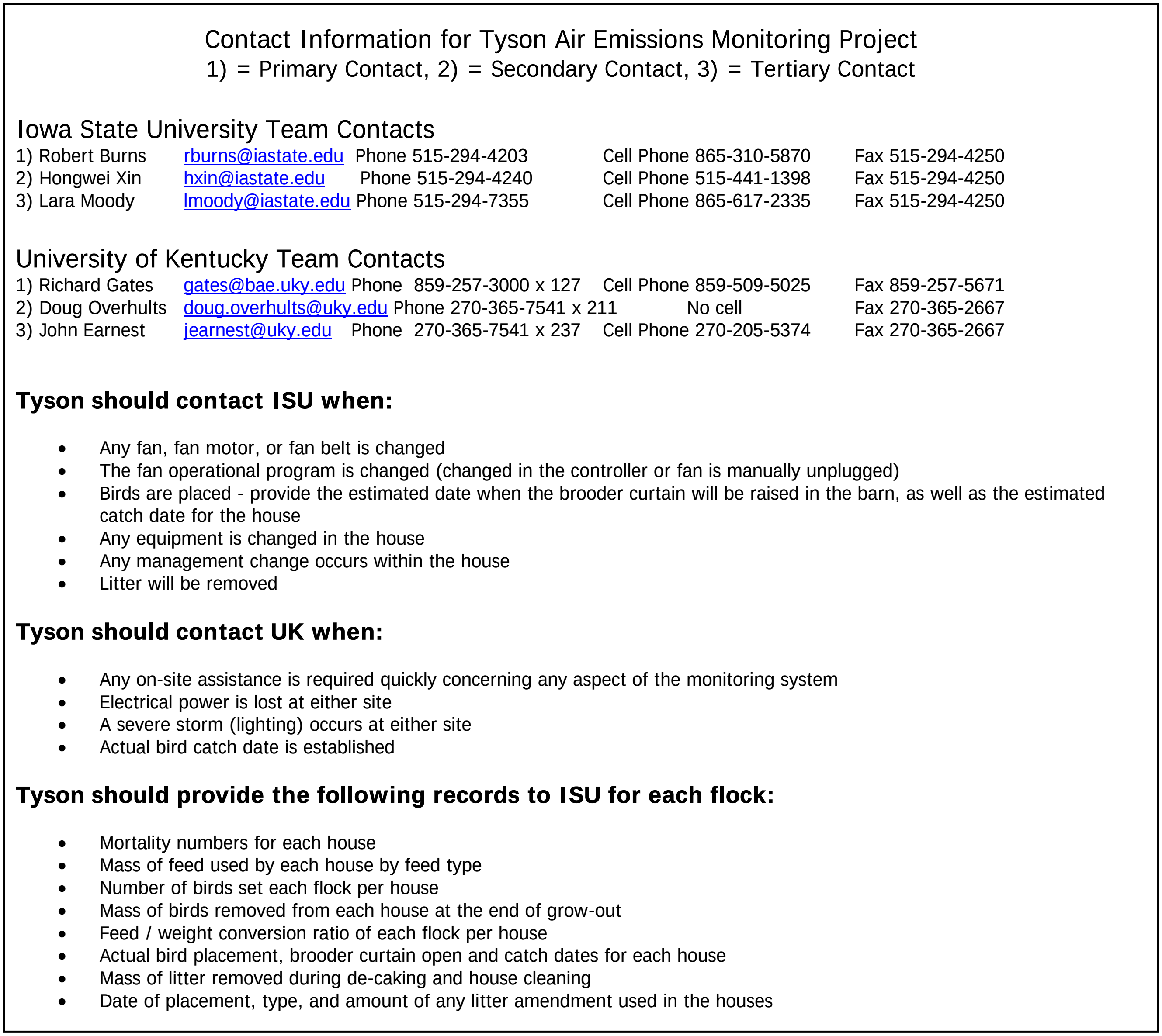
8.2 Laboratory Activities

Laboratory activities for this project include archiving, reviewing, and processing of data and litter sample analysis. SOPs for managing and processing emissions data are included in the following Appendices:

1. Appendix I: SOP of Data Management at ISU
2. Appendix J: SOP of Reporting and Calculation of Containment Concentration, Ventilation, and Emissions

Hong Li is handling all the data management and processing activities. For a description of his qualifications and training that has prepared him to work in this area, please see Section 4.3 of this document.

The litter sample analyses are performed in the ISU Agricultural Waste Management Laboratory. Individuals processing the samples and handling the analyses are trained by the Laboratory Director. Training documentation is archived by the QA Manager.



Contact Information for Tyson Air Emissions Monitoring Project

1) = Primary Contact, 2) = Secondary Contact, 3) = Tertiary Contact

Iowa State University Team Contacts

1) Robert Burns	rburns@iastate.edu	Phone 515-294-4203	Cell Phone 865-310-5870	Fax 515-294-4250
2) Hongwei Xin	hxin@iastate.edu	Phone 515-294-4240	Cell Phone 515-441-1398	Fax 515-294-4250
3) Lara Moody	lmoody@iastate.edu	Phone 515-294-7355	Cell Phone 865-617-2335	Fax 515-294-4250

University of Kentucky Team Contacts

1) Richard Gates	gates@bae.uky.edu	Phone 859-257-3000 x 127	Cell Phone 859-509-5025	Fax 859-257-5671
2) Doug Overhults	doug.overhults@uky.edu	Phone 270-365-7541 x 211	No cell	Fax 270-365-2667
3) John Earnest	jearnest@uky.edu	Phone 270-365-7541 x 237	Cell Phone 270-205-5374	Fax 270-365-2667

Tyson should contact ISU when:

- Any fan, fan motor, or fan belt is changed
- The fan operational program is changed (changed in the controller or fan is manually unplugged)
- Birds are placed - provide the estimated date when the brooder curtain will be raised in the barn, as well as the estimated catch date for the house
- Any equipment is changed in the house
- Any management change occurs within the house
- Litter will be removed

Tyson should contact UK when:

- Any on-site assistance is required quickly concerning any aspect of the monitoring system
- Electrical power is lost at either site
- A severe storm (lighting) occurs at either site
- Actual bird catch date is established

Tyson should provide the following records to ISU for each flock:

- Mortality numbers for each house
- Mass of feed used by each house by feed type
- Number of birds set each flock per house
- Mass of birds removed from each house at the end of grow-out
- Feed / weight conversion ratio of each flock per house
- Actual bird placement, brooder curtain open and catch dates for each house
- Mass of litter removed during de-caking and house cleaning
- Date of placement, type, and amount of any litter amendment used in the houses

Figure 8.1. Information and responsibility sheet provided to project and broiler facility managers.

9.0 Documents and Records

9.1 QAPP Distribution

Following EPA's approval of the QAPP, the plan will be distributed in both an electronic and paper document to all individuals on the QAPP distribution list included in Section 3.0 – QAPP Distribution List. In addition, a bound paper copy of the current approved QAPP will be maintained in each MAEMU as an on-site reference. The QAPP has a date and version number to keep track of the most updated version.

9.2 QAPP Updates

As the project progresses it is anticipated there will be instances where changes to some SOPs and/or data acquisition and collection methods would result in improved data quality. Where the need for such changes is demonstrated, the QAPP will be updated to reflect the improved operational methods. The QAPP format is prepared so individual sections can be updated and replaced without revising the entire document. When a section is revised, a new date and version number will be assigned to that section. All updated sections of the QAPP will be distributed electronically via email to all persons included on the QAPP distribution list included in Section 3.0 – QAPP Distribution List. In addition, the reference copy of the QAPP maintained in each MAEMU will be updated with the revised section.

Before distribution of the updated sections, the revisions will be reviewed by the Project Investigators. Following their review, the revised sections will be submitted to the EPA Project Manager and QA Officer for approval. Because of the QAPP format, individual sections can be reviewed and approved without revising the whole document.

9.3 Identification and Recording of Project Records

In addition to the QAPP, records associated with this project include data generated on-site for gaseous and particulate matter emission rate determination, instrument calibration and maintenance records, quality control sample records, litter sample chain of custody and result records, weekly site visit reports, flock records (for example, number of birds per flock, in and out dates, and mortalities), quality control reports, and corrective action reports. For further information about the records to be maintained see Table 9.1 and Section 20 – Data Management.

All data and records collected for this project are maintained at ISU. All electronic records are maintained in redundancy to ensure that no data is lost due to computer theft or failures. Monitoring data redundancy begins at the field monitoring site in the MAEMU. Raw data is collected and stored on memory in the National Instruments Compact Field Point Modules. Raw data is automatically transferred to a dedicated PC located in each MAEMU. This PC performs pre-processing of data to calculate values required for emissions determinations. The raw data is automatically emailed each day at midnight to a computer dedicated to project data storage located at ISU. The pre-processed data is automatically downloaded from the MAEMU PC to the dedicated ISU project computer each day at 2:00 p.m. Following data quality review, final processing to calculate emissions is completed at ISU by project personnel. Additionally, the University of Kentucky (UK) personnel archive both raw and pre-processed data from the MAEMU PC to a data storage CD on a weekly basis during their site checks.

Table 9.1. Project record identification and handling

Record	Type	Retention	Archival	Disposal
On-site gaseous and particulate matter emission data	Electronic database	On-site computer and ISU computer	ISU computer	Records will be kept for at least 3 years after end of the project
Instrument calibration and maintenance	Paper database	Original database kept on-site, copies maintained at ISU	ISU paper files	Records will be kept for at least 3 years after end of the project
Quality control records	Electronic and paper database	ISU computer and ISU paper files	ISU computer and ISU paper files	Records will be kept for at least 3 years after end of the project
Litter sample results	Electronic database	ISU computer	ISU computer	Records will be kept for at least 3 years after end of the project
Litter sample chain of custody	Paper database	ISU paper files	ISU paper files	Records will be kept for at least 3 years after end of the project
Site visit reports	Electronic database	UK computer and ISU computer	ISU computer	Records will be kept for at least 3 years after end of the project
Flock information	Electronic and paper database	ISU computer and ISU paper files	ISU computer and ISU paper files	Records will be kept for at least 3 years after end of the project
Quality control reports	Electronic database	ISU computer	ISU computer	Records will be kept for at least 3 years after end of the project
Corrective actions	Electronic and paper database	ISU computer and ISU paper files	ISU computer and ISU paper files	Records will be kept for at least 3 years after end of the project

A designated PC at ISU processes the electronic data downloaded from on-site computers. Information on the data handling is detailed in Section 20 – Data Management. In order to reduce the level of manual data processing, automated systems are utilized where appropriate. In order to provide a backup, a hardcopy of automated data collection information is stored for the appropriate time frame in project files. Following data quality review, final processing to calculate emissions is completed at ISU by project personnel.

University of Kentucky personnel prepare written notes in Microsoft Word following each site visit, which document all activities and observations made during the visit. These weekly site visit notes include the results of each week's instrument calibration and checks with calibration gas. These notes are distributed by email to the entire project team on a weekly basis. In addition, these notes are archived in an electronic format at ISU. A calibration record notebook is also maintained at each MAEMU. Records of each required instrument calibration are entered into this notebook during calibration events for each instrument. Following each flock, UK personnel photocopy these calibration records and submit them to ISU personnel, who maintain a paper copy and archive them electronically by entering the records into an electronic format.

As necessary, manual entry field logs are maintained including, but not limited to, site drawings, daily notes about the monitoring operation and the production buildings, results of field quality control measures, and any deviations from this QAPP. These records should be recorded with a pen only.

As part of the project, some production information is being collected. Tyson Foods maintains production records concerning consumed feed weights, broiler market weights, mortalities within each grow-out, and feed conversion rates. ISU monitors water use in the house and will analyze the litter for nutrient content. UK personnel will collect daily bird weight data and feed weight data and submit it to ISU at the end of each flock. This data will be submitted to ISU and maintained electronically. The Tyson production manager at each facility is to record certain activities at the facility that affect air quality in the production house, (for example, generator tests, manure removals, change in diet and animal health, house temperature set points, ventilation interventions, building cleaning, and power failures). See Appendix A for SOP.

Records resulting from this project will be retained for a period of not less than three years following the end of the project. It is the responsibility of the lead PI, Robert Burns, to oversee archiving and disposal of all project records. When records are reviewed, corrections may be required. If any member of the project team needs to perform a data correction, the proposed correction must first be reviewed by a project PI, not including the individual performing the data correction. All data corrections will be recorded in the corrective action report.

10.0 Biosecurity Plan

Biosecurity refers to a set of management practices that reduce the potential for the introduction or spread of disease-causing organisms onto and between sites. Disease carriers can be anything and/or anybody that comes in contact with infected animals, materials or equipment. Bacterial or viral particles transmitted by animals can survive for variable lengths of time almost anywhere under normal environmental conditions. A person or item can become a disease carrier when it comes into contact with contaminated materials such as feces, bedding or air within the area. When a non-disinfected contaminated source leaves one environment and enters another (for example, enters a vehicle to leave the facility), the new area becomes contaminated (Hill, 2003).

Standard operating procedures for the broiler houses in this study require biosecurity practices to be in place that are designed to eliminate, contain, or reduce the exposure and spread of poultry pathogens. For this project, three levels of biosecurity management practices will be in place. Stage 1 procedures should be in place under normal conditions when no disease is present locally or in adjacent regions. Stage 2 procedures should be in place when a disease is present locally or in an adjacent region. Stage 3 procedures should be in place when a disease is present on the farm or a severe disease is present in the immediate area.

During Stage 1 conditions (normal operation), individuals on the project team wear clean clothes and footwear when entering the farm. Personnel wear protective boots, coveralls, hair hats, and gloves. Clothing will not be used at different sites. Shoes are covered with either washable rubber boots or disposable plastic boots. If disposable boots are worn, the used materials are left on the farm. If washable boots are worn, the boots are disinfected before departing the facility. Individuals wash hands before leaving the farm; acceptable methods include waterless gels, disinfecting hand wipes, or soap and water. All reuseable equipment leaving the facility is cleaned and disinfected. Vehicle tires and wheel wells are sprayed with a bio-disinfectant both when arriving and departing the site. Vehicles remain parked in one location until departure from the sight.

During Stage 2 conditions (no disease on site, but disease present in surrounding areas), individuals follow all of the procedures described above, as well as develop a log of visits to and from the two facilities in chronological order.

During Stage 3 conditions (a disease on-site) project team members restrict all visits to the facility, unless a site visit is mandatory. In the case of a site visit during this stage of operation, the visit must be approved by the live production manager. If an individual must visit the facility during this time, they arrive with a prepared biosecurity kit. The kit contains disposable coveralls, boots, hair nets, gloves, hand sanitation items, paper towels, and trash bags in a sealed plastic container. All disposable items must be double-bagged and left on the farm site. Any samples leaving the farm must be double-bagged. The individual’s vehicle should be emptied of all nonessential items before arriving at the farm.

11.0 Sampling Process Design

11.1 Measurement of Gaseous and Particulate Matter Concentrations

The basis for the sampling design of this monitoring is continuous measurement of gaseous and particulate pollutant concentrations and the corresponding building ventilation rates to determine the pollutant emission rate (ER) from two commercial broiler houses for one year. The gases and particulate matter (PM) measured in this project include NH_3, H_2S, CO_2, non-methane hydrocarbons (NMHC), total suspended particulates (TSP), PM_{10} and $PM_{2.5}$.

Two broiler houses, each measuring 13.1m x 155.5m (43 x 510 ft) and built in the early 90s, are being monitored at two farm sites 40 miles apart in western Kentucky. Characteristics for each site are included in Table 11.1. Each house has an initial placement of 25,800 Cobb-Cobb straight-run (mixed sex) broilers in winter and 24,400 in summer, generally grown to 53 days of market age. The houses feature insulated drop ceilings (about R19), box air inlets (15 x 66 cm each) along the sidewalls (26 per sidewall), 26 pancake brooders (8.8 kW or 30,000 Btu/hr each), three space furnaces (65.9 kW or 225,000 Btu/hr each), four 91-cm (36-in) diameter sidewall exhaust fans spaced about 120 ft apart, and ten 123-cm (48-in) diameter tunnel fans. The 91-cm (36-in) fan (SW1) for minimum ventilation is located in the brood end of the houses. Two 24-m (80-ft) sections of evaporative cooling pads are located in the opposite end of the tunnel fans. The houses are also equipped with foggers for additional cooling, if needed. A mixture of rice hulls and sawdust is used as litter bedding.

Air samples are drawn from three locations in each house as well as from an outside location to provide ambient background data (Figure 11.1). One sampling location is near the primary minimum ventilation (36-in) sidewall fan (SW1) used for cold weather ventilation (in the brooding half of the house). The second sampling location is near the fourth sidewall (36-in) exhaust fan (SW3) (non-brooding end). The third location is at the tunnel end (TE). The ambient sample location (A) is between the inlet boxes opposite of the sidewall with the exhaust fans. The quantity of gas in the background (for example, inlet air) is subtracted from that in the exhaust air when calculating aerial emissions from the house.

Placement of the air sampling ports are as follows: for the two sidewall sampling locations, the sampling ports and temperature sensors are located 1.2 m (4.0 ft) away from the fan in the axial direction, 2.3 m (7.5 ft) in the radial direction, and 1 m (3 ft) above the floor; for the tunnel-end sampling location, the sampling port and temperature sensor is located at the center across the house (for example, 6.6 m or 21.5 ft from each sidewall) and 7.3 m (24.0 ft) from the end wall. Figure 11.2 shows the axial and vertical location of the sampling points in relations to the fan centers. Sampling locations and placement of the sampling ports were chosen to maximize representation of the air leaving the houses. Each sample inlet point is equipped with a dust filter to keep large particulate matter from plugging the sample tubing.

The schedules of sampling events and sequences are as follows (refer to figure 11.3). If the ventilation fans at the three in-house sampling locations (SW1-location 1, SW3-location 2 and TE-location 3) are all running, air samples from each location are analyzed sequentially via the controlled operation of the servo values of the gas sampling system (GSS). In this case, sampling/analysis sequence is SW1, SW2, and TE, and the cycle repeats. The time of analysis per sampling episode for each location is 120 seconds (s), involving four consecutive 30-s readings by the INNOVA 1412 multi-gas analyzer. The fourth reading is considered to be the equilibrium value of the location and used in the subsequent analysis of emission rate. The selection of 120-s sample analysis time is based on extensive laboratory tests and field verification with calibration gases and concurrent measurement of the sampling location by INNOVA 1412 analyzers located inside the house and inside the MAEMU. If fans at SW3 or TE are not running (for example, during half-house brood), sample analysis will repeat for the SW1 location only, and the same is true for TE sampling when fans at SW1 and SW3 are not running (for example, during tunnel ventilation mode). Every two hours, air samples from the ambient (background) location are drawn and analyzed for 8 minutes. The longer sample analysis time for the ambient point is due to the longer response time of the instrument when measuring a large step change in gas concentration. Selection of a 2-hour interval for the analysis of the ambient concentrations is due to the fact that ambient conditions remain relatively constant, as compared to the in-house conditions. Such an arrangement helps maximize the number of data points collected for the exhaust air and thus, house emissions.

The sequential sampling makes the assumption that any concentration changes at the given location during the two adjacent measurements (generally 360 seconds) follow a linear pattern. Hence, linear interpolation from the two measured values is used to determine intermediate values for the location, as needed. Use of one sampling location at the tunnel fan end also assumes homogeneity in distribution of aerial concentrations. Examination of ammonia concentrations across the house in this section, through concurrent measurements using four INNOVA 1412 analyzers, has confirmed the validity of this assumption. Moreover, it was assumed that the vertical stratifications in aerial concentrations are negligible when the exhaust fans are in operation. Once again, this assumption has been verified by concurrent measurements of vertical distribution of ammonia and CO_2 concentrations (from floor to ceiling). Incidentally, appreciable vertical stratifications exist when the fans are off. For measurement of emissions, we are only concerned with the concentrations that correspond to operation of the fans.

Air samples will be collected via 0.95-cm (3/8-inch) o.d. and 0.64-cm (1/4-inch) i.d. *Teflon* tubing (Fluorotherm FEP tubing). Individual supply pumps (with all internal wetted parts *Teflon* coated) are used to continuously draw air from each of the sampling locations. Use of individual pumps dedicated to each sampling location eliminates potential residual effects from sharing pumps among sampling locations, this is especially the case between ambient/background air and in-house exhaust air samples. The sampling scheme is designed such that air is continuously drawn from all four sampling points. When a sample point is not being analyzed, the flow is bypassed from the instrument in the MAEMU. This arrangement is designed to minimize the residence time and thus, the sample-to-sample purging time.

Considerable discussion and investigation has gone into the placement of the Tapered Element Oscillating Microbalance (TEOM) particulate matter samplers (TSP, PM_{10}, $PM_{2.5}$) in the house. Since no data was available in terms of TEOM responses to different air velocity fields, as would be encountered in the broiler houses, we conducted an in-house evaluation of the TEOM performance for air velocity ranging from 1.3 – 6 $m \cdot s^{-1}$ (250 to 1200 feet per minute). The results revealed that the TEOM readings are unaffected by the tested air velocity range. Prior to the TEOM tests, we had assumed continuity in PM concentrations from the center of the house to the exhaust. Since we were concerned that the TEOMs might not function properly under high velocity conditions near the exhaust fan, we placed the TEOMs near the center, across the width of the house. Comparison of two TEOM readings near the center versus near the exhaust of the house, revealed that concentrations near the exhaust were generally lower than concentrations near the center. Since velocity showed no impact on the concentration measurement and we are to quantify the emissions going out of the house, we located the TEOMs near the exhaust fan(s). The specifics of TEOM placement are as follows. During the half-house brooding period, the TEOMs are placed near SW1. The TSP TEOM is located 0.6 m (2.0 ft) away from the fan in the axial direction, 1.1 m (3.5 ft) in the radial direction to the left of the fan, and 1.5 m (5.0 ft) above the floor. The PM_{10} TEOM is located 0.6 m (2.0 ft) away from the fan in the axial direction, 1.1

m (3.5 ft) in the radial direction to the right of the fan, and 1.5 m (5.0 ft) above the floor. The $PM_{2.5}$ TEOM is located 0.6 m (2.0 ft) away from the fan in the axial direction, 2.2 m (7.0 ft) in the radial direction to the right of the fan, and 1.5 m (5.0 ft) above the floor. Once the birds are given the full house (between 10-14 days of age), the TEOMs are moved to the TE location. For the TE sampling location, the TSP TEOM is located 4.9 m (16.0 ft) away from the tunnel fan in the axial direction, 11 m (36 ft) from the tunnel end of the house, and 1.5 m (5.0 ft) above the floor. The PM_{10} TEOM is located 0.6 m (2.0 ft) away from tunnel the fan in the axial direction, 9.8 m (32.0 ft) from the tunnel end of the house, and 1.5 m (5.0 ft) above the floor. The $PM_{2.5}$ TEOM is located 0.6 m (2.0 ft) away from the tunnel fan in the axial direction, 8.5 m (28.0 ft) from the tunnel end of the house, and 1.5 m (5.0 ft) above the floor.

All the sampling locations are accessible, although some are relatively easier than others when placing the TEOM units.

Tables 11.2 and 11.3 summarize the variables monitored, the instruments used, and the sampling intervals, for easy reference.

Table 11.1. Characteristics of the broiler houses monitored

	Site 1-5	**Site 3-3**
Species	Broilers	Broilers
# buildings at site	8	24
Year of buildings	1992	1991
Ridgeline orientation	North-South	North-South
Building type	litter	litter
Manure storage, days	~ 1 year	~ 1 year
Animal residence time, days	53	53
Outdoor storage	none	none
Mortality disposal	Composting	Composting
Spacing, ft	60	60
Ridge height, ft	17.2	17.2
Sidewall height, ft	7	7
# air inlets	52	52
Type of inlet	Box	Box
Inlet control method	automatic	automatic
# fans/bldg or room	14	14
Largest fan diameter, in.	48	48
Smallest fan diameter, in.	36	36
# ventilation stages	12	13
Fan company	CanArm	Euroemme
Controls company	Chore-Time	Rotem
Artificial heating?	Yes	Yes
Summer cooling	EP/tunnel	EP/tunnel
Brooding section	South half of barn	South half of barn
24/7 internet	Satellite	Satellite
Distance to site, mi.	30 miles	18 miles
Inventory/building	24,400 (summer) 25,800 (winter)	24,400 (summer) 25,800 (winter)
Building width, ft	43	43
Building length, ft	510	510
Building area, ft^2	21,930	21,930
Shower in/out?	Not required	Not Required
Start date	January 2006	January 2006
Completion date	January 2007	January 2007

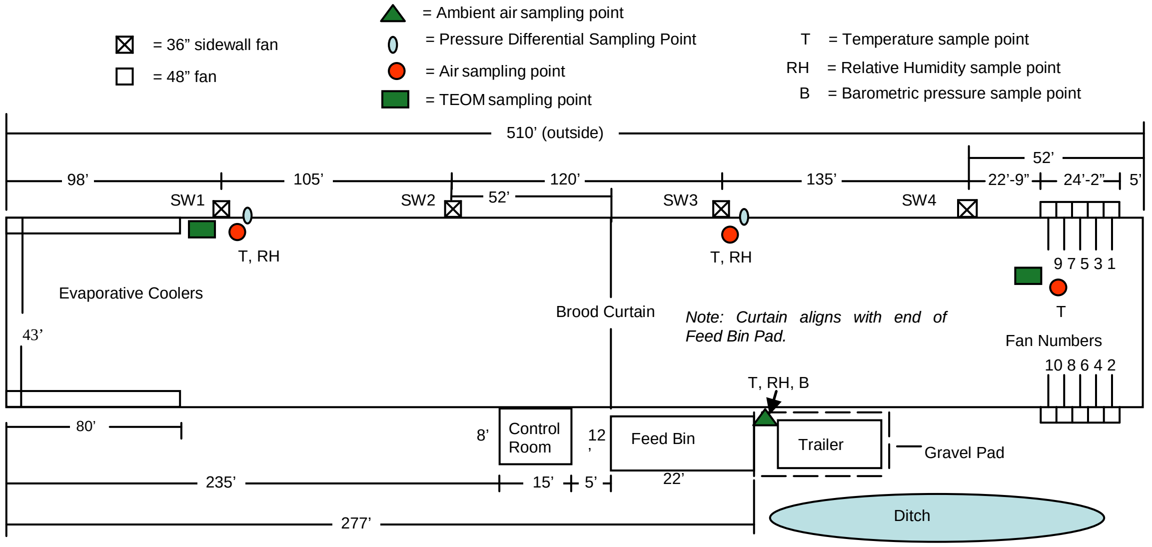
Table 11.2. Summary of instruments and sampling intervals used for the monitored variables.

Variables	Analyzer Matrix	Sample Category	Sampling Interval	Critical Nature (c = critical)
NH_3, ppm	INNOVA 1412	Air	30 s	c
CO_2, ppm	INNOVA 1412	Air	30 s	c
CH_4, ppm	INNOVA 1412	Air	30 s	c
Non-CH_4, ppm	INNOVA 1412	Air	30 s	c
H_2S, ppm	API 101E	Air	1 s	c
CH_4	VIG 200	Air	3 min	c
Non-CH_4, ppm	VIG 200	Air	3 min	c
Temperature (°C)	Type-T T.C.	Environment condition	1 s	c
RH (%)	HMW 61U	Environment condition	1 s	c
Static Pressure, Pa	Setra 264	Environment condition	1 s	c
Barometric pressure, kPa	WE100	Environment condition	1 s	c
TSP, $\mu g/m^3$	TEOM 1400	Environment condition	1 s	c
PM_{10}, $\mu g/m^3$	TEOM 1400	Environment condition	1 s	c
$PM_{2.5}$, $\mu g/m^3$	TEOM 1400	Environment condition	1 s	c
Fan ON/OFF	Current Switch	Ventilation	1 s	c

Table 11.3 Sampling intervals for each air sampling location in each the broiler house

Air Sampling Location	**Exhaust Fans Running Combinations**							
	No Fan	**SW 1 or 2**	**SW 3 or 4**	**Any Tunnel Fan (TF)**	**SW 1 or 2 SW 3 or 4**	**SW 1 or 2 + any TF**	**SW 3 or 4 + any TF**	**SW 1 or 2 + + SW 3 or 4 + any TF**
SW1	120 s	120 s			240 s	240 s		360 s
SW3			120 s		240 s		240 s	360 s
Tunnel End				120 s		240 s	240 s	360 s
Outside	2 hr	2 hr	2 hr	2 hr	2 hr	2 hr	2 hr	2 hr

Tyson 1-5
Drawing not to scale



Tyson 3-3
Drawing not to scale

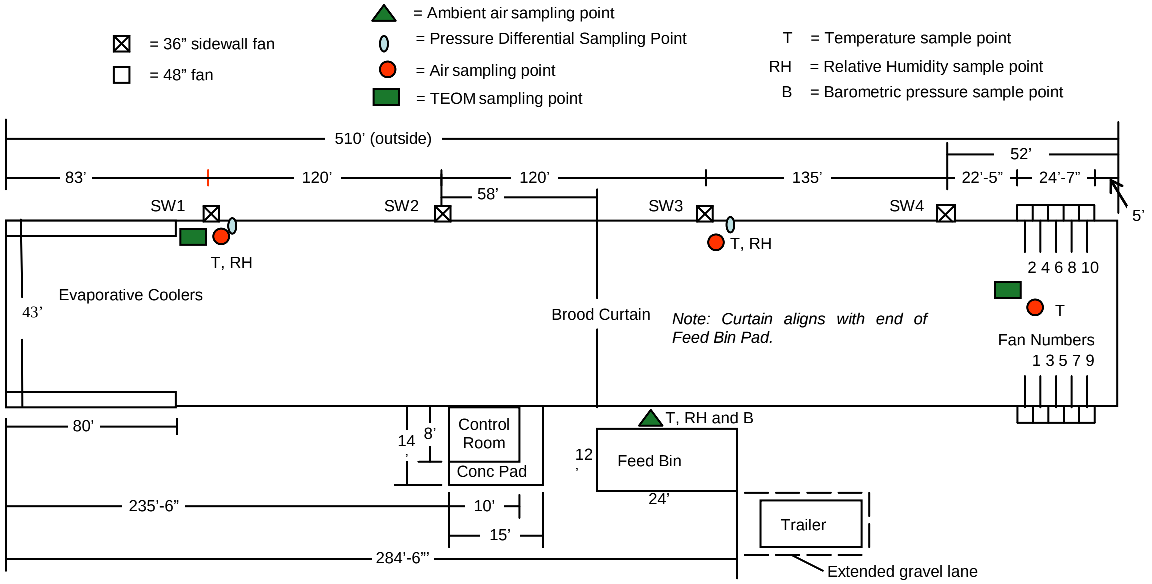


Figure 11.1. Schematic layout of Tyson 1-5 and Tyson 3-3.

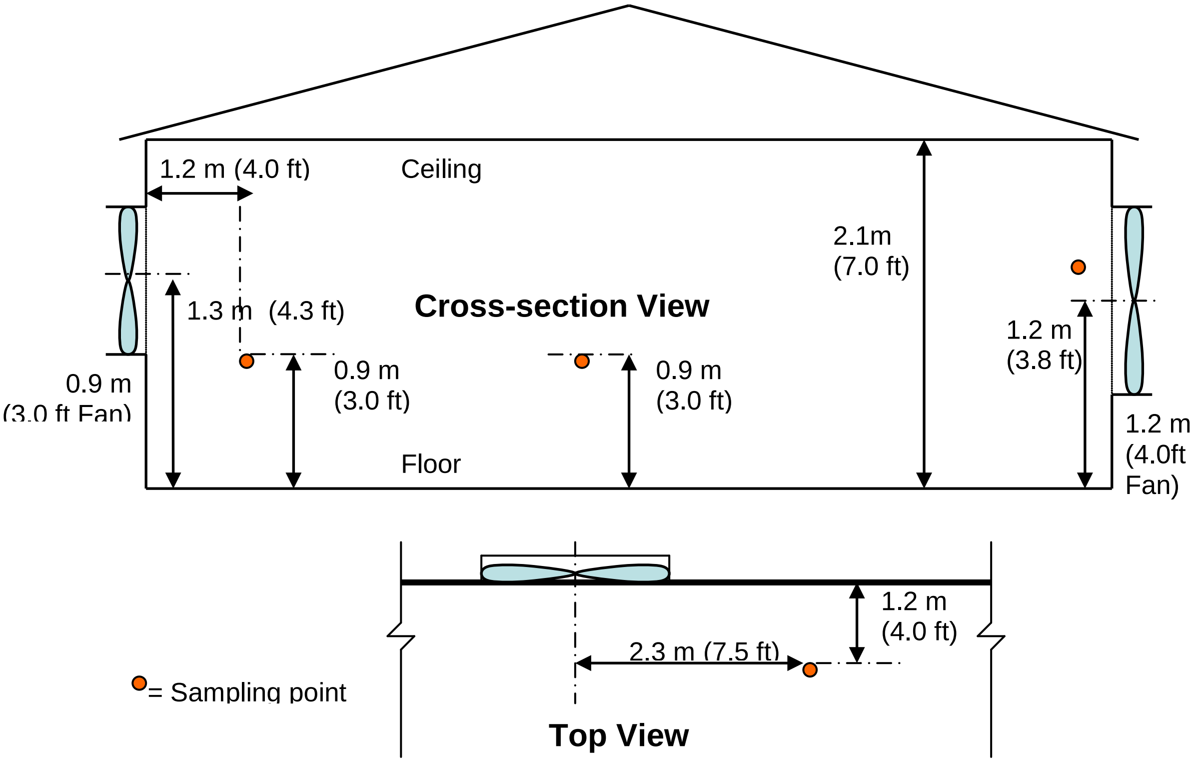


Figure 11.2. Cross sectional view of the sidewall sampling points.

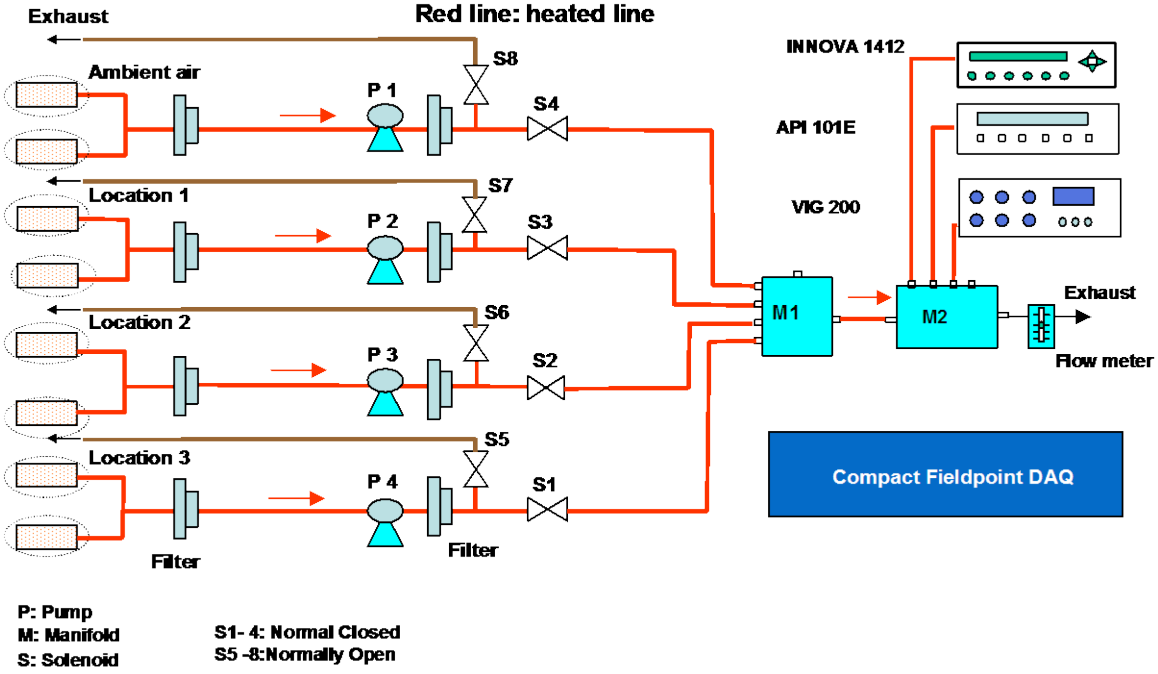


Figure 11.3. Schematic representation of the positive pressure GSS used in the MAEMU for measurement of broiler house air emissions. The GSS features continuous drawing of sample air from all locations with individual pumps. The sample air is bypassed when not analyzed.

11.2 Measurement of Ventilation Rate

Ventilation rates of the houses are measured using the following procedure. First, all exhaust fans have been calibrated in situ, with a state-of-the-art Fan Assessment Numeration System (FANS) to obtain the actual ventilation curves (airflow rate versus static pressure). Guidelines for FANS calibration are presented in Appendix C. This calibration is essential for accurate measurement of the house ventilation rate, because actual fan airflow rates can differ by 10-25% as compared with the default values provided by the fan manufacturer. The deviation arises from the field operational conditions that differ drastically from those under which the default values were established, (for example, loose motor belt, dirty shutter or fan blades). Runtime of each fan is monitored continuously using an inductive current switch (with analog output) attached to the power supply cord of each fan motor (Figure 11.5) as described in Appendix R, and recorded by the compact Fieldpoint modules as described in Appendix G. Concurrent measurement of the house static pressure is made with two static pressure sensors (Model 264, Setra, Boxborough, MA), each for half of the house. While the pressure differential is not expected to differ at the two locations, two sensors are used to provide redundancy in this critical measurement. Summation of airflows from the individual fans during each monitoring cycle or sampling interval produces the overall house ventilation rate. This method of determining dynamic ventilation rates of mechanically ventilated animal confinement has been successfully used in recent AFO air emission studies in the United States.

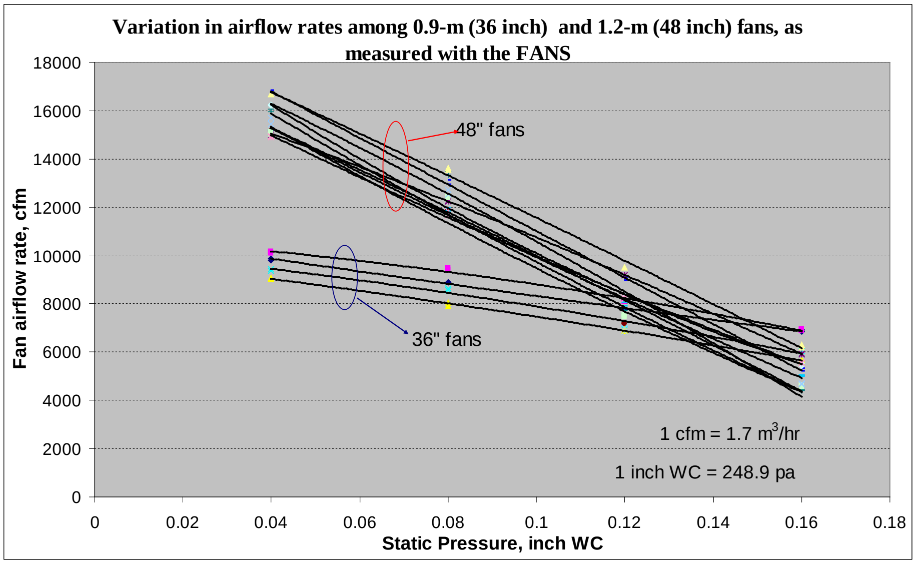
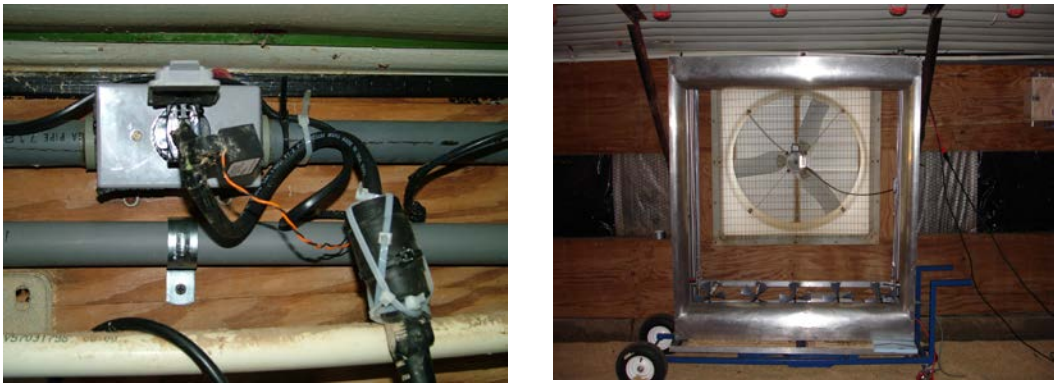


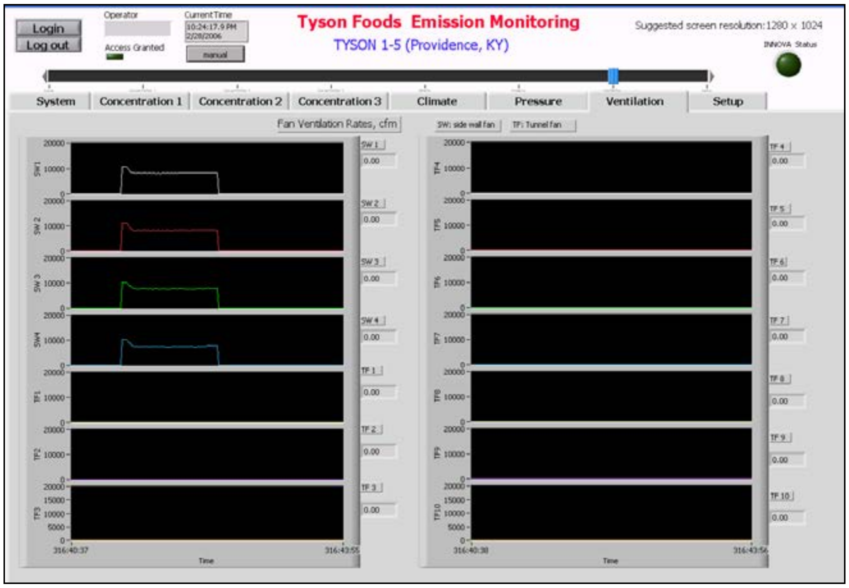
Figure 11.4. Variation in the fan airflow rates among the 36-in and 48-in fans in a Tyson broiler house.

At the beginning of the project, all 14 ventilation fans in each house were calibrated and fan curves were developed. Afterward, three to four fans in each house (less than 20% of total fans) were randomly chosen and tested at the beginning of each flock. If airflow rates of the randomly selected fans deviate from the initial calibration values by 10% or greater, all fans will be recalibrated, and the fan performance curves will be updated and incorporated into the LabView program for real-time ventilation rate monitoring (Figure 11.6).



Fan runtime sensor **Fan calibration by FANS unit**

Figure 11.5. Photographical views of the fan calibration and operation monitoring devices



Current Time 10:24:17.9 PM 2/28/2006

Figure 11.6. Real-time monitoring of fan airflow rate in the LabView program.

In addition to the directly measured ventilation rate, a functional relationship between CO_2 concentration of the house and the measured building ventilation rate at different bird ages has been established for use as a back-up, at least for recovering short-term missing data in the directly measured ventilation rate. The CO_2 balance method has been shown by research team members to be a viable alternative for estimating building ventilation rate under certain circumstances (for example, integration time of 30 minutes or longer). The fan numbers and ventilation stages for Tyson 1-5 and 3-3 are shown in Table 11.4 and 11.5.

Table 11.4. Fan number and ventilation stages for Tyson 1-5

TYSON 1-5	STAGE	# FANs	SIDE WALL FAN #'s	Tunnel Fan #'s	ON (min)	OFF (min)	TEMP. DIFF., °F
Cross Ventilation Mode	1	4SWF	1,2,3,4		0.5	4.5	
		4SWF	1,2,3,4		1	4	
		4SWF	1,2,3,4		1.5	3.5	
		4SWF	1,2,3,4		2	3	
		4SWF	1,2,3,4		2.5	2.5	
		4SWF	1,2,3,4		3	2	
		4SWF	1,2,3,4		3.5	1.5	
		4SWF	1,2,3,4		4	1	
	2	4SWF	1,2,3,4				2
	3	4SWF 1TF	1,2,3,4	1			3
	4	4SWF 2TF	1,2,3,4	2 & 1			4
	5	4SWF 3TF	1,2,3,4	3,2,1			5
Tunnel Ventilation Mode	6	4TF		4,3,2,1			7
	7	5TF		10,4,3,2,1			8
	8	6TF		6,5,4,3,2,1			9
	9	7TF		10,6,5,4,3,2,1			10
	10	8TF		10,9,8,7,4,3,2,1			11
	11	9TF		9,8,7,6,5,4,3,2,1			12
	12	10TF		All			13

Table 11.5. Fan number and ventilation stages for Tyson 3-3

TYSON 3-3	STAGE	# FANs	SIDE WALL FAN #'s	Tunnel Fan #'s	ON (min)	OFF (min)	TEMP. DIFF., °F
Cross Ventilation Mode	1	4SWF	1,2,3,4		0.5	4.5	
		4SWF	1,2,3,4		1	4	
		4SWF	1,2,3,4		1.5	3.5	
		4SWF	1,2,3,4		2	3	
		4SWF	1,2,3,4		2.5	2.5	
		4SWF	1,2,3,4		3	2	
		4SWF	1,2,3,4		3.5	1.5	
		4SWF	1,2,3,4		4	1	
	2	4SWF	1,2,3,4				1
	3	4SWF 1TF	1,2,3,4	10			2
	4	4SWF 2TF	1,2,3,4	9 & 10			3
	5	4SWF 3TF	1,2,3,4	10,9,8,			4
	6	4SWF 4TF	1,2,3,4	10,9,8,7			5
Tunnel Ventilation Mode	7	4TF		10,9,8,7			7
	8	5TF		10,9,8,7,1			8
	9	6TF		10,9,8,7,6,5			9
	10	7TF		10,9,8,7,6,5,1			10
	11	8TF		10,9,8,7,4,3,2,1			11
	12	9TF		10,9,8,7,6,5,4,3,2			12
	13	10TF		All			13

11.3. Determination of Aerial Emission Rate (ER)

The emission rate (ER) of a pollutant from a broiler or any animal house to the atmosphere is the difference between the quantity of the pollutant leaving the house and the quantity of the pollutant entering the house or the background in a given period of time (for example, per minute, hour, or day). Namely,

$$ER = Q_{STP(e)}[P]_{M(e)} - Q_{STP(i)}[P]_{M(i)} \qquad [1]$$

where $Q_{STP(i)}, Q_{STP(e)}$ = Incoming and exhaust airflow rate of the house at standard temperature and pressure, respectively, volume hr^{-1} $house^{-1}$
$[P]_{M(i)}, [P]_{M(e)}$ = Incoming and exhaust mass concentration of the pollutant, respectively, mass per volume of air

When considering the effects of temperature, pressure and moisture on the measured airflow rate, and thus, the volume of the gaseous pollutants, the following equations are used to calculate ER,

$$ER_{[g]} = ([G]_e \times Q_e \times \frac{T_{std}}{T_e} - [G]_i \times Q_i \times \frac{T_{std}}{T_i}) \times 10^{-6} \times \frac{P_a}{P_{std}} \times \frac{w_m}{V_m} \qquad [2]$$

where $ER_{[g]}$ = Gas emission rate for the house, g hr^{-1} $house^{-1}$
Q_i, Q_e = Incoming and exhaust ventilation rate of the house at field temperature and barometric pressure, respectively, m^3 hr^{-1} $house^{-1}$
$[G]_i, [G]_e$ = Gas concentration of incoming and exhaust house ventilation air, respectively, parts per million by volume (ppm_v)
w_m = molar weight of the gas, g $mole^{-1}$ (e.g., 17.031 for NH_3)
V_m = molar volume of gas at standard temperature (0°C) and pressure (101.325 kPa) or STP, 0.022414 m^3 $mole^{-1}$
T_{std} = standard temperature, 273.15 °K
T_i, T_e = absolute temperature of incoming and exhaust air, respectively, °K
P_{std} = standard barometric pressure, 101.325 kPa
P_a = atmospheric barometric pressure at the monitoring site, kPa

As described in the previous section, exhaust ventilation rate of the house (Q_e) is continuously measured by monitoring the runtime of individual exhaust fans that have been calibrated in-situ at the beginning of each flock. Although there exists an inherent change in air compositions between the incoming and exhaust air due to animal respiration and manure/litter decomposition, the impact of this change on the mass of dry air flowing through the house is considered negligible. This premise of constant dry air mass throughout the ventilated house leads to the following functional relationship between Q_e and Q_i:

$$\frac{Q_i}{\upsilon_i} = \frac{Q_e}{\upsilon_e} \qquad [3]$$

where υ_i and υ_e are specific volumes of incoming and exhaust air, respectively, m^3 moist air per kg dry air. Refer to Appendix J (SOP of Reporting and Calculation of Contaminant Concentrations, Ventilation and Emissions) for calculation of thermodynamic properties of the moist air. Submitting Q_e into equation [2] yields the following equation for calculation of gaseous ER:

$$ER_{[g]} = Q_e \left(\frac{[G]_e}{T_e} - \frac{\upsilon_i}{\upsilon_e} \times \frac{[G]_i}{T_i} \right) \times 10^{-6} \times T_{std} \times \frac{P_a}{P_{std}} \times \frac{w_m}{V_m} \qquad [4]$$

All the variables of pollutant concentration, fan runtime, static pressure, air temperature and relative humidity (RH) will be continuously measured and recorded at 30-second intervals throughout the one-year monitoring period. The 30-second interval of raw data will be processed to yield hourly emission rates by the following equation:

$$ER_{[g]} = \sum_{k=1}^{n} \sum_{l=1}^{3} Q_{k,l} \left(\frac{[G]_{e(k,l)}}{T_{e(k,l)}} - \frac{\upsilon_{i(k,l)}}{\upsilon_{e(k,l)}} \times \frac{[G]_{i(k,l)}}{T_{i(k,l)}} \right) \times 10^{-6} \times T_{std} \times \frac{P_a}{P_{std}} \times \frac{w_m}{V_m} \qquad [5]$$

where k = number of valid concentration measurements per location within the hour
l = number of sampling locations per house
$Q_{k,l}$ = amount of airflow during the kth time period corresponding to the measured gas concentration at lth location, m^3
w_m = molar weight of the gas, g mole-1 (e.g., 17.031 for NH3)
V_m = molar volume of gas at standard temperature (0°C) and pressure (101.325 kPa) or STP, 0.022414 m3 mole-1
T_{std} = standard temperature, 273.15 °K
T_i, T_e = absolute temperature of incoming and exhaust air, respectively, °K
P_{std} = standard barometric pressure, 101.325 kPa
P_a = atmospheric barometric pressure at the monitoring site, kPa
υ_i, υ_e = specific volume of incoming and exhaust air, respectively, m^3 moist air per kg dry air

Concentrations of the PM have the unit of $\mu g \cdot m^{-3}$. Consequently, ER of PM is calculated with the following equation:

$$ER_{[PM]} = Q_e \left(\frac{[PM]_e}{T_e} - \frac{\upsilon_i}{\upsilon_e} \times \frac{[PM]_i}{T_i} \right) \times 10^{-0.16} \times T_{std} \times \frac{P_a}{P_{std}} \qquad [6]$$

where $ER_{[PM]}$ = PM (TSP, PM_{10}, or $PM_{2.5}$) emission rate for the house, kg hr^{-1} $house^{-1}$

$[PM]_i$, $[PM]_e$ = PM concentration of incoming and exhaust house ventilation air, respectively, µg per m^3 of air at Standard Temperature and Pressure

11.4 Measurement of Air Temperature and Relative Humidity

Indoor and outdoor temperature and RH are measured with robust and stable temperature (type T thermocouples) and RH probes (Vaisala HMW 61 units) that are connected to the PC-based data acquisition (DAQ) system (National Instruments Compact Field Point running LabView 7.1). Analog output of the static pressure sensor is connected to the DAQ system.

11.5 Litter Sampling

Litter from the production houses is analyzed for nitrogen content. Litter is sampled after removal of each flock as described in Section 12.4 – Litter Sampling Methods. Analyzed samples, in conjunction with litter mass removed during cleanout are used to estimate non-gaseous nitrogen movement in and out of the house.

11.6 Schedule of Peer Review Activities

The sampling process design presented here incorporates extensive experience in air emission monitoring accumulated by the research team members over the years. Nonetheless, we have selected two nationally renowned experts (Dr. Jacobson and Dr. Parker) in air quality monitoring to serve as the external peer reviewers of the sampling system and protocols. Upon approval by the EPA, the on-site review by the peer experts will be conducted. The experts have been contacted and alerted about the time sensitive nature of the review, and they are prepared to do so. Prior to the site visit, the reviewers will be provided a copy of our QAPP and any additional information pertaining to the monitoring system that they may wish to have.

11.7 Procedures for Coping with Sample Design Changes

Any proposed changes in the sample design are first discussed among the research team members. Upon agreement among the team, we submit the proposed changes to the EPA Project Manager and QA Officer for their approval. Once approved, the changes will be implemented and documented in the updated QAPP.

Any deviation in system maintenance or operation to ensure the integrity of the sampling system operation and thus, the data collected is reported to the entire research team and documented in the project logbook and the updated QAPP in a timely and meticulous fashion. The QA Manager is promptly notified about the changes as well.

12.0 Sampling Methods Requirements

These methods provide for continuous measurement of the gas concentration, particulate matter concentration, ventilation rate, environment conditions, DAQ recording and litter samples.

12.1 Gas Concentration Analysis Methods

Ammonia. The NH_3 concentrations of background and exhaust air are measured with an advanced photo-acoustic, highly accurate, responsive and stable NH_3 analyzer. This type of analyzer has been widely used by European and Japanese scientists and recently used by U.S. scientists in AFO air emission studies (Battye, 1994). The sampling interval of the advanced INNOVA 1412 photo-acoustic multi-gas analyzer is set at 30 sec/sample for measuring three different air pollutants (NH_3, CO_2, non-methane hydrocarbons) with three individual optical filters (INNOVA filter number: 976, 983, 987 for NH_3, CO_2 and NMHC respectively). The low detection limit for NH_3 is 0.2 ppm with up to 2,000 ppm maximum range. The response time of the INNOVA 1412 is shorter than four sampling cycles (30 s X 4 =120 s) described in Appendix D. In addition, two Drager Polytron I electro-chemical ammonia monitoring units (at location SW1 and TE1 are used as a backup for NH_3 monitoring.

Hydrogen Sulfide. Advanced Pollution Instrumentation, Inc., Model 101E H_2S analyzer is being used to measure the H_2S concentrations of background and exhaust air. The detection limit of the analyzer is 0.4 ppb with maximum range 20,000 ppb. The response time of T95 for both rising and falling is shorter than 100 sec, which was tested in the lab (see Appendix K and API 101E instruction manual).

Non-Methane Hydrocarbons. The VIG Industries, Inc. Model-200 is a microprocessor-based, dual-channel, oven heated methane/non-methane/total hydrocarbon gas analyzer. Designated for use as U.S. EPA Method 18 and Method 25A, it measures total hydrocarbons and methane and non-methane components (VOC) of background and exhaust air (Appendix L). The detection limit is 0.01 ppm for a 0-10ppm range. Total hydrocarbon is continuously measured with a less than 5-s response time of T90. Methane and non-methane hydrocarbon are measured and updated every three minutes. VIG 200s have been used to measure NMHC for a period of two months to date. In this period the units have been unable to meet our data completeness criteria of 75%. As such, we have added the capacity to measure NMHC to the INNOVA 1412 and found the unit to be far more robust and stable than the VIG while providing comparable measurements. The INNOVA 1412 multi-gas analyzer with filter 969 and 987 is used for methane and non-methane hydrocarbon monitoring due to the limits of the VIG 200. The detection limit of filter 969 for methane monitoring is 0.4 ppm with a maximum range 4,000ppm. The detection limit of filter 987 non-methane hydrocarbon is 0.1ppm with a maximum range 1,000ppm.

Carbon Dioxide. The CO_2 concentrations of background and exhaust air are measured with an advanced photo-acoustic, highly accurate, responsive and stable multi-gas analyzer. The sampling frequency of the advanced INNOVA 1412 photo-acoustic analyzer was set at 30 sec/sample for measuring three different air pollutants (NH_3, CO_2, non-methane hydrocarbon) with three individual optical filters. The low detection limit for CO_2 is 3.4 ppm with up to 34,000 ppm maximum range. The response time of the INNOVA 1412 is shorter than four sampling cycles (30 s X 4 =120 s).

12.2 Gas Sampling Collection and Preparation

Individual air samples, as defined in Section 11, for both in-house and background locations are collected using a gas sampling system (GSS) that is designed to collect samples from four locations on a cyclical basis. Three sampling points are located inside each broiler house at two sidewall fans and at the tunnel end. The fourth sampling point is located outside of the broiler house and is used as the ambient measurement point for background concentration determination. The location of the sampling points in Tyson 1-5 and Tyson 3-3 are shown in Figure 11.1. The samples are pumped into the GSS with pumps on the inlet side of the GSS. This arrangement results in the GSS being a positive pressure system. By using this positive pressure approach, if a leak were to develop at any connection point on the GSS it cannot compromise the integrity of the gas sample. A more detailed description of the GSS is provided below and in Appendix B: SOP of GSS.

12.3 Gas Sampling Equipment, Preservation and Handling Time Requirements

Vacuum pumps (P1-P4) with *Teflon* wetted parts will be used to deliver air from the sampling locations via solenoids and a manifold (M1), and transport the air stream to another manifold (M2), which connects to the gas analyzer. *Teflon* or *Teflon* coating will be used in all wetted parts of the sampling system (pump, solenoid valves, manifold, and tubing). Four pairs of 2-way solenoid valves (S1-S8) located in sampling lines are controlled by the DAQ and control unit to allow measurements of gas concentrations by automatic gas sampling from four locations (Figure 11.3). To avoid the malfunction of solenoid valves due to overheating, solenoid cool boards are used to drive the solenoid valves. When the control module sends the signal to the cool boards, the cool boards provide full power (12 VDC) to the solenoids during the first 100 msec and then cut the power to approximately half (5 VDC) and hold it for 120 or 480 sec until the DAQ system receives the fourth output signal from INNOVA 1412 analyzer via RS232. The cool boards solve the overheating problem of the solenoid valves. Individual supply pumps with 16 L/min delivering capacity are used to continuously draw air from each of the sampling locations. The sampling train is designed such that samples are drawn from all four sampling points continuously. When a sampling point is not being analyzed, the flow is bypassed through the normally open solenoid valve (S5-S8). This arrangement is designed to minimize the residence time, and thus, greatly reducing the sample-to-sample purging time. When a sampling stream is selected, the corresponding normal close valve will open and the normal open valve will close; and the selected gas stream will flow from the sample inlet via the tubing through the manifolds (M1 and M2). The internal pump of the gas analyzers draws air from manifold M2. The gas sampling system is designed such that all solenoid valves, manifolds and associated connections are under positive pressure. Using this positive pressure approach, if a leak were to develop on the gas sampling control board at any of these components, it would not impact the integrity of the gas sample.

Two pleated paper filters enclosed in plastic, then shrouded in screen wire are used to exclude coarse debris from entering the sample lines. Additionally, a 47-mm diameter, in-line *Teflon* PFA filter holder housing a 47-mm diameter, *Teflon* PTFE-laminated polypropylene membrane filter with 20-µm pore size is installed at the sampling end of each gas sampling tube to remove airborne particulate from the sampled air (Figure 12.1). Another 5-µm pore size PTFE filter is installed after the vacuum pump to provide double protection. The in-house sample-point, intake filters are changed weekly and the in-line, 20- µm filter is changed at the midpoint and at the end of the flock growout period.

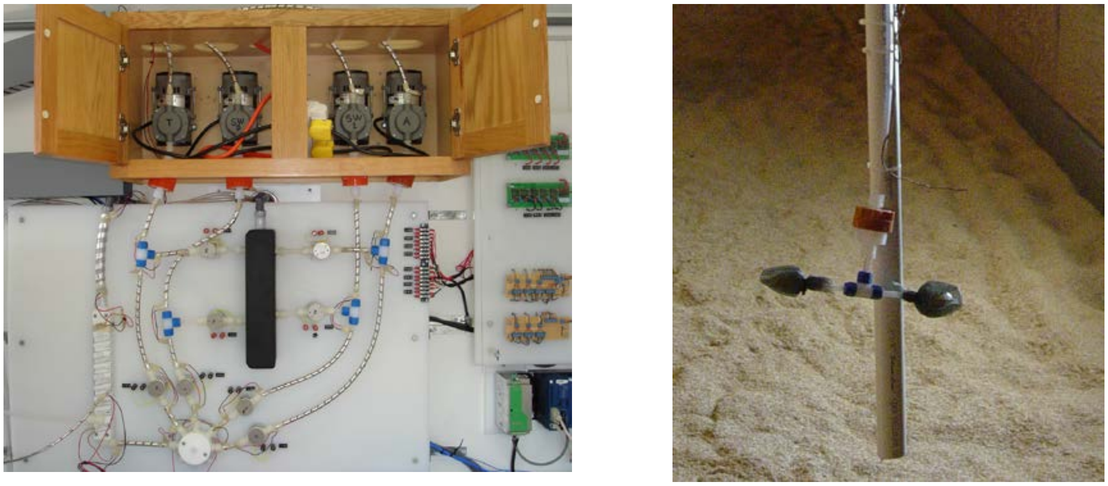


Figure 12.1. Photographical views of the air sampling system

All portions of the sample tubing that go from a warm area to, or thru, a cooler area is heat traced to a temperature of 120° F to maintain a temperature well above dew point in order to prevent in-line condensation. The GSS is heat traced and maintained at 100° F to avoid any condensation in the system. Temperature of the sampling line, and thus, the power input of the heat trace or tape is continuously monitored and regulated through the DAQ and control system.

Gas samples are analyzed using an INNOVA 1412 Photoacoustic Multi-gas monitor with RS232 output, API 101E UV Fluorescence H_2S Analyzer and Non-methane hydrocarbon using VIG200 methane/non-methane/total hydrocarbon analyzer and the INNOVA 1412 (Figure 11.3). Because the INNOVA 1412 has a separate filter for each analyzed component, it can continuously monitor five pollutants. For more details on the operation and specifics for the INNOVA 1412 (NH_3, CO_2, non-methane hydrocarbon), see Appendix D. The INNOVA 1412 is specified with 1 second sampling integration time and fixed flushing time (chamber 2 seconds and tubing 3 seconds). Using a 30-s measurement cycle, the INNOVA demonstrates a T95-97 response time of 120 s (i.e., four measurement cycles), see Appendix D. Hence, the first 2-3 readings during each sampling period are considered invalid and excluded in the determination of the emission rate. The volume of sample air is 100cm^3/sample. The INNOVA 1412 sampling flow rate is 1.8 L/min. The response time of the API 101E UV Fluorescence H_2S Analyzer to step changes in gas concentrations was tested. For more details on the operation and specifics for the API 101E UV Fluorescence H_2S Analyzer, see Appendix K. The response time of the API 101E is shorter than 100 seconds. The API 101E sampling flow rate is 0.6 L/min. The VIG model 200 methane/non-methane/total hydrocarbon analyzer uses column technology to separate methane and non-methane from total hydrocarbons and use a dual FID (flame ionization detectors) to measure each component in the air sample. The VIG model 200 sampling flow rate is 2.5-3 L/min. To obtain continuous gas data to match continuous airflow, the data in long intervals between valid readings is estimated by linear interpolation, as described in section 11.1.

The air sampling schedule from four locations is determined by the fan running status at three inside locations. Tables 12.1 summarizes the sampling methods and intervals for easy reference.

Table 12.1. Gas Sampling Locations and Sampling Methods/SOPs

		Sampling location			
		Sidewall fan 1	**Sidewall fan 3**	**Tunnel end**	**Outside**
Location ID Number		**1**	**2**	**3**	**0**
Analytical parameters		**NH_3, CO_2, H_2S, NMHC, and CH_4 (ppm)**	**NH_3, CO_2, H_2S, NMHC, and CH_4 (ppm)**	**NH_3, CO_2, H_2S, NMHC, and CH_4 (ppm)**	**NH_3, CO_2, H_2S, NMHC, and CH_4 (ppm)**
Sampling SOP		**Appendix B, D, G, K, and L**	**Appendix B, D, G, K, and L**	**Appendix B, D, G, K, and L**	**Appendix B, D, G, K, and L**
Sample flow rate		**15 L/min**	**15 L/min**	**15 L/min**	**15 L/min**
Sampling time		**120 s**	**120 s**	**120 s**	**480 s**
Exhaust Fans Running Combinations	**No Fan**	**120 s**			**2 hr**
	SW 1 or 2	**120 s**			**2 hr**
	SW 3 or 4		**120 s**		**2 hr**
	Any Tunnel Fan (TF)			**120 s**	**2 hr**
	SW 1 or 2 + SW 3 or 4	**240 s**	**240 s**		**2 hr**
	SW 1 or 2 + any TF	**240 s**		**240 s**	**2 hr**
	SW 3 or 4 + any TF		**240 s**	**240 s**	**2 hr**
	SW 1 or 2 + SW 3 or 4 + any TF	**360 s**	**360 s**	**360 s**	**2 hr**

12.4 Particulate Matter Concentration Methods

TSP. The TSP mass concentration of the exhaust air is measured by the Rupprecht & Patashnick TEOM series 1400a PM_{10} monitor (Appendix M) designated as Reference Method number EQPM-1090-79 as per 40 CFR Parts 58. For measuring TSP, The PM_{10} inlet will be replaced by a TSP inlet. The TEOM 1400a is a true gravimetric instrument that draws ambient air through a filter at a constant flow rate, continuously weighting the filter and calculating near real-time (2 sec) mass concentration. The mass concentration is calculated by the exponential smoothing based on the total mass loaded on the filter. The TSP TEOM is operated in the house with a flow rate of 16.7 L/min (1 L/min main flow and 15.67 L/min auxiliary flow); the total mass and mass rate/mass concentration averaging times are set at 300 seconds; the temperature of the sample stream will be set at 50^oC. The mass concentration unit of ug/m^3 is used. The output of the mass concentration is based on a standard temperature and pressure of 25^o C and 1 atmosphere (atm), respectively.

<u>PM_{10}.</u> The PM_{10} mass concentration of the exhaust air is measured by the Rupprecht & Patashnick TEOM series 1400a PM_{10} monitor (Appendix N) designated as Reference Method number EQPM-1090-79 as per 40 CFR Parts 58. The TEOM 1400a is a true gravimetric instrument that draws ambient air through a filter at a constant flow rate, continuously weighing the filter and calculating near real-time (2 sec) mass concentration. The mass concentration is calculated by the exponential smoothing based on the total mass loaded on the filter. The PM_{10} TEOM is operated in the house with a flow rate of 16.7 L/min (1 L/min main flow and 15.67 L/min auxiliary flow); the total mass and mass rate/mass concentration averaging times are set at 300 seconds; the temperature of the sample stream is set at 50^o C. The mass concentration unit of ug/m^3 is used. The output of the mass concentration is based on a standard temperature and pressure of 25^o C and 1 atmosphere (atm), respectively.

<u>$PM_{2.5}$.</u> The $PM_{2.5}$ mass concentration of the exhaust air is measured with the Rupprecht & Patashnick TEOM series 1400a PM_{10} monitor (Appendix O) with the addition of the $PM_{2.5}$ cyclone designated as Reference Method number EQPM-1090-79 as per 40 CFR Parts 58. The $PM_{2.5}$ TEOM is operated in the house with a flow rate of 16.7 L/min, with the total mass and mass rate/mass concentration averaging times set at 300 seconds. The detection limit of the TEOM is 0.01 ug/m^3. TEOM is a U.S. EPA recognized, correlated acceptable continuous monitor for continuous $PM_{2.5}$ measurements.

TSP, PM_{10} and $PM_{2.5}$ TEOMs are placed in the houses at location SW1 or tunnel end (Figure 11.1 and 11.2). The analog outputs (mass concentration, pressure drop percentage and auxiliary flow rate) from TSP, PM_{10} and $PM_{2.5}$ TEOMs will be connected to and recorded by compact Fieldpoint. With the fan flow rate from fan runtime monitoring and calibrated fan curve, the particulate matter emission will be calculated (see Appendix J). During the brooding period, the TEOMs are placed at SW1 sampling location. When the brood curtain is open, the TEOMs are moved to the tunnel end sampling location. Because of the intermittent fan operation in broiler houses it is critical that PM concentration be correlated to fan operational periods to avoid large over-estimation of the PM emissions. The TEOMs provide time-stamped data required for an accurate calculation of TSP, PM_{10} and $PM_{2.5}$ emissions.

Table 12.2. Particulate Matter Sampling Locations and Sampling Methods/SOPs

	Sidewall fan 1 (SW1)	**Tunnel end (TE)**
Location ID number	**1**	**3**
Analytical parameters	**TSP, PM_{10}, $PM_{2.5}$**	**TSP, PM_{10}, $PM_{2.5}$**
Sampling SOP	**Appendix M, N and O**	**Appendix M, N and O**
Sample flow rate	**1 L/min**	**1 L/min**
Sampling average time	**30 s**	**30 s**
Sampling period	**Brooding**	**Full house**

12.5 Environment Conditions Sampling

Electronic transmitters (Vaisala Model HMW 61U) will be used to monitor relative humidity in the houses, while type T thermocouples will be used to monitor indoor air temperature at the air sampling locations. A 0.0 to 0.5 inch WC (0 to 125 pa) differential pressure transducer (Setra Model 264) will be used to measure house static pressure. An 800-1100 mbar barometric pressure sensor (WE100) will be used to measure atmospheric pressure. For more details on the operation and specifics for the Vaisala Model HMW 61U, type T thermocouple, Setra Model 264, and WE100, see Appendix E and F.

12.6 Ventilation Rate Sampling

A device for in-situ exhaust fan airflow capacity measurement, referred to as the Fan Assessment Numeration System (FANS) device, previously developed and constructed at the USDA-ARS Southern Poultry Research Laboratory, was refined and reconstructed by UK (Gates et al., 2004). FANS measures the total airflow rate of a ventilation fan by integrating the intake velocity field obtained from an array of five propeller anemometers used to perform a real-time traverse of the airflow entering ventilation fans of up to 122 cm (48 in) diameter. At the beginning of the project, all 14 ventilation fans in each house were calibrated by FANS and fan curves were developed. Three to four fans in each house (at least 20% of the total fans) are randomly chosen and calibrated at the beginning of each flock. The fan running status is monitored by an induction current switch (Muhlbauer et al., 2006). The voltage signal from induction current switches attached to the fan power cords are sampled every second and recorded into the compact Fieldpoint modules every 30 seconds as the average or duty cycle of the time interval (see Appendix R).

12.7 DAQ System Recording Methods

The RS232 output generated by the INNOVA 1412 analyzer, as well as the analog output signal from API 101 E, VIG Model 200, TSP PM_{10} and $PM_{2.5}$ and the analog output signal other sensors for environmental conditions and equipment operations monitoring are logged by the National Instruments (NI) compact Fieldpoint control and measurement modules. The NI compact Fieldpoint is an expandable programmable automation controller composed of rugged I/O modules and intelligent communication interfaces. The monitoring and controlling program generated from LabView 7 is downloaded to the embedded controller and temperature, RH and pressure sensors connected directly to the analog and discrete I/O modules. The I/O modules are the cFP-TC-120 8-Channel Thermocouple input module, the cFP-AI-110 8-Channel Analog Voltage and Current input module, the cFP-AI-112 16-Channel Analog Voltage, and the cFP-DO-400 8-Channel digital output module. The signals from the analyzers and sensors are sampled every second and recorded into the compact Fieldpoint modules and on-site PC every 30 seconds as average or duty cycle of the time interval, see Appendix G. The recorded data will be managed by the following procedures in Section 20. Specifics sheets for the above listed materials are provided in Appendix V.

12.8 Sampling/Measurement System Corrective Action

Corrective action measures in the gas concentration, particulate concentration, ventilation rate, environment conditions, and DAQ system recording, will be taken to ensure the data quality objectives are attained. There is the potential for many types of sampling and measurement system corrective actions. If the corrective actions involve calibration, please check corresponding instrument SOPs. Table 12.3 details the expected problems and corrective actions.

Table 12.3 Possible problems and planned corrective actions.

Item	Problem	Action	Notification
Gas Concentration	NH_3, CO_2, NMHC, or CH_4 concentration from INNOVA 1412 out of Specification (± 5% of QC standard)	1). Check sampling line connection. 2). Replace inlet filter. 3). Recalibrate	Document on field data sheet
Gas Concentration	H_2S concentration out of Specification (± 5% of QC standard)	1). Check sampling line connection. 2). Recalibrate	Document on field data sheet
Gas Concentration	NMHC or CH_4 concentration from VIG 200 out of Specification (± 5% of QC standard)	1). Check sampling line connection. 2). Recalibrate	Document on field data sheet
Gas Sampling	Low flow rate in sampling manifold	1). Check solenoid valve and pump. 2). Check in line filters. 3). If any valve or pump fails, replace it. 4). If inline filter is clogged, replace it.	Document on field data sheet
Gas Sampling	Sampling line air leakage	1). Check all tubing adaptors on the sampling line. 2). If need, change the adaptors.	Document on field data sheet
Gas Sampling	Heat traced and heat taped sampling line temperature out of control	1). Turn off all pumps and stop sampling. 2). Check program. 3). Check line voltage.	Document on field data sheet Notify ISU personnel

		4). Check control module. 5). Check control relay.	
PM Concentration	Air leak	Inspect all seals and O-rings, replace as necessary and re-perform leak test	Document on field data sheet
Environment Conditions	Temperature out of Specification (±0.5°C)	Replace thermocouple	Document on field data sheet
Environment Conditions	Relative humidity out of Specification (±5% of QC standard)	Recalibrate	Document on field data sheet
Environment Conditions	Barometric pressure out of Specification (±5% of QC standard)	Recalibrate	Document on field data sheet
Environment Conditions	Static pressure out of Specification (±5% of QC standard)	Recalibrate	Document on field data sheet

Item	Problem	Action	Notification
Power	Power Interruptions	1). Check UPS log event from computer. 2). Check line voltage	Document on field data sheet Notify field manager
DAQ	PC locked up	Reboot	Document on field data sheet Notify ISU personnel
DAQ	No internet connection	1). Check satellite modem. 2). Check satellite dish. 3). Check computer setup, open remote desktop. 4). If needed, reboot modem 5). If needed, contact with vender.	Document on field data sheet Notify ISU personnel
DAQ	No connection between compact Fieldpoint and PC	1). Check cable. 2). Check router. 3). Check PC IP address.	Document on field data sheet Notify ISU personnel
Instrument	Instrument failure	1). Contact ISU personnel. 2). Contact vender for technical support.	Document on field data sheet Notify ISU personnel
Ventilation Rate	Current Switch failure	Replace	Document on field data sheet

12.9 Litter Sampling

In House, Total Litter Sampling - The differences between brooding areas and non-brooding areas in terms of organic matter and nitrogen content and proximity of feeders and waterers to the sampling point within a broiler house make accurate sampling and nutrient testing essential if best management practices are to be followed during handling and land application of poultry litter (Singh et al., 2004). Currently, there are two preferred methods that are suitable for sampling litter, the trench and the point methods (random walking method). In the case of very dry litter (e.g., dry matter of 80% or more), it can be very difficult to dig a trench and obtain an intact sample using a shovel. Location of water lines and feeders may further complicate the process of digging trenches. It is also difficult to sample litter using the trench method when the birds are in the house. Alternatively, litter can be sampled using the point or random walking method. For this method, the number of random sampling points within each zone of a section should be proportional to the contributing area of that zone (Figure 12.3). Both the trench and point method lead to similar results but the point method has easy implementation with representative samples for analysis. The point method (or random walking method) is used for sampling broiler litter.

For the point method the broiler facility is divided in two main zones: non-brooding and brooding zone. Each zone is subdivided in three sections, for replication.

Zone: division of the facility (two zones per one facility)
Section: division of the zone (three sections per one zone)

The sampling points are distributed uniformly in each section. In order to obtain representative samples from each zone, the number of sub-samples taken from each section in areas affected by sidewall, feeders, waterers, and the central area are proportional to the areas they represented in the house. Twenty random samples are collected from each section inside of a zone, and pooled together to form one composite sample per section (three composite sub-samples per zone).

The samples are collected with a tulip bulb digger to a maximum depth of 7.6 cm. Samples from each subsection (20) are pooled together in a container and mixed thoroughly using a shovel before collecting a composite sample. About 1 kg sample from each subsection is stored in labeled plastic bags and transported in a cooler with ice packs to keep the temperature near 4°C. The excess sample left in the container is discarded. The sampling equipment is decontaminated by cleaning them with detergent, preferably anti-bacterial, after sampling each house.

Caked Litter Sampling – During the clean up between the flock, only the surface layer of litter (referred to as “cake”) is removed from the house. Shovel samples are taken from each load of removed cake and combined to form two, 20 L samples which are stored in plastic buckets. The two buckets are labeled and transported to a freezer at the UK Research and Education Center (less than an hour of transport time).

Sample Identification - The sample labels include site ID, sampling zone, sampling section and date. For example, a sample collected from site 3-3, from the brooding area and from the west side of the brooding area on Feb. 3, 2006 will be labeled as 3-3 loose B1 020306 where,

Site ID: 3-3 or 1-5
Type of litter:
Loose broiler litter: Loose Caked boiler litter: Cake
Sampling Zone:
Brood Area: B Non-Brood Area: N
Section:
West side: 1 Middle: 2 East side: 3
Date: mmddyr

The samples will be collected after the removal of each flock, and will be analyzed for pH, moisture content, ammonia, and total Kjeldahl nitrogen. Information on the analytical methods is in Section 14.

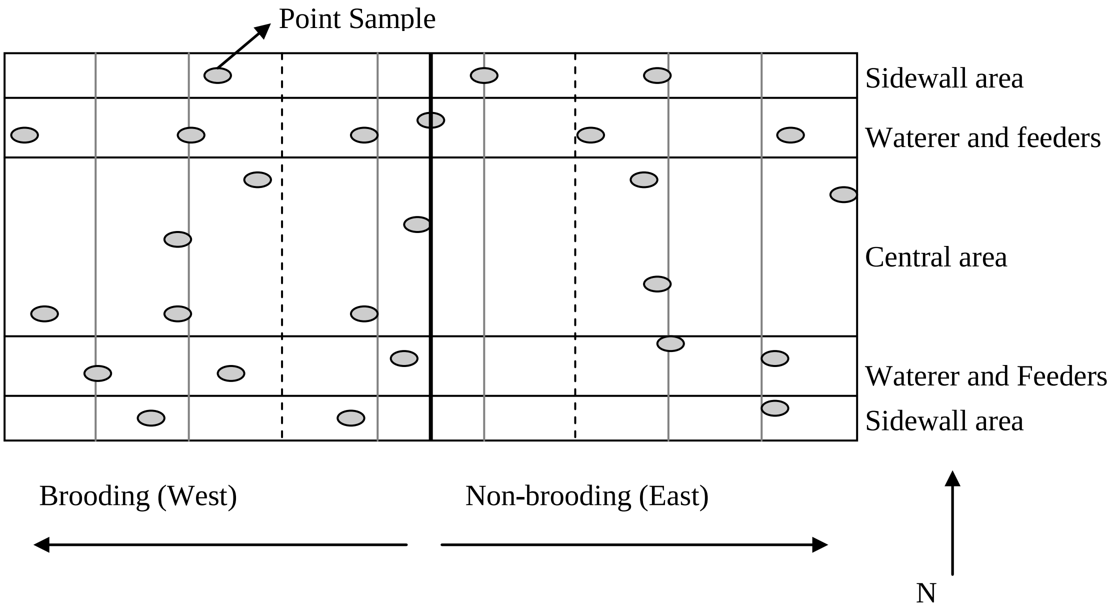


Figure 12.2. Schematic of litter sampling scheme.

13.0 Sample Handling and Custody

13.1 Gaseous and Particulate Matter Samples

Data recorded by the monitoring equipment will be available to authorized project members through remote viewing using LabView 7 over the Internet and will be handled and recorded as described in Section 20 – Data Management and in Appendix I.

13.2 Litter Samples

When litter samples are collected as described in Section 12.4 – Litter Sampling Methods, the following handling method is used. All collected samples are solid in nature. In-house, total litter samples are collected in one gallon air tight bags and cake litter samples are collected in 20 L plastic buckets. Samples are labeled by sample type, location, and date. An example of the sample label is included in Figure 13.1. Collected samples are transported to the UK Research and Education Center with a completed chain of custody form and stored in a freezer for transport to ISU for analysis. The chain of custody form is shown in Figure 13.2. The form is completed by the sampler and shipped with the samples inside of a Ziplock bag to the Agricultural Waste Management Lab at ISU. Coolers used for transport are taped closed and have a chain of custody seal placed over a location on the cooler closure. Samples are either shipped within 24 hrs via a ground transportation service or brought back by individuals returning to Iowa after working at the project site. If samples are shipped, the individual initiating the shipment contacts Lara Moody via email to notify her of the samples arrival and to provide her with a shipment tracking number. Samples are shipped to:

Lara Moody
Iowa State University
3252 NSRIC
Ames, IA 50011

Sample Date: _______________

Sample ID: _________________

Sample Type: _______________

Figure 13.1. Example litter sample label.

Upon arrival at the laboratory, a laboratory technician checks for shipment integrity and ensures the chain of custody seal is still intact on the cooler closure. The chain of custody form is retrieved from the samples. The completed chain of custody form is provided with the analysis results. Regulatory requirements indicate samples should be analyzed for ammonia and total Kjeldahl nitrogen to be analyzed within 28 days of collection. Samples are analyzed in the

Agricultural Waste Management Laboratory at ISU. Samples are analyzed for pH, moisture content, ammonia and total Kjeldahl nitrogen. Samples arriving at the Agricultural Waste Management Laboratory are logged into the laboratory's "Samples to Analyze" notebook. Information entered into the notebook for each sample set includes: date of arrival, sample sender, sample receiver, sample storage (refrigerator, freezer, freezer to freeze dry, or ambient), sample set ID and date, required analyses, and project ID. Analyzed samples are held by the laboratory until the results are reviewed. After acceptance of the litter analysis data, the project PIs give the laboratory permission to dispose of the samples. It is the responsibility of the lead PI, Robert Burns, to oversee the filing and archiving of the sample handling documents.

Sample Collection and Chain of Custody Form

(fill out one form for each shipping container used)

Sample Collector Information	**Shipping Information**	**For Lab Use Only**
Organization Name: **Address:**	**Lab Name:** Iowa State University Agricultural Waste Management Lab **Address:** 3165 NSRIC Ames, IA 50010 Ph.: (515) 294-4167 Fax: (515) 294-4250	**Date received:** **Time received:** **Sample temperature on receipt:** **Sample condition on receipt:**
Sampler Name:	**Date Shipped:** **Carrier:**	

Sample Identification and Collection Information

Facility ID:	**Sample collection point ID:**	**Sample collection date:**	**Sample volume:**	**Number of containers per sample:**	

Additional Comments:

Sampler signature:

Date:

Lab technician signature:

Date:

Figure 13.2. Litter sample chain of custody form

14.0 Analytical Methods

14.1 Litter Samples

All litter samples will be processed by the Agricultural Waste Management Laboratory in the Department of Agricultural and Biosystems Engineering at ISU. Upon arrival, samples are placed in the cooler at 4° C. Moisture Content and pH are analyzed within 7 days after arrival. Also, the samples are freeze dried and ground within 7 days after arrival. The ground samples are then placed in a freezer at -20° C until analysis. The ground samples are then analyzed for extractable ammonia and total Kjeldahl nitrogen. The methods and equipment to be used are shown in Table 14.1. Full method descriptions are included in Appendix S.

The laboratory manager is responsible for obtaining and completing the Chain of Custody form. The manager acts as the common point of reference between activities performed in the laboratory and activities required by the project PIs. The laboratory manager is responsible for result reporting and laboratory analysis quality control (QC) checks.

The laboratory currently maintains QC by performing triplicate analysis and spike matrices on methods used. For this project, triplicate analyses and spiked matrices are performed on one sample from each between-flock sampling period.

Analyzed samples are placed in a freezer at -20°C for archiving until the project PIs permit sample disposal. Samples will be disposed of in accordance with ISU Environmental Health and Safety requirements. If a failure in one of the analytical systems occurs, Lara Moody is to be contacted. She will then notify the lead project personnel. If the problem cannot be resolved in a time period sufficient to complete the analyses, the samples will be analyzed using an equivalent alternative method or instrument.

Table 14.1. Methods for litter analysis.

Parameter	**Method**	**Quantity**	**Container**	**Preservative**	**Analytical Instrument**
pH (water 1:2)	Manure pH (Combs et al., 2003)	20 g	Ziplock Bag	Cool to 4°C	Orion 4-Star pH meter
Moisture Content	Standard Method 2540 G (APHA et al., 1998)	2 g	Ziplock Bag	Cool to 4°C	Fisher Isotemp Oven
Ammonia	Standard Methods 4500-NH_3 B & C (APHA et al., 1998)	20 g	Ziplock Bag	Cool to 4°C	Labconco Rapid Still II
Total Kjeldahl Nitrogen	Standard Methods 4500-N_{org} D and C (APHA et al., 1998)	5 g	Ziplock Bag	Cool to 4°C	Labconco Block Digester and Rapid Still II

15.0 Quality Control Measures

Quality assurance and quality control include the use of properly maintained and reliable instrumentation, approved analytical methodologies and standard operating procedures, external validation of data, well-trained analysts, audits, and documentation. When appropriate, published EPA analytical methodologies are used. The QC measurements for all instruments are listed in the table 15.1. Logs are maintained for each instrument.

Specific quality control procedures will include the following:

1. A measurement of certified zero air is included as a field blank for gas concentration measurements once a week.
2. A replicated multipoint calibration of analyzers is performed initially and whenever the span checks are beyond the acceptable limits shown in Table 15.1.
3. Calibration checks (zero and span) of gas analyzers are conducted twice a week. Calibration records are maintained in the project logbook.
4. Thermocouples are calibrated before and after the 6-month collection period with spot checks of each sensor every flock.
5. Relative humidity probes are tested with a National Institute of Standards and Technology (NIST) transfer standard or equivalent every 6 months.
6. Calibrations of the differential pressure transmitters are conducted every 6 months. Zero checks are conducted every flock.
7. Barometric sensors are tested every 6 months and calibrated if the zero or span drift is beyond the acceptable limit shown in Table 15.1.
8. The TSP, PM_{10} and $PM_{2.5}$ TEOM analyzers are maintained weekly and calibrated yearly.
9. Online results of all the continuous measurement variables are displayed on a PC video monitor and published to the Web where continuous Internet connection is available. Project personnel check the online display at least daily by either remote or on-site access.
10. An email alarm mechanism was developed and is used when critical data is out of range, which could be caused by malfunction of instruments, over detection limit of instruments and power failures. The alarm email is generated automatically by the program and sent to all project personnel. The problems are addressed and solved the next business day.
11. Logged data files in the PC in the previous day are checked the next business day to find and correct any problems with the system.
12. Experienced analysts run all equipment.
13. An uninterruptible power supply with battery backup is used to prevent damage to sensitive equipment and data loss in case of power failure.
14. Surge suppressors are used to protect the PC and the instruments.
15. Internal performance and internal and external system audits are performed to evaluate the accuracy of field measurements of air pollutants.

Table 15.1. QC checks of the project

Category	**Requirement**	**Frequency**	**Acceptance Criteria**	**Analyzer**	**Reference**	**Information provided**
Calibration Standards	Flow rate	1/yr	±2 % of NIST-traceable standard			Certification of Traceability
Calibration Standards	Thermometer	1/yr	±0.1 ^oC resolution			Certification of Traceability
Calibration Standards	Field Barometer	1/yr	±1 mm Hg resolution			Certification of Traceability
Calibration/ Verification	NH_3	if needed	±5 % of Transfer standard	Innova 1412	Appendix D	Calibration drift/Verification to assure proper function
Calibration/ Verification	CO_2	if needed	±5 % of Transfer standard	Innova 1412	Appendix D	Calibration drift/Verification to assure proper function
Calibration/ Verification	CH_4	if needed	±5 % of Transfer standard	Innova 1412	Appendix D	Calibration drift/Verification to assure proper function
Calibration/ Verification	Non-CH_4	if needed	±5 % of Transfer standard	Innova 1412	Appendix D	Calibration drift/Verification to assure proper function
Calibration/ Verification	H_2S	if needed	±5 % of Transfer standard	API 101 E	Appendix K	Calibration drift/Verification to assure proper function
Calibration/ Verification	NMHC	if needed	±5 % of Transfer standard	VIG 200	Appendix L	Calibration drift/Verification to assure proper function
Calibration/ Verification	CH_4	if needed	±5 % of Transfer standard	VIG 200	Appendix L	Calibration drift/Verification to assure proper function
Calibration/ Verification	Temperature	if needed	±0.5 oC	Type-T Thermocouple	Appendix E	Calibration drift/Verification to assure proper function
Calibration/ Verification	Static pressure	if needed	±5 % of Transfer standard	Setra 264	Appendix F	Calibration drift/Verification to assure proper function
Calibration/ Verification	Relative humidity	if needed	±5 % of Standard	Vaisala HMW61 U	Appendix E	Calibration drift/Verification to assure proper function
Calibration/ Verification	Barometric pressure	if needed	±5 % of Transfer standard	WE100	Appendix P	Calibration drift/Verification to assure proper function
Calibration/ Verification	Flow controller (software)	1/Six month	±5 % of Transfer standard	TEOM	Appendix M, N, O	Calibration drift/Verification to assure proper function
Calibration/ Verification	Flow controller (Hardware)	1/yr	±5 % of Transfer standard	TEOM	Appendix M, N, O	Calibration drift/Verification to assure proper function
Calibration/ Verification	Analog I/O Amplifier board Ambient air temp Ambient pressure Mass transducer	1/yr	±5 % of Transfer standard	TEOM	Appendix M, N, O	Calibration drift/Verification to assure proper function
Accuracy or Bias Checks/ Audits	GSS Leak Check	1/Flock	±5 % of Transfer standard	GSS	Appendix B (Inject cal-gas from sampling port)	Measure system bias
Accuracy or Bias Checks/ Audits	GSS flow rate check	2/week	±5 % of Transfer standard	GSS	Appendix B (Check flow rate)	Measure system bias
Accuracy or Bias Checks/	NH_3	2/wk	±5 % of Transfer standard	Innova 1412	Appendix D	Instrument bias

Audits						
Accuracy or Bias Checks/ Audits	CO_2	2/wk	±5 % of Transfer standard	Innova 1412	Appendix D	Instrument bias
Accuracy or Bias Checks/ Audits	CH_4	2/wk	±5 % of Transfer standard	Innova 1412	Appendix D	Instrument bias
Accuracy or Bias Checks/ Audits	Non-CH_4	2/wk	±5 % of Transfer standard	Innova 1412	Appendix D	Instrument bias
Accuracy or Bias Checks/ Audits	H2S	2/wk	±5 % of Transfer standard	API 101 E	Appendix K	Instrument bias
Accuracy or Bias Checks/ Audits	NMHC	2/wk	±5 % of Transfer standard	VIG 200	Appendix L	Instrument bias
Accuracy or Bias Checks/ Audits	CH4	2/wk	±5 % of Transfer standard	VIG 200	Appendix L	Instrument bias
Accuracy or Bias Checks/ Audits	Static pressure (0 point)	1/Flock	±5 % of Transfer standard	Setra 264	Appendix F	Instrument bias
Accuracy or Bias Checks/ Audits	Relative humidity	1/Six months	±5 % of Standard	Vaisala HMW61 U	Appendix E	Instrument bias
Accuracy or Bias Checks/ Audits	Barometric pressure	1/Six months	±5 % of Transfer standard	WE100	Appendix P	Instrument bias
Accuracy or Bias Checks/ Audits	Leak Check	1/Flock	±5 % of Transfer standard	TEOM	Appendix M, N, O	Instrument bias
Accuracy or Bias Checks/ Audits	Change inlets	Everyday	±5 % of Transfer standard	TEOM	Appendix M, N, O	Instrument bias
Accuracy or Bias Checks/ Audits	Exhaust fan	1/flock	±10 % of Transfer standard	FANS	Appendix C	Instrument bias
Data Quality	Alarm	If needed			Appendix I	Data processing
Data Quality	Raw data check	Everyday			Appendix I	Data processing
Data Quality	Processing data	Everyday			Appendix I	Data processing

15.1 Calibration

Calibration is the comparison of a measurement standard or instrument with another standard or instrument to report, or eliminate by adjustment, any variation (deviation) in the accuracy of the item being compared. The purpose of calibration is to minimize bias.
For air and PM, calibration activities follow a two step process:

1. Certifying the calibration standard and/or transfer standard against an authoritative standard
2. Comparing the calibration standard and/or transfer standard against the routine sampling/analytical instruments

Calibration requirements for the critical field and equipment are found in Table 15.1; the details of the calibration methods are included in the calibration section (Section 17) and Appendixes for SOPs.

15.2 Accuracy or Bias Checks

Accuracy is defined as the degree of agreement between an observed value and an accepted reference value and includes a combination of random error (precision) and systematic error (bias). In this program, the following accuracy checks are implemented:

- GSS leak check and flow rate checks
- Gas analyzer checks
- TEOMs flow rate audit
- TEOMs leak checks
- Static pressure checks
- Relative humidity checks
- Barometric pressure checks
- Exhaust fans flow rate checks

GSS leak check and flow rate check

The response times of the analyzers have been tested in the lab. However, the actual on-site performance of the sampling system had to be tested also. Therefore, ammonia span gas was injected into a sampling line on-site through the longest sampling line (tunnel end) (Figure 15.1). The results of INNOVA 1412 analyzers from both houses are shown in Figures 15.2 and 15.3. For both sampling system, the fourth ammonia concentration readings (30 s X 4=120 s) reached 96% and 97% of the span concentration.

Figure 15.1. Picture of span gas injection from sampling points.

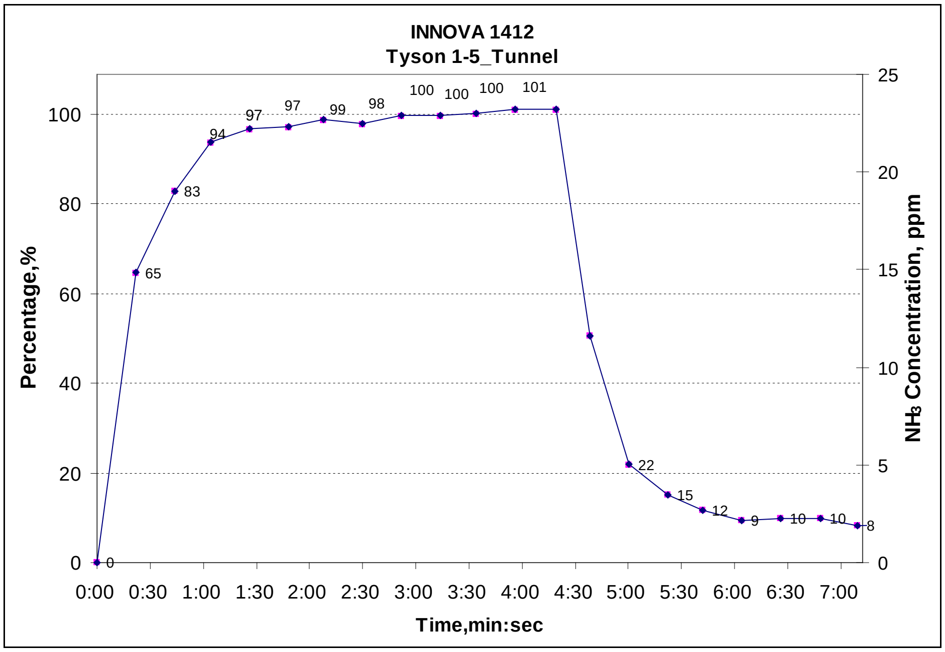


Figure 15.2. Tyson 1-5, sampling system and INNOVA analyzer response time check.

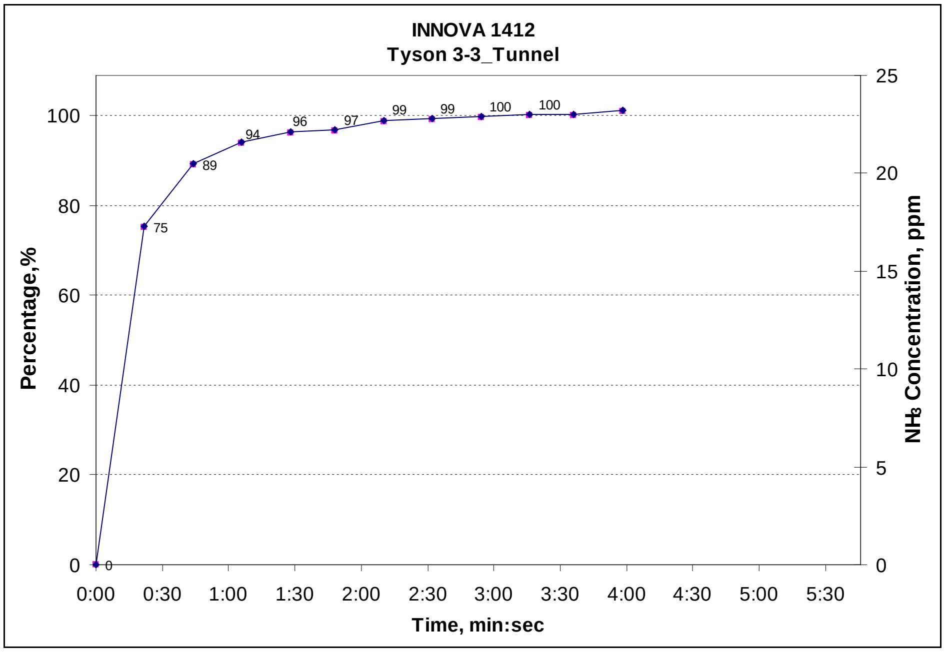


Figure 15.3. Tyson 3-3, sampling system and INNOVA analyzer response time check.

As well as using span gas to challenge the sampling system at one location, multiple point sampling system tests have been done by comparing the readings of INNOVA 1412 analyzer inside of the monitoring trailer with three INNOVA 1412 analyzers located at three sampling locations (SW1, SW3 and TE). Three INNOVA 1412 analyzers were located near the three sampling locations and continuously took samples during the whole testing period (Figure 15.4).

All INNOVA 1412 analyzers were synchronized and calibrated by the same NH_3 calibration gases before this test.

Figure 15.4. INNOVA side-by-side comparison between in-house and MAEMU NH_3 readings.

At Tyson 1-5 site, the number of sampling cycles per location of the INNOVA in the MAEMU were set to 4, 6 and 8 per location for testing the response time effect. The NH_3 readings from the INNOVA 1412 in the MAEMU were compared with the readings in three locations (Figure 15.5). Only the last readings from the MAEMU in each sampling cycle at each location were compared with the most recent readings from the INNOVAs in the houses. At the Tyson 1-5 site, five pairs of readings for each sampling number at each location were chosen. Two-way ANOVA test was used for the statistic analysis. There was neither a sampling number effect nor location effect ($P = 0.37$). Table 15.2 provides a comparison of continuous in-house NH_3 readings with those obtained from location cycling by the MAEMU INNOVA at 4, 6, or 8 sampling iterations from Tyson 1-5 (unit: ppm). It indicated that the NH_3 reading in the MAEMU matched to the reading in the house at all three locations and there was no difference for using 4, 6 and 8 sampling numbers at each location. As such, four sampling iterations were chosen to reduce the time required to cycle from each sampling location in the house. Because fan operation periods can be as short as 30 seconds in a typical broiler facility, it is very important to move between sample locations quickly to capture temporal variability due to fan operation cycles as ammonia-laden air is exhausted and fresh air is introduced through the box inlets. Because four samples were proven to provide equivalent performance as a higher sampling frequency, only a 4-cycle test was performed at Tyson 3-3. The value of this test at both Tyson 1-5 and Tyson 3-3 was to provide an indirect leak check of each sample line system and the GSS in each MAEMU. Since the NH_3 reading in the MAEMU matched the reading in the house at each location, it can be concluded that no dilution air was entering the system, thus, no leakage was occurring.

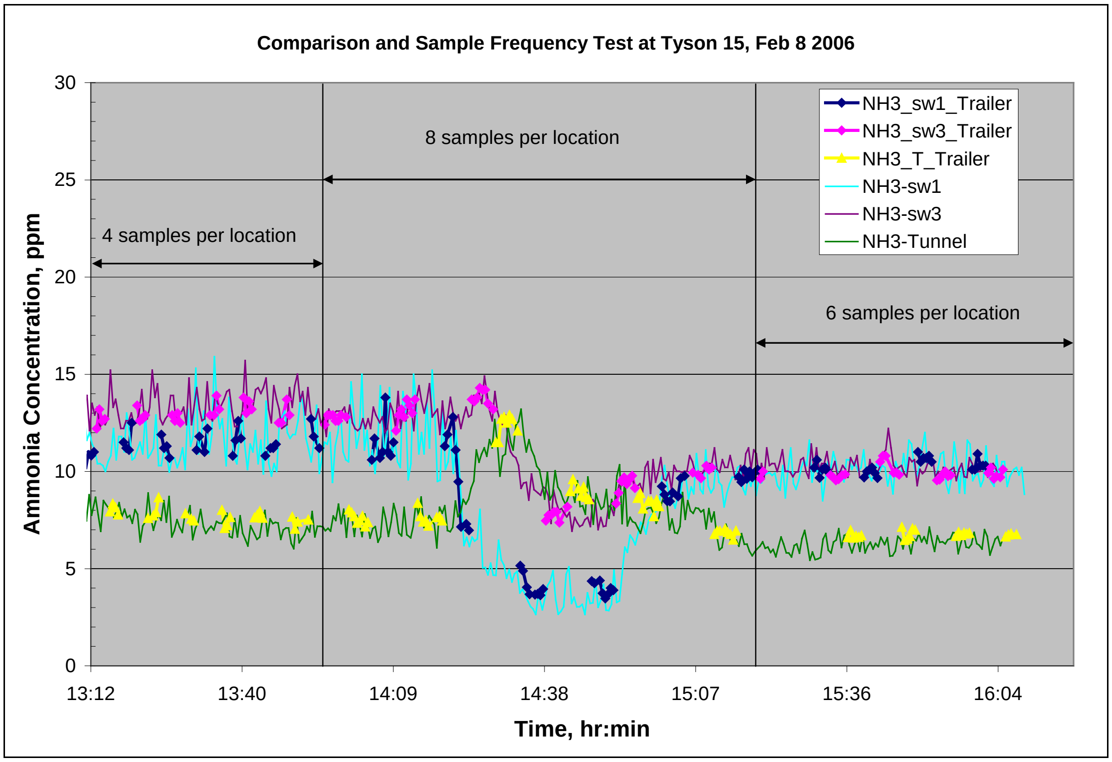


Figure 15.5. Ammonia readings from the MAEMU and in-house INNOVAs

At Tyson 3-3 site, six pairs of readings at each location with four sampling numbers were chosen. A one-way ANOVA test was used for the statistic analysis. There was no location effect for NH_3 reading in the trailer (P = 0.26). Table 15.3 provides a comparison of continuous in-house ammonia readings with those obtained from location cycling by the MAEMU INNOVA at four sampling iterations at Tyson 3-3 (unit: ppm). The mean values are $NH_{3(in\text{-}house)} - NH_{3(MAEMU)}$.

It indicated that the NH_3 reading in the trailer matched the reading in the house at all three locations.

Table 15.2. Comparison of in-house NH_3 readings with those obtained from location cycling by the MAEMU INNOVA

No. of sampling iterations	$NH_{3(in\text{-}house)} – NH_{3(MAEMU)}$ For sampling locations of			(ppm)	P=0.37
	SW1	SW3	Tunnel	Mean	SD
4	0.72	0.20	0.31	0.41^{a}	0.65
6	0.26	0.08	-0.19	0.05^{a}	0.37
8	0.18	-0.02	0.46	0.20^{a}	0.39
Mean	0.39^{b}	0.09^{b}	0.19^{b}	Total mean	0.22
SD	0.66	0.33	0.40	Total SD	0.50

*Column or row means with the same superscript letter are not significantly different (P>0.10)

Location	Mean (ppm)	SD
SW1	0.45^{a}	0.46
SW3	0.03^{a}	0.83
Tunnel	-0.27^{a}	0.98
Total	0.03	0.82

*Column means with the same superscript letter are not significantly different (P>0.10)

GSS flow rate check

The sampling flow rate at each sampling line is checked by monitoring the air flow rate at each sampling port through an in-line flow indicator. The flow rate change between two check points should be lower than the QC standard.

Corrective action- The whole sampling line and all connectors will be inspected and the leakage will be sealed.

Gas Analyzer Checks

The analyzers of INNOVA 1412, API 101E and VIG 200 are challenged by NIST-traceable calibration gases. The interferences of each gas are tested as well. For INNOVA 1412, the interference of gases will be compensated by the analyzer self. For API 101E and VIG 200, the interference will be recorded.

Corrective action- The analyzer will be calibrated.

TEOMs flow rate audit

This flow rate audit means the flow controller audits. Details of the audit are included in the TEOM manual and Appendixes M, N and O. The audit is made by measuring the analyzer's normal operating flow rate using a certified flow rate transfer standard.

Corrective action- The flow controller will be calibrated.

TEOMs leak checks

A leak check is performed after every movement of TEOMs and inlet change. A leak test kit will be used.

Corrective action- The whole sampling lines and all connectors will be inspected and the leakage will be sealed.

Static pressure checks
The static pressure sensors are tested under “0” differential pressure condition. Details of the audit are included in the SOP of differential static pressure sensor transmitters (Appendix F).

Corrective action- The transmitter will be calibrated.

Relative humidity checks
The relative humidity sensors are tested with multiple points. Details of the audit are included in the SOP of temperature and humidity measurement (Appendix E).

Corrective action- The transmitter will be calibrated.

Barometric pressure checks
Details of the audit are included in Appendix P. The audit is made by measuring the sensor’s normal operating pressure using a certified barometric pressure transfer standard.

Corrective action- The barometer will be calibrated.

Exhaust fans flow rate checks
Twenty percent of the total exhaust fans are calibrated and details of the checks are included in Appendix C. The audit is made by measuring the fan flow rate using the FANS system.

Corrective action- All exhaust fan will be calibrated.

15.3 Data Quality Control

Online results of all the continuous measurement variables are displayed on a PC video monitor and published to the Web where continuous Internet connection is available. Project personnel check the online display at least daily by either remote or on-site access. An email alarm mechanism was developed and is used when critical data is out of range, which could be caused by malfunction of instruments, over-detection limit of instruments and power failures. The alarm email is generated automatically by the program and sent to all project personnel. The problems are addressed and solved the next business day. Logged data files in the PC in the previous day are checked the next business day to find and correct any problems with the system. Details of data processing are included in Sections 20 and 24.

15.4 Control Charts

Control charts are used extensively by the project. They provide a graphical means of determining whether various phases of the measurement process are in statistical control. The project utilizes charts which graph single measurements of a standard or a mean of several measurements. Table 15.3 indicates which QC samples are control charted.

Table 15.3 Control charts

QC Check	**Plotting technique**
GSS leak check	Single values plotted
GSS flow rate check	Single values plotted
Innova check	Single values plotted
API 101 E check	Single values plotted
VIG 200 Check	Single values plotted
TEOM leak check	Single values plotted
TEOM flow controller check	Single values plotted
Static pressure sensor check	Single values plotted
Relative humidity check	Single values plotted
Barometric pressure check	Single values plotted
Exhaust fans flow check	Multiple values plotted

16.0 Instrument/Equipment Testing, Inspection, and Maintenance

The purpose of this element in the QAPP is to discuss the procedures used to verify that all instruments and equipments are maintained in sound operating condition and are capable of operating at acceptable performance levels. See Section 9 for document and record details.

16.1 Testing

All instruments and equipment are or will be purchased new with NIST-traceable or manufactory certifications. The INNOVA 1412, API 101E and VIG 200 are calibrated with NIST-traceable certification. The project personnel runs the analyzers at the laboratory. NIST-traceable calibration gases are used for the verification checks. If any of these checks are out of specification (see Table 15.1), the project personnel contacts the vendor for initial corrective action. Once installed at the sites, the field operators run the tests mentioned above. These tests are properly documented and filed as indicated in Section 9.

16.2 Inspection

Inspection of various equipment and components are provided here. Inspections are subdivided into two sections: one pertaining to online monitoring and one associated with field activities.

Online monitoring

Online monitoring is performed daily through real-time display on computers. There are several items that need daily inspection in the online monitoring. Table 16.1 details the items to inspect and how to appropriately document the inspection.

Inspection of Field Items

There are several items that need inspection in the field. Table 16.2 details the items to inspect in the field and how to appropriately document the inspection.

Table 16.1. Inspections online

Item	Inspection Frequency	Inspection Parameter	Action if Item Fails Inspection	Documentation Requirement
Innova 1412	Daily	Sampling frequency 30~32 sec	Check analyzer Call service provider that holds maintenance agreement	1). Document in logbook 2). Notify field personnel
API 101E	Daily	H_2S concentration > 0 ppb	Check analyzer Call service provider that holds maintenance agreement	1). Document in logbook 2). Notify field personnel
VIG 200	Daily	Concentration > 0 ppm	Check analyzer Call service provider that holds maintenance agreement	1). Document in logbook 2). Notify field personnel
Computer	Daily	Remote desktop	Reboot computer	1). Document in logbook 2). Notify field personnel
Internet Service	Daily	IP address	Check satellite receiver and modem Call service provider that holds maintenance agreement	1). Document in logbook 2). Notify field personnel
Heat trace temperature	Daily	Temp. > 45 ^{o}C	Check compact Fieldpoint Check breaker Check AC relay	1). Document in logbook 2). Notify field personnel
Heat tape temperature	Daily	Temp. > 40 ^{o}C	Check compact Fieldpoint Check breaker Check AC relay	1). Document in logbook 2). Notify field personnel
Static pressure	Daily	$\Delta P > 0$ when fans are on	Check compact Fieldpoint Check fuses on board Check signal wire	1). Document in logbook 2). Notify field personnel
Trailer temperature	Daily	20-30 ^{o}C	Check thermostat Check heater Check AC	1). Document in logbook 2). Notify field personnel
TEOM filter load	Daily	< 10%	Change filters	1). Document in logbook 2). Notify field personnel
TEOM main flow rate	Daily	1 L/min	Check pump Check in-line filter Leak check	1). Document in logbook 2). Notify field personnel
Barometric pressure check	Daily	0.97-1.0 bar	Check compact Fieldpoint Check fuses on board Check signal wire	1). Document in logbook 2). Notify field personnel
Relative humidity sensor	Daily	10-99%	Check compact Fieldpoint Check fuses on board Check signal wire	1). Document in logbook 2). Notify field personnel

Table 16.2. Inspections performed in the field before and after samples are taken.

Item	**Inspection Frequency**	**Inspection Parameter**	**Action if Item Fails Inspection**	**Documentation Requirement**
Innova 1412	Twice/wk	Self check warning message	Check analyzer Call service provider that holds maintenance agreement	Document in logbook
API 101E	Twice/wk	Warning message	Check analyzer Call service provider that holds maintenance agreement	Document in logbook
VIG 200	Twice/wk	Pressure	Check analyzer Check corresponding gas tank Call service provider that holds maintenance agreement	Document in logbook
Gas tanks	Twice/wk	Pressure > 400psi	Replace	Document in logbook
GSS Flow meter	Twice/wk	~15 LPM	Check pump Check connectors Check sampling tubing	Document in logbook
TEOM in-line filters	Twice/wk	Loaded particulate	Change filters	Document in logbook
TEOM inlet heads	Twice/wk	Loaded particulate	Change inlet	Document in logbook
Fuses	Twice/wk	Continuity	Replace	Document in logbook
UPS	Twice/wk	Warning light	Check software Check breaker	Document in logbook
Air compressor	Twice/wk	55 psi	Check pump	Document in logbook
Zero Air generator	Twice/wk	Pressure 30 PSI	Adjust regulator	Document in logbook
Current switch	Every flock	ON/OFF	Replace	Document in logbook
Power supplies	Every flock	Measure the output voltage	Check fuses Replace	Document in logbook
Thermocouples	Every flock	0 to 50 ^{0}C	Replace	Document in logbook
Solenoid valve	Every flock	ON/OFF	Replace	Document in logbook
TEOM pump	Six months	Flow drop < 90%- with kits	Rebuild pump	Document in logbook

16.3 Maintenance

All analytical equipment is properly tested (as described in Section 15.1) and maintained regularly to ensure it is functioning properly in accordance with the manufacturer's recommended intervals and acceptance parameters. All equipment, including sampling pumps and analytical instrument, is inspected regularly during weekly site visits by the project field personnel. Equipment is repaired as soon as possible upon discovery of a problem. The manufacturer's instructions for routine maintenance of equipment are followed. Standard operating procedures for each instrument included in the project are listed in the Appendices. Table 16.3 details the appropriate maintenance checks of the equipments and their frequency. All testing, inspection and maintenance activities are documented in the field project logbook. An example of the logbook entry forms and entries are included in Appendix T.

Table 16.3 Preventive Maintenance of Field Items

Item	**Maintenance Frequency**	**Location Maintenance Performed**
INNOVA Calibration	Twice/week	Field
VIG Calibration	Twice/week	Field
TEOM inlet heads	Twice/week	Field
TEOM filter	Weekly	Field
Poultry Scale System RSC-2	Weekly	Field
Computer Virus Check	Weekly	Field
Sampling port filter	Weekly	Field
Computer files backup	Weekly	Field
TEOM leak check	Twice/flock	Field
Polytron I	Every flock	Field
Thermocouple	Every flock	Field
Current switch	Every flock	Field
Fan	Every flock	Field
GSS sampling line	Every flock	Field
Pump	Every flock	Field
Solenoid valve	Every flock	Field
Static pressure sensor	Every flock	Field
Humidity sensor	Every flock	Field
Barometric sensor	Every flock	Field
Air compressor	Every flock	Field
HVAC	Every flock	Field
Zero Air generator	Yearly	Field
TEOM	Yearly	Field

At the end of each grow-out and prior to entry of the next flock, the following maintenance checklist (see Appendix T) is performed on the broiler houses. Another checklist for six months and annual regular maintenance are shown in Appendix T.

17.0 Instrument/Equipment Calibration and Frequency

The TSP, PM_{10} and $PM_{2.5}$ analyzers (TEOM 1400, R & P Thermo Electron, East Greenbush, NY) are maintained weekly or more often as warranted. The TEOM 1400s are calibrated yearly. See Appendix M, N and O for SOPs. TEOM filters are changed weekly and TEOM inlet heads and 2.5 micron cut cyclones are exchanged with clean units semi-weekly.

At the beginning of the project, all fans were calibrated by FANS unit and fan curves were developed. Afterward, three to four fans from each house (less than 20% of the total fans) were randomly chosen and calibrated at the beginning of each flock. If the fan flow rates differences with the pervious calibration are larger than 10%, all fans were recalibrated. See Appendix C for SOP.

Calibration records of gas analyzers, RH sensors, pressure transmitters and TEOMs are maintained weekly with the schedule specified by the manufacturer in accordance with applicable standard operating procedures. The maintenance and calibration of the instruments are recorded in the Maintenance/Calibration sheets developed in each SOP. The records are submitted to and maintained by ISU and UK personnel on a weekly basis.

All the critical spare parts for the instruments are prepared and kept in the on-site MAEMUs. An inventory list of all spare parts is provided for each site. The manufacturer contact information is provided in the SOPs.

17.1 Instrumentation Requiring Calibration

17.1.1 INNOVA 1412 Multi-gas analyzer

Initially, a multipoint calibration of the analyzers is conducted in triplicate using either a precision gas mixing or dynamic dilution system with a span gas and zero air or multiple cylinders of calibration gases that provide a series of concentrations that span the range of expected concentrations for the target analysis. Accuracy and precision of the analyzer are determined from these measurements.

17.1.2 API 101E H_2S analyzer

Initially, a multipoint calibration of the analyzers is conducted in triplicate using either a precision gas mixing or dynamic dilution system with a span gas and zero air or multiple cylinders of calibration gases that provide a series of concentrations that span the range of expected concentrations for the target analysis. Accuracy and precision of the analyzer are determined from these measurements.

17.1.3 VIG 200 non-methane hydrocarbons analyzer

The VIG 200 non-methane hydrocarbon analyzer is challenged with zero air, an EPA protocol CH_4 span gas and an EPA protocol propane span gas. The routine check is conducted semi-weekly and the calibration is conducted if it cannot meet the QC limit of ±5%. See Appendix L for SOP.

17.1.4 Temperature, Pressure and Relative Humidity sensors

A precision ASTM mercury-in-glass thermometers (-8 to 32 °C and 25 to 55 °C, 0.1 °C precision) are used for calibrating thermocouple in the field as standard. A stationary mercury manometer in the UK laboratory is used as a primary standard to calibrate the one electronic barometer that go out in the field as transfer standards. An inclined manometer is used as a standard to calibrate differential pressure sensor.

The barometric pressure transmitters (WE100, Global Water, Gold River, CA) are calibrated prior to use and recalibrated every six months. See Appendix P for SOP.

The differential pressure transmitters (Model 264, Setra, Boxborough, MA) are calibrated prior to use and recalibrated at the conclusion of the test at 0 and typical building static pressure of 20-40 Pa by direct comparison with an inclined manometer every six months. The zero is checked monthly. See Appendix F for SOP.

A salt calibrator kit (Model HMK15, Vaisala, Woburn, MA) or equivalent methods are used to calibrate the capacitance-type RH sensors (HMW 61U, Vaisala, Woburn, MA) prior to commencing the study, and every six months thereafter if it cannot meet the QC limit of 5%. See Appendix E for SOP.

17.1.5 TEOM 1400 TSP, PM_{10} and $PM_{2.5}$ Particulate Monitors

Since the TEOM monitors can be directly mass calibrated, it can be directly quality assured using a mass standard. All QA procedures are coordinated with routine maintenance procedures to minimize down time. Procedures are based on routine flow auditing, leak checking, and mass calibration verification. See Appendix M, N and O for SOPs.

17.1.6 Field

As indicated above, the following calibrations are performed in the field:

- Calibration of gas analyzers in MAEMU against the bottle calibration standard gas.
- Calibration of thermocouples and pressure sensors against the NIST-traceable standard or transfer standard.
- Calibration of TEOMs against pre-weighed filters certified by the manufactory.
- Calibration of TEOM flow controller against a calibrated flow meter, transfer standard.

17.2 Calibration Method that Will Be Used for Each Instrument

17.2.1 INNOVA 1412 Gas Concentration Calibration

The calibration and QC checks of the INNOVA 1412 are addressed in Section 17.1.1 and Section 15 and Appendix D of this QAPP. The linearity of the INNOVA 1412 was tested in the range of 0 to 80 ppm. The gas concentration selected for the multipoint calibrations is 80% of the expected concentration levels. Routine calibration checks are conducted twice per week by introducing a span gas into manifold M2 (see Figure 1 of Appendix B). In this way, the calibration gas flows through the same plumbing that the samples flow through in the trailer except for the solenoids. Every site visit, zero gas and span gases are manually introduced into the analyzer. For INNOVA 1412 analyzers, PC-based calibration software (Gas Monitoring Software 7304, INNOVA) will allow consistent calibration, thus eliminating human error.

The INNOVA 1412 analyzers are challenged with zero air, span calibration gases. Certifications for calibration gases are according to EPA protocol, where available for a given concentration. The certified calibration gases consist of zero air, NH_3 in N_2, CO_2 in N_2, Methane in N_2 and Propane in N_2. All calibration gases need to have a certificate of analysis and not be used outside there expiration date. When calibration gases expire, new cylinders are purchased.

17.2.2 API 101E H_2S Gas Concentration Calibration

The calibration and QC checks of the API 101E are addressed in Section 17.1.2 and Section 15 and Appendix K of this QAPP. The linearity of the API 101E was tested in the range of 0 to 1000 ppb. The gas concentration selected for the multipoint calibrations was 90% of the expected concentration levels. Routine calibration checks are conducted twice per week by introducing a span gas into manifold M2 (see Figure 1 of Appendix B). In this way, the calibration gas flows through the same plumbing that the samples flow through in the MAEMU except for the solenoids. Every week, zero gas and diluted span gas are manually introduced into the analyzer. Certifications for calibration gases are according to EPA protocol, where available for a given concentration. The certified calibration gases consist of zero air, H_2S in N_2. All calibration gases need to have a certificate of analysis and cannot be used outside their expiration date. When calibration gases expire, new cylinders are purchased.

17.2.3 VIG 200 Gas Concentration Calibration

The calibration and QC checks of the VIG 200 are addressed in Section 17.1.3 and Section 15 and Appendix L of this QAPP. The VIG 200 non-methane hydrocarbon analyzer is challenged with zero air, an EPA protocol methane span gas and an EPA protocol propane span gas. The routine check is conducted semi-weekly and the calibration is conducted if it cannot meet the QC limit of ±5%. See Appendix L for SOP. All calibration gases need to have a certificate of analysis and cannot be used outside their expiration date. When calibration gases expire, new cylinders are purchased.

17.2.4 Thermocouple Temperature Calibration Procedure

All thermocouples for sampling ports are calibrated once per flock. A three-point verification/calibration is conducted at the field site. Several steps to follow in calibrating ambient air temperature are given in the following summary:

- Remove the ambient temperature thermocouple from the sampling pipe. Prepare a convenient container (an insulated vacuum/wide mouth thermos bottle) for the ambient temperature water bath and the ice slurry bath. Wrap the sensor(s) and a thermometer together with rubber band; ensure that all the probes are at the same level. Prepare the ambient or ice slurry solution. Immerse the sensor(s) and the attached thermometer in the ambient temperature bath. Wait at least 5 minutes for the ambient thermal mass and the sensor/thermometer to equilibrate. Wait at least 15 minutes for equilibration with the ice slurry before taking comparative readings.

- For each thermal mass, in the order of Ambient, Cold, Ambient, Hot, Ambient, make a series of five measurements, taken about 1 minute apart. If the measurements indicate equilibrium, average the five readings and record the result as the sensor temperature relative to the thermometer.

17.2.5 Pressure Calibration Procedure

A barometer can be calibrated by comparing it with a secondary standard traceable to a NIST primary standard. Protect all barometers from violent mechanical shock and sudden changes in pressure. A barometer subjected to either of these events must be recalibrated. Locate the instrument so as to avoid direct sunlight, drafts, and vibration.

A Fortin mercury type of barometer is used in the laboratory to calibrate and verify the aneroid barometer used in the field to verify the barometric sensors in field. Details are provided in Appendix P.

17.2.6 Relative Humidity Calibration Procedure

The functioning of the relative humidity calibration is based on the fact that certain salt solutions generate a certain relative humidity in the air above them. The salt solutions suitable for the calibration are lithium chloride LiCl (11% RH) and sodium chloride NaCl (75% RH). For calibration, the sensor head is inserted into a salt chamber containing a saturated salt solution. The probe/transmitter reading is then adjusted to the correct value. Calibration is usually performed at least at two different humidities to ensure the sensor accuracy over the entire humidity range (0-100 % RH). A relative humidity transmitter will be calibrated in the laboratory as a transfer standard for field calibration. Details of the calibration are provided in Appendix E.

17.2.7 TEOM 1400 TSP, PM_{10} and $PM_{2.5}$ Particulate Monitors Calibration Procedures

Procedures are based on routine flow auditing, leak checking, and mass calibration verification. Since the TEOM monitor can be directly mass calibrated, it can be directly quality assured using a mass standard. All QA procedures should be coordinated with routine maintenance procedures to minimize down time.

- Flow Audit: A flow audit adapter is provided and the procedures are outlined in the operating manual. Both the sample flow rate and total flow rate may be checked using the flow audit adapter with a capped nut for closing the flow splitter bypass line port. It is recommended that the volumetric flow rates be within ±7% of the set points. The U.S. EPA requires a tolerance of ±10% for the total flow through the inlet. If measured flows differ by more than the stated tolerances, recheck all settings, and perform the test again. Large errors in the flow may indicate other sources of error, such as a malfunctioning flow controller, a system leak, or improper temperature and pressure settings. The flow controllers of a TEOM are verified and calibrated by a certified calibrated flow meter. The details of the flow controller calibration are in the TEOM service manure Section 3.5.

- Leak Check: The leak check procedures are included in the operating manual (Section 7.6). The leak check is performed with NO sample filter attached to the mass transducer, which prevents accidental damage from occurring to the sample filter cartridge when exposed to the high pressure drop (vacuum) in the sample line that the leak check creates. Flow rates should indicate less than 0.15 L/min for the main flow and less than 0.65 L/min for the auxiliary flow with the end of the sample line closed, if not, systematically check plumbing for connector leaks.
- Mass Calibration Verification: The mass transducer is permanently calibrated and never requires recalibration under normal use. However, the mass measurement accuracy of the instrument may be verified following procedures in the operating manual. R&P offers a mass calibration verification kit to help perform this procedure. A detailed explanation of how the calibration is performed can be found in Appendix M, N, and O and TEOM service manure Section 3.2.5.

17.3 Calibration Standards

Flow Rate

The flow rate standard apparatus used for flow-rate calibration (field-NIST-traceable, piston-type volumetric flow rate meter; laboratory-NIST-traceable manual soap bubble flow meter and time monitor) has its own certification and is traceable to other standards for volume or flow rate that are themselves NIST-traceable. A calibration relationship for the flow-rate standard, such as an equation, curve, or family of curves, is established by the manufacturer (and verified if needed) that is accurate to within 2% over the expected range of ambient temperatures and pressures at which the flow rate standard is used. The flow rate standard will be recalibrated and recertified at least annually.

The actual frequency with which this recertification process must be completed depends on the type of flow rate standard; some are much more likely to be stable than others. The project team will maintain a control chart (a running plot of the difference or percentage difference between the flow rate standard and the NIST-traceable primary flow rate or volume standard) for all comparisons.

In addition to providing excellent documentation of the certification of the standard, a control chart also gives a good indication of the stability of the standard. If the two standard-deviation control limits are close together, the chart indicates that the standard is very stable and could be certified less frequently. The minimum recertification frequency is one year. On the other hand, if the limits are wide, the chart indicates a less stable standard that will be recertified more often.

Temperature

The EPA Quality Assurance Handbook, Volume IV (EPA 1995), Section 4.3.5.1, gives information on calibration equipment and methods for assessing response characteristics of temperature sensors.

The temperature standard used for temperature calibration has its own certification and is traceable to a NIST primary standard. A calibration relationship to the temperature standard (an equation or a curve) is established that is accurate to within 2% over the expected range of ambient temperatures at which the temperature standard is to be used. The temperature standard must be reverified and recertified at least annually. The actual frequency of recertification depends on the type of temperature standard; some are much more stable than others. The best way to determine recertification requirements is to keep a control chart. The project team will use an ASTM- or NIST-traceable mercury in glass thermometer, for laboratory calibration.

Pressure

The Fortin mercurial type of barometer works on fundamental principles of length and mass and is therefore more accurate but more difficult to read and correct than other types. By comparison, the precision aneroid barometer is an evacuated capsule with a flexible bellows coupled through mechanical, electrical, or optical linkage to an indicator. It is potentially less accurate than the Fortin type but can be transported with less risk to the reliability of its measurements and presents no damage from mercury spills. The Fortin type of barometer is best employed as a higher quality laboratory standard which is used to adjust and certify an aneroid barometer in the laboratory.

17.4 Document Calibration Frequency

See Table 15.1 for a summary of QC checks that includes frequency and acceptance criteria and references for calibration and verification. All of these events, as well as calibration equipment maintenance are documented in field data records and notebooks and annotated with the flags required in the manufacturer’s operating instruction manual and any others indicated in Section 23 of this document. Laboratory and field activities associated with equipment used by the respective technical staff are kept in record notebooks as well. The records are normally controlled by the Managers, and located in the labs or field sites when in use or at the manager’s offices when being reviewed or used for data validation.

18.0 Inspection/Acceptance of Supplies and Consumables

18.1 Purpose

The purpose of this element is to establish and document a system for inspecting and accepting all supplies and consumables that may directly or indirectly affect the quality of the project. The MAEMU relies on various supplies and consumables that are critical to its operation. By having documented inspection and acceptance criteria, consistency of the supplies can be assured. This section details the supplies/consumables, their acceptance criteria, and the required documentation for tracking this process.

18.2 Critical Supplies and Consumables

Each MAEMU is equipped with a certain amount of spare parts and consumables (Table 18.1).

18.3 Acceptance Criteria

If a spare is used to replace an existing part (pump, solenoid valve) or a consumable is used at the correct replacement interval (filters) the person doing the replacement must follow the correct inspection criteria outlined in Table 18.1. The same applies to usage of calibration equipment. Supplies are inspected immediately upon receipt, and returned to the vendor if found to be unusable. A supply of spare parts in working condition is maintained whenever possible in order to ensure continuous data collection.

18.4 Tracking and Quality Verification of Supplies and Consumables

Tracking and quality verification of supplies and consumables have two main components. The first is the need of the end user of the supply or consumable to have an item of the required quality. The second need is for the purchasing department to accurately track goods received so that payment or credit of invoices can be approved. In order to address these two issues, the following procedures outline the proper tracking and documentation procedures:

1. Receiving personnel perform a rudimentary inspection of the packages as they are received from the courier or shipping company. Note any obvious problems with a receiving shipment such as crushed box or wet cardboard.
2. The package is opened, inspected and contents compared against the packing slip.
3. Supply/consumable is compared to the acceptance criteria in Table 17.2.
4. If there is a problem with the equipment/supply, note it on the packing list, notify the supervisor of the receiving area and immediately call the vendor.
5. If the equipment/supplies appear to be complete and in good condition, sign and date the packing list and send it to accounts payable so that payment can be made in a timely manner.
6. Notify appropriate personnel that equipment/supplies are available.
7. Stock equipment/supplies in appropriate pre-determined area.
8. For supplies, consumables, and equipment used throughout the project, document when these items are changed out. If available, include all relevant information such as model number, lot number, and serial number.

Table 18.1. Supplies at Tyson 3-3 MAEMU and Tyson 1-5 MAEMU

Qty.	Description	Company Contact	Inspection Criteria
2	pump, 115 VAC, 16.4L/min, 1/4" NPT ports, teflon diaphram, Thomas	Combined Fluid Products (847-540-0054)	Visual Inspection--no dents or cracks Operational Check before data collection
8	pump diaphram rebuild w/ teflon liner	Combined Fluid Products (847-540-0054)	Visual Inspection--no dents or cracks
4	valve, teflon, solenoid operated, 12V, 1/8" NPT ports, normally closed (648T011)	Neptune Research (973-808-8811)	Visual Inspection--no dents or cracks Operational Check before data collection
4	valve, teflon, solenoid operated, 12V, 1/8" NPT ports, normally open (648T021)	Neptune Research (973-808-8811)	Visual Inspection--no dents or cracks Operational Check before data collection
2	Cool Drive Board, voltage reducing (648D5X12)	Neptune Research (973-808-8811)	Visual Inspection--no dents or cracks Operational Check before data collection
4	PFA-220-1-2, 1/8"NPT-1/8" OD	Swaglok (402-733-7636)	Visual Inspection--no dents or cracks
4	PFA-620-1-4, 1/4" NPT - 3/8" OD	Swaglok (402-733-7636)	Visual Inspection--no dents or cracks
4	PFA-620-2-4, 1/4" NPT - 3/8" OD elbow	Swaglok (402-733-7636)	Visual Inspection--no dents or cracks
4	PFA 620-9, 3/8" OD elbow	Swaglok (402-733-7636)	Visual Inspection--no dents or cracks
4	NY 600-2-1, 1/8" NPT - 3/8" OD elbow	Swaglok (402-733-7636)	Visual Inspection--no dents or cracks
10	fitting, 1/8" NPT - 3/8" OD, Nylon (NY-600-1-2)	Swaglok (402-733-7636)	Visual Inspection--no dents or cracks
2	Power supply, 5V, 15W, 2A, switching (Z1151-ND)	Digikey (800-344-4539)	Visual Inspection--no dents or cracks Operational Check before data collection
2	Power supply, 12V, 100W, 8.6A, switching (602-1045-ND)	Digikey (800-344-4539)	Visual Inspection--no dents or cracks Operational Check before data collection
10	Induction style current switch, (CR9321-PNP)	CR Magnetics (636-343-8518)	Visual Inspection--no dents or cracks Operational Check before data collection
6	6-47-6 teflon filter holder	Savilex (954-936-2295)	Visual Inspection--no dents or cracks
15	filter (30-60 micron) (pkg. 10)	Savilex (954-936-2295)	Visual Inspection--no dents or cracks
1	N_2 zero gas (99.999%)	Matheson (800-416-2505)	Visually Inspect Bottle for cracks or dents
1	NH_3 span gas (2ppm)	Matheson (800-416-2505)	Visually Inspect Bottle for cracks or dents
1	CO_2 span gas (2000ppm)	Matheson (800-416-2505)	Visually Inspect Bottle for cracks or dents
1	CH_4 span gas (3ppm)	Matheson (800-416-2505)	Visually Inspect Bottle for cracks or dents
1	Propane span gas (3ppm)	Matheson (800-416-2505)	Visually Inspect Bottle for cracks or dents
1	H_2S span gas (10ppm)	Matheson (800-416-2505)	Visually Inspect Bottle for cracks or dents
1	Cablibration equipment, hoses, glass impinger, flowmeter	NA	Visual Inspection--no dents or cracks Operational Check before data collection

19.0 Data Acquisition Requirements (Non-Direct Measurement)

Not applicable.

20.0 Data Management

All original and final data is reviewed and/or validated by technically qualified staff, and so documented in the program records. The documentation includes the dates the work was performed, the name of the reviewer(s), and the items reviewed or validated.
Corrections and additions to original data must be made as follows:

1. After correction, original entries must remain legible (for manual corrections) or intact (for computerized corrections).
2. The correction or addition must be readily traceable to the date and the staff who performed the correction or addition.
3. Corrections must be explained.

20.1 Background and Overview

This section describes the data management operations pertaining to air emission measurements for the MAEMU stations operated by ISU and UK personnel. This includes an overview of the mathematical operations and analyses performed on raw (“as-collected”) data. These operations include data recording, validation, transformation, transmittal, reduction, analysis, management, storage, and retrieval.

Data processing for air emissions data is summarized in Figure 20.1. Originally, all electronic data is collected automatically using a set of programs written in LabView 7, which resides on a machine running the Windows XP operating system. And, the data, which resides on a machine running the Windows XP operating system, is processed using a set of programs written in Windows Excel 2003. This machine is shown in the upper left of Figure 20.1.

Each MAEMU has a compact Fieldpoint DAQ system. These DAQ systems continuously provide data collection at each site. The collected data is remotely acquired through a high speed satellite internet system.

Data tracking and chain of custody information is entered into the DAQ system at four main stages as shown in Figure 20.2. Project personnel are able to remotely view the real-time system display on status of site, fan status, sampling location and results of analyzer, etc. using the DAQ system. All users must be authorized by the QA Manager to log on to the DAQ system.

Different privileges are given to each authorized user depending on that person's need. The following privilege levels are defined:
Data Entry Privilege - The individual may see and modify only data that he or she has personally entered. After a data set has been "committed" to the system by the data entry operator, all further changes generate entries in the system audit trail.

Reporting Privilege - This privilege permits generation of data summary reports available under DAQ system. No data changes are allowed without additional privileges.

Data Administration Privilege - Data Administrators for the DAQ system are allowed to change data as a result of QA screening and related reasons. All operations resulting in changes to data values are logged to the audit trail. The Data Administrator is responsible for performing the following tasks on a regular basis merging/correcting the duplicate data entry files

- running verification and validation routines and correcting data as necessary
- generating summary data reports
- uploading verified/validated data to EPA

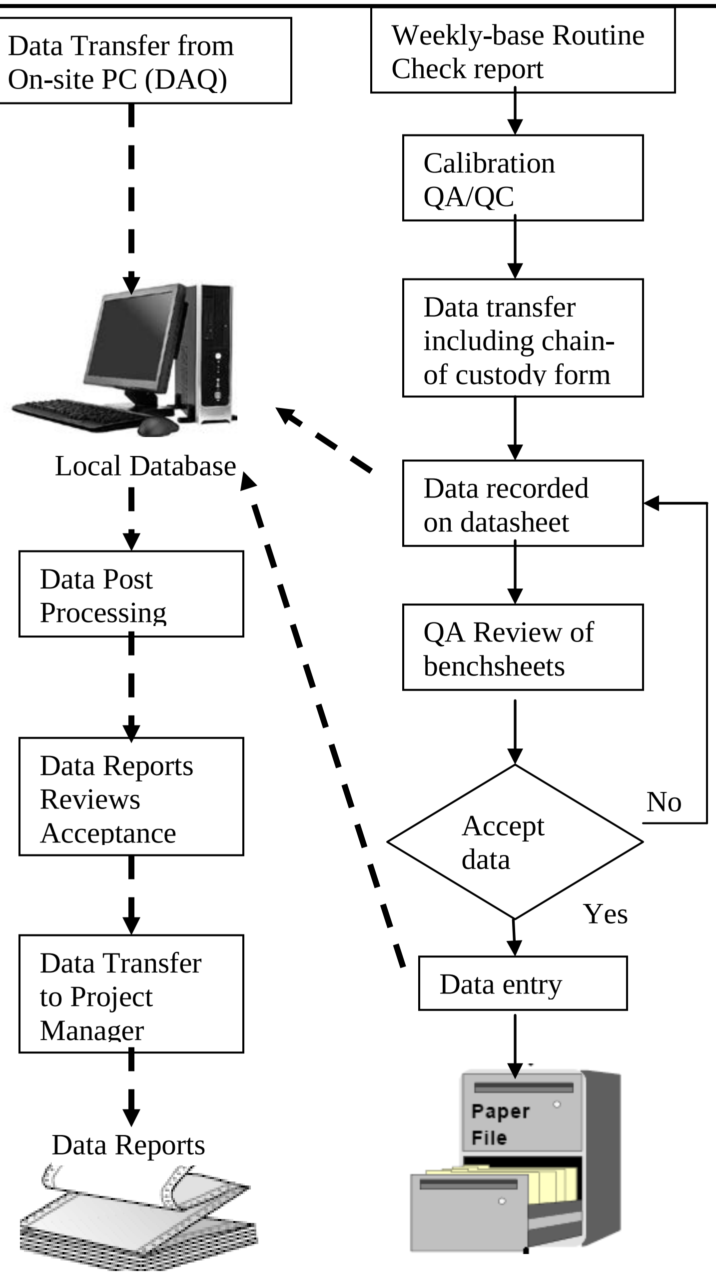


Figure 20.1 Data tracking and chain of custody information

20.2 Data Recording

Any internal checks (including verification and validation checks) that are used to ensure data quality during data encoding in the data entry process, are identified together with the mechanism for detailing and correcting recording errors. Examples of data entry forms and checklists should be included.

Data entry, validation, and verification functions are all integrated in the routine report, DAQ system and Post Process. Bench sheets shown in Figure 20.1 are entered by laboratory personnel. Procedures for data recording and subsequent data entry are provided in SOPs listed in Table 20.1 and included in the corresponding Appendix.

Table 20.1. List of SOPs for data processing

SOP	Title	Description
Appendix I	Data Management	Describes the data processing operations, validation, and reduction.
Appendix J	Reporting and Calculation of Contaminant Concentrations, Ventilation and Emissions	Describes the procedures for data reporting and processing,

20.3 Data Validation

The details of the process of data validation and pre-specified criteria are documented in this element of the QAPP. This element addresses how the method, instrument, or system performs the function it is intended to consistently, reliably, and accurately in generating the data.

Data validation is a combination of checking that data processing operations have been carried out correctly and monitoring the quality of the field operations. Data validation can identify problems in either of these areas. Once problems are identified, the data can be corrected or invalidated, and corrective actions can be taken for field or laboratory operations. Numerical data stored in the DAQ system are never internally overwritten by condition flags. Flags denoting error conditions or QA status are saved as separate fields in the database, so that it is possible to recover the original data.

The following validation functions are incorporated into the DAQ system to ensure quality of data entry and data processing operations:

Range Checks - almost all monitored parameters have simple range checks programmed in. For example, valid times must be between 00:00 and 23:59, summer temperatures must be between 10 and 50 degrees Celsius, etc. The data operator is notified immediately when data are out of range. The operator has the option of correcting the entry or overriding the range limit. The specific values used for range checks may vary depending on season and other factors. The currently used range values for data acceptance are provided in SOPs. Since these range limits for data input are not regulatory requirements, the data operators may adjust them from time to time to better meet quality goals.

Completeness Checks - When the data is processed, certain completeness criteria must be met. For example, each air sample must have a start time, end time, average flow rate, temperature, relative humidity, and operator and technician names. The data entry operator is notified if an incomplete record has been entered before the record can be closed.

Data Retention - Raw data sheets are retained on file at ISU for a minimum of five years, and are readily available for audits and data verification activities. After five years, hardcopy records and computer backup media are cataloged and boxed for storage at ISU. Physical samples, such as litter samples, shall be discarded with appropriate attention to proper disposal of potentially hazardous materials.

Statistical Data Checks - Errors found during statistical screening are traced back to original data entry files and to the raw data sheets, if necessary. These checks are run on a monthly schedule and prior to any data submission to the project manager. Data validation is the process by which raw data is screened and assessed before it can be included in the main database.

Data Validation – Data validation, which is discussed in Section 24, associates flags that are generated by QC values outside of acceptance criteria. Data containing too many flags is rerun and or invalidated.

20.4 Data Transmittal

Data transmittal occurs when data is transferred from one person or location to another, or when data is copied from one form to another. Some examples of data transmittal are copying raw data from a notebook onto a data entry form for keying into a computer file and electronic transfer of data over a telephone or computer network. The QAPP describes each data transfer step and the procedures used to characterize data transmittal error rates and to minimize information loss in the transmittal. Table 20.2 summarizes data transfer operations.

Table 20.2. Data Transfer Operations

Description of Data Transfer	**Originator**	**Recipient**	**QA Measures Applied**
Calibration and Audit Data	Auditor or field supervisor	Data base Computer	Entries are checked by QA Manager
Electronic data transfer	(Between computers or over network)		Parity checking; transmission protocols
Data summaries	Data processing operators	Air Quality Supervisor	Entries are checked by QA Manager

20.5 Data Reduction

Data reduction includes all processes that change the number of data items. This process is distinct from data transformation in that it entails an irreversible reduction in the size of the data set and an associated loss of detail. For manual calculations, the QAPP includes an example in which typical raw data is reduced. For automated data processing, the QAPP clearly indicates how the raw data is to be reduced with a well-defined audit trail, and reference to the specific software documentation is provided.

Data reduction processes involve aggregating and summarizing results so that they can be understood and interpreted in different ways. The monitoring regulations require certain summary data to be computed and reported regularly to U.S. EPA. Other data is reduced and reported for other purposes such as station maintenance. Examples of data summaries include:

- average air concentration and emissions for a station or set of stations for a specific time period
- accuracy, bias, and precision statistics based on accumulated data
- data completeness reports based on numbers of valid samples collected during a specified period

The post process is another important concept associated with data transformations and reductions. Post process is a data structure that provides documentation for changes made to a data set during processing. Typical reasons for data changes that would be recorded include the following:

- corrections of data input due to human error
- application of revised calibration factors
- addition of new or supplementary data
- flagging of data as invalid or suspect
- logging of the date and times when automated data validation programs are run

The DAQ post process is implemented as a separate table in the Microsoft Excel database. Post process records will include the following fields:

- operator's identity (ID code)
- date and time of the change
- table and field names for the changed data item
- reason for the change
- full identifying information for the item changed (date, time, site location, parameter, etc.)
- value of the item before and after the change

When routine data screening programs are run, the following additional data is recorded in the audit trail:

- version number of the screening program
- values of screening limits (e.g., upper and lower acceptance limits for each parameter)
- numerical value of each data item flagged and the flag applied

The post process is produced automatically and can only document changes; there is no "undo" capability for reversing changes after they have been made. Available reports based on the Post Process include:

- log of routine data validation, screening, and reporting program runs
- report of data changes by site for a specified time period
- report of data changes for a specified purpose
- report of data changes made by a specified person

Because of storage requirements, the System Administrator must periodically move old Post Process records to backup media.

20.6 Data Analysis

Data analysis sometimes involves comparing analyzer readings with standard calibration gas. It frequently includes computation of summary statistics, standard errors, confidence intervals, and goodness-of-fit tests. This element briefly outlines the proposed methodology for data analysis and a more detailed discussion will be included in the final report.

ISU is currently implementing the data summary and analysis requirements, see Appendix A. It is anticipated that as the monitoring program develops, additional data analysis procedures will be developed. The following specific summary statistics will be tracked and reported for the network:

- Analyzer bias or accuracy (based on cal-gas routine check, flow rate performance audits, and sensor performance evaluations)
- Analyzer precision
- Data completeness

Equations used for these reports are given in Table 20.3.

Table 20.3 Report Equations

Criteria	**Equation**	**Reference**
Accuracy of analyzer-single gas Check (d_i) X_i is reference flow; Y_i is measured	$d_i = \frac{Y_i - X_i}{X_i} \times 100$	40 CFR 58 Appendix A, Section 5.5.1.1
Bias of a single check - Annual Basis (D_i)- average of individual percent differences between sampler and reference value; n_j is the number of measurements over the period	$D_j = \frac{1}{n_i} \times \sum_{i=1}^{n_j} d_i$	5.5.1.2
Percent Difference for a Single Check (d_i) - X_i and Y_i are concentrations from the primary and duplicate samplers, respectively.	$d_i = \frac{Y_i - X_i}{(Y_i + X_i)/2} \times 100$	5.5.2.1
Coefficient of Variation (CV) for a single Check	$CV_{j,q} = \sqrt{\sum_{i=1}^{n_j} \frac{CV_i^2}{n_{j,q}}}$	5.5.2.2
Completeness	$\text{Completeness} = \frac{N_{\text{valid}}}{N_{\text{theoretical}}} * 100$	

20.7 Data Flagging

A sample qualifier or a result qualifier consists of three alphanumeric characters, which act as indicators of the fact and the reason that the data value (a) did not produce a numeric result, (b) produced a numeric result, but it is qualified in some respect relating to the type or validity of the result or (c) produced a numeric result, but for administrative reasons is not to be reported outside the laboratory. Qualifiers are used both in the field and in the laboratory to signify data that may be suspect due to contamination, special events, or failure of QC limits. Some flags are generated by the sampling instrument. Appendix I contains a complete list of the data qualifiers for the field and laboratory activities. Qualifiers will be placed on field and bench sheets with additional explanations in free form notes areas. When the validation process runs (see Section 24), flags are generated. During the sample validation process, the flags are used to decide on validating or invalidating individual samples or batches of data. Section 24 discusses this process.

20.8 Data Tracking

Data management includes tracking the status of data as it is collected, transmitted, and processed. The QAPP describes the established procedures for tracking the flow of data through the data processing system.

The DAQ contains the necessary input functions and reports necessary to track and account for the whereabouts of calibration and the status of data processing operations for specific data. Information about analyzer calibration is updated at distributed data entry terminals at the points of significant operations. The following input locations are used to track calibration location and status:

- Mobile Laboratory
    - Calibration gas checking on analyzers
    - Calibration data for analyzers
    - Fan calibrations
- Emailing and Shipping (calibration data is entered for both sending and receiving)
- Laboratory
    - Data entering
    - Post processing

In most cases, the tracking database and the monitoring database are updated simultaneously. For example, when the calibration checking and calibrating data is entered into the monitoring database and the calibration time and location are entered into the tracking database.

20.9 Data Storage and Retrieval

The QAPP should discuss data storage and retrieval including security and time of retention, and it should document the complete control system. The QAPP should also discuss the performance requirements of the data processing system, including provisions for the batch-processing schedule and the data storage facilities.

The DAQ system consists of a PC and compact Fieldpoint (National Instruments Corporation, Austin, TX) which is a data acquisition and automation controller composed of rugged I/O modules and intelligent communication interfaces. Real-time DAQ program developed using LabView 7 software (National Instruments, Corporation, Austin, TX) is used to acquire data, automate sampling location control, display real-time data, and deliver data and system operation status. The DAQ program consists of two sub-programs: an embedded program running in the CFP-2020 network module for collecting raw signals and controlling sampling location and a PC-based program running in the on-site project computer for data post-processing and data publishing on the webpage. The embedded program can stand-alone run and send out data and alarm email. All the real-time readings of the instruments are recorded and displayed on the front panel of the program. Using LabView 7, the front panel can be published as a web page, and viewed in real-time and controlled from a remote location, through Internet. The recorded data are stored daily to the on-site PC and backed up by a remote computer via a satellite high-speed internet connection. The stored data are also automatically transmitted through an email sever on a daily basis to provide redundant data transfer.

Electronic data will be recorded and stored on the on-site computer and downloaded daily with a scheduled time via a high-speed internet connection to a dedicated project computer at ISU. The data is backed-up weekly to CDs onsite by the UK personnel and to an external hard drive at ISU. As the data redundant system, the compact Fieldpoint stand-alone controller records the electronic raw data in a compact flash memory and sends the data out by email via a high-speed Internet connection (see Appendix G). For the precise data post process in the dedicated project computer, all the processed data will be stored in the computer and backed-up to the external hard drive. In addition to computer storage, raw tables or graphs are printed out and stored in loose-leaf notebooks.

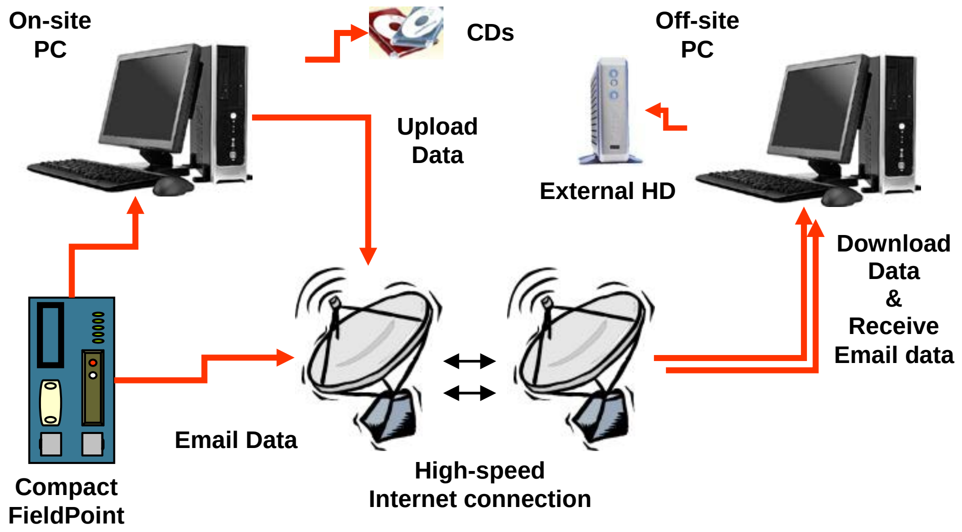


Figure 20.2. Flowchart of electronic data back-up and storage

Field test documentation and electronic data storage are maintained in accordance with standard operating procedures (see Appendix H) including storage of all raw electronic data in ASCII file format for later analysis using commercially-available spreadsheet and statistical programs (Appendix I). A large portion of the data is be maintained electronically in the form of spreadsheets. All pollutants, temperature, pressure, RH and fan ON/OFF data is electronically stored and compiled in a manner that will facilitate computation of hourly and daily averages.

Accurate working files of all documentation, including logbook entries, original data, calculations, deviations from approved procedures, data uncertainties, assumptions, QA/QC results and external performance data, audits, and review, inspection, and validation are maintained by the principal investigators as appropriate until archived after the completion of the project. Project records are maintained in a systematic and logical form and adequately filed for rapid retrieval, accounted for and appropriately indexed.

Data archival policies for the air emission data are shown in Table 20.4.

Table 20.4 Data Archive Policies

Data Type	Medium	Location	Retention Time	Final Disposition
Laboratory Notebooks	Hardcopy	Laboratory	3 years	Discarded
Database	Electronic	Laboratory	Indefinite (may be moved to backup media after 5 years)	Backup
Audit trail	Electronic	Laboratory	3 years	Discarded
Samples		Laboratory	1 year	Discarded

The air emission data resides on an IBM-PC compatible computer at ISU. This computer has the following specifications:

- Processor: Pentium 2.8 GHZ
- Operating System: Windows XP
- Memory: 1 GB
- Storage: 200 GB
- Backup: Incremental backups daily; full backups weekly (750 MB CD-ROM)
- Network: Windows XP, 100 Mbps Ethernet network (Satellite internet connection via 196 kbps modem)
- Database Software: Microsoft Excel, Labview 7.0
- Security: Password protection on all PCs and internet connection; Additional password
- Protection applied by application software, internet connection with firewall.

Security of data in the air emission database is ensured by the following controls:

- Password protection on the data base that defines three levels of access to the data
- Regular password changes
- Independent password protection on internet connection
- Logging of all incoming communication sessions
- Storage of media including backup tapes in locked, restricted access areas

21.0 Assessments and Response Actions

The principal investigators (PIs) are responsible for the initial assessment and evaluation of data in accordance with the validation procedures. Internal QA/QC audits of data collection and validation are conducted by the project QA Manager. The project PIs are responsible for initiating necessary response actions in response to data assessment or internal audit findings. In the event that work must be stopped in order to conduct any response action required to comply with QAPP requirements or for other necessary reasons, the following project personnel have the authority to stop work: Kevin Igli and Steve Patrick with Tyson Foods (Funding Agency), Robert Burns and Hongwei Xin with ISU, Rich Gates with UK (Primary Project PIs) and Lara Moody (Project QA Manager). The following assessment mechanisms, shown in Table 21.1, are implemented as part of the project quality assurance. As indicated Lara Moody will serve as the Project Quality Assurance Manager. While Moody is an employee of ISU she will not be under the supervision of any of the project PIs in regards to this project. Raj Raman is serving as Moody's direct supervisor in regards to her duties as Quality Assurance Manager for this project. Moody will report the results of her QA/QC activities on the project directly to Raman. Raman will review her findings and communicate the results and required actions to the project PIs.

Table 21.1. Quality assurance assessments and implementation frequency

Assessment Type	Daily	Twice Weekly	Weekly	Every Flock	Once
Remote System Observance	X				
On-site System Inspection		X			
Internal Technical System Audits				X	
External Technical System Audits					X
Data Completeness and Out of Range Data Flagging / Review	X		X		
Flock Data Completeness & Emissions				X	

21.1 Remote System Observance

Remote observation of the monitoring system performance is a normal part of daily project activities and is conducted on a daily basis by ISU personnel (Hong Li) via a high-speed Internet connection to each MAEMU. Using a web-based remote interface all pollutant monitoring readings are viewed daily in real-time, as well as individual fan operational status, pressure differential, and temperature, relative humidity and dew point conditions at all four sampling points. The sample line heat trace temperatures are reviewed, as well as the GSS heat tape temperatures, GSS exhaust air flow and the temperature inside each MAEMU.

21.2 On-site System Inspection

A complete on-site inspection of the monitoring system is conducted twice per week by UK personnel (John Earnest and Doug Overhults) who are located 30 minutes from each monitoring site. During a twice-weekly visit to each site, project personnel conduct a visual check on all system components including in-house sampling points, TEOMs and fans, the ambient monitoring point, and all instruments and components located inside the MAEMU at each location. During one visit per week the paper element filters and the 20 micron *Teflon* filters are replaced. The TSP, PM_{10} and $PM_{2.5}$ TEOM heads are also exchanged for clean heads during this visit (TEOM heads are exchanged twice per week due to the high dust conditions encountered in the broiler houses). A report detailing assessment observations and any required response actions is prepared by John Earnest following each visit and emailed to all team members the next business day following the site visit.

21.3 Internal Technical System Audits

The broiler houses are empty for approximately ten days following the removal of each flock of birds (each flock is in the house for ~ 52 days). During this ten day period between each flock ISU and UK project personnel (Robert Burns, Hongwei Xin, Rich Gates, Doug Overhults, John Earnest and Hong Li) conduct an Internal Technical Systems Audit at both Tyson 1-5 and Tyson 3-3. This audit includes a visual inspection of all system components, and a flow check at each of the four sample points to confirm pump flows are maintaining a 15 L/min flow rate. A flow-audit is conducted on each TEOM during the audit. Leak checks of the GSS and supply lines are conducted by calibrating an additional INNOVA 1412 with the INNOVA 1412 located in the MAEMU, and then placing the second INNOVA 1412 at each sample point inside the broiler house and confirming matching ammonia readings. This provides a confirmation that no dilution air is entering the system, and that no leaks are present. The results of each Internal Technical System Audit are documented and provided to the Quality Assurance Manager for review. During a minimum of two Internal Technical System Audits the Project QA Manager (Lara Moody) will conduct a field oversight of sampling and analysis activities at each site, during which performance audit samples will be analyzed During field oversight, the Project QA Manager will visually observe sample collection and analysis to verify that the procedures outlined in this QAPP are being followed and that any corrective action initiated previously is being continued. Field documentation of samples, calibration, QC measures, and corrective action will also be reviewed. In addition, the Project QA Manager will conduct a review of data and record management systems during the field monitoring period. During this review, the Project QA Manager will verify that the data management procedures are being followed. Reports from these two field assessments that document all issues identified during these reviews will be provided to Raj Raman and copied to Kevin Igli and Steve Patrick with Tyson Foods (Funding Agency), Robert Burns and Hongwei Xin with ISU, Rich Gates with the UK (Primary Project PIs) and the EPA Project Manager and the EPA Quality Officer. The project PIs will prepare an action plan that identifies how all items will be addressed and the schedule that the responses will be implemented in.

21.4 External Technical System Audits

An external technical systems audit team has been established and will conduct an audit following acceptance of the project QAPP. The audit team members are Drs. Larry Jacobson and David Parker. Both are national recognized experts in AFO air emissions monitoring. Dr. Larry D. Jacobson is a Professor of Biosystems and Agricultural Engineering at the University of Minnesota located in St. Paul, MN. Dr. David B. Parker is an Associate Professor of Environmental Science and Engineering in the Division of Agriculture at West Texas A&M University located in Canyon, Texas USA.

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2. Dr. Larry Jacobson, Professor
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   612-625-8288

An external technical system audit will be conducted in the 4th quarter of 2006. External auditors and EPA personnel will be asked to provide a field review of all monitoring system and data acquisition components to confirm that they have been installed in accordance with the QAPP. The project records including the notebooks that log all site visits and system calibrations, the twice-weekly On-site Visit Reports, the Internal Technical System Audit reports, the daily Data Completeness and Out of Range Data Flagging/Review reports, and the Flock Data Completeness and Emissions reports will be made available to the external auditors. The external audit team will be asked to review the above mentioned reports and emissions data to determine if the project data collection and management has been conducted in accordance with the project QAPP. The external auditors will provide a report that details their findings and any suggested changes in project execution as needed per their findings. This report will be distributed to EPA, Tyson Foods, ISU and UK project personnel. Following the distribution and review of the report the project PIs will develop a plan to implement any required changes to data collection, management or analysis that are required as a result of the external audit findings. The project PIs will meet with the Project QA Manager, the EPA Project Manager, the EPA QA Officer and

Tyson management to propose an implementation schedule that outlines each identified deficiency, the planned action and the schedule for implementation.

21.5 Data Completeness and Quality Reviews

As described in Section 24, a data processing program is run daily to process data collected on the previous day. This program calculates data completeness and automatically flags out of range data. ISU project personnel will review flagged data within two working days to confirm that the data is either invalid and cannot be used or valid and can be used. Only project PIs have the authority to validate flagged data following a review of the data. Flagged data that has not been validated will not be used in emissions calculations. A record of data review and any removal of data flags following review will be maintained. The response action to data flagged as out of range will be to investigate and document the reason that the data was flagged and to follow-up with a site visit if any data flags were the result of equipment malfunction and correct the problem.

22.0 Reports to Management

During the project, the following reports will be prepared; Quarterly QA/QC Review Reports, On-Site System Inspection Reports, Internal System Audit Reports, External System Audit Reports, Daily Data Completeness and Validity Posting, Flock Data Completeness and Emissions Postings, Field Oversight Assessment Reports, Mid-Term Project Report and a Final Emissions Report. Table 22.1 provides the frequency, content, distribution and individuals responsible for the generation of each report.

Table 22.1. Reports to Management

Report Type	Content	Frequency	Distribution	Responsible Person
Quarterly QA/QC Review	Results of QA Managers review of project data management	Quarterly	Dr. Raj Raman	Mrs. Lara Moody
On-site System Inspection Reports	Description of on-site visit & any identified issues	Twice - Weekly	All ISU and UK project personnel	Mr. John Earnest
Internal Technical System Audit Reports	Confirmation and results of each system check performed in audits	At the end of each flock (~ 52 days)	Mrs. Lara Moody Dr. R.T. Burns Dr. Hongwei Xin Dr. Rich Gates Dr. Steve Hoff Dr. Doug Overhults Mr. John Earnest	Dr. Hong Li
External Technical System Audit Reports	Results of External Audit Findings	Once during 4th Quarter of 2006	Mrs. Lara Moody Ms. Sharon Nizich Mr. Joe Elkins Dr. R.T. Burns Dr. Hongwei Xin Dr. Rich Gates Dr. Steve Hoff Dr. Doug Overhults Mr. John Earnest	Dr. David Parker Dr. L. Jacobson

Data Completeness and Validity Posting	Data completeness & validity determination for daily environmental & emissions data	Daily	All ISU and UK project personnel via web	Dr. Hong Li
Flock Data Completeness & Emissions	Data completeness & validity determination for flock emissions data	Each flock (~ 52 days)	All ISU and UK project personnel via web	Dr. Hong Li
Field Oversite Assessment Reports	Assessments of Internal Technical System Audits Execution	Twice during project	Dr. Raj Raman	Mrs. Lara Moody
Mid-Term Project Report	Project and milestone completion status	3rd Quarter 2006	Mr. Kevin Igli Mr. Steve Patrick Ms. Sharon Nizich	Dr. Robert Burns
Final Emissions Report	Emissions results	3rd Quarter 2007	Mr. Kevin Igli Mr. Steve Patrick Ms. Sharon Nizich Mr. Joe Elkins	Dr. R.T. Burns Dr. Hongwei Xin Dr. Rich Gates Dr. Steve Hoff

23.0 Data Review, Verification, and Validation Requirements

For this project, data review is the examination of data to ensure that the information has been recorded, transmitted, and processed correctly; including checking for errors pertaining to data entry, transcription, calculation, reduction and transformation. Data review for the gaseous and particulate matter sampling includes 1) quality control information as described in Section 15 – Quality Control Measures (i.e., instrument set-up, calibration, and accuracy and bias check data), 2) instrument testing and maintenance information as described in Section 16 – Instrument/Equipment Testing, Inspection and Maintenance (i.e., online and on-site inspection and maintenance data), 3) instrument calibration and frequency records and described in Section 17 – Instrument/Equipment Calibration and Frequency (i.e., calibration dates, instrument calibration offsets from standards, and corrective measures), and 4) generated gaseous, particulate matter, fan flow and environmental condition data used for emission rate calculations. Data review for the litter analysis includes 1) quality control information as described in Section 14 – Analytical Methods (i.e., spiked matrices and triplicate analyses), 2) records verifying litter sample collection and handling methods as described in Sections 12 and 13 describing Sampling Methods, Handling and Custody, and 3) nutrient concentration data generated through litter sample analysis.

Data verification is the process for evaluating the completeness, correctness and conformance of a data set against the collection methods specifications. For the gaseous and particulate matter sampling, this means insuring the data sets are 75% complete and that daily emission rates meet the Measurement Performance Criterion of less than 10% uncertainty as per the DQO stated in Section 7 – Quality Objectives and Criteria for Measurement Data, and insuring that individual concentration and fan flow data falls within the ranges specified for the equipment and the project as described in Section 7 – Quality Objectives and Criteria for Measurement Data. For the litter analyses, data verification means insuring the standard deviations between replicated samples and generated data are acceptable for the methods described in Section 14 – Analytical Methods. Data validation extends beyond data verification and is to determine the quality of the data for end use. Data validation for both gaseous and particulate matter sampling and litter sampling will occur throughout the project. Data is compared to other data already available in the literature to determine if it is within the expected range. Data verification and validation are described below in additional detail.

All UK and ISU project personnel who perform work on-site have a responsibility to report any deviation from the SOPs established for the project. Any deviations from the SOPs that occur during twice-weekly on-site visits conducted by UK personnel will be recorded in the On-Site System Inspection Reports. Any deviations from standard SOPs that occur during the Internal System Audits will be documented and explained in the Internal System Audit Report generated following the audit visit.

23.1 Gas and Particulate Matter Sampling System

Section 11 – Sampling Process Design describes the sampling system design for this project; including, emission rate calculations, sampling equipment selection, in-house sample locations, and data collection frequency. The objective of the sampling design is to determine air emissions representative of broiler houses and to ensure adequate levels of spatial and temporal resolution. It is the responsibility of the project PIs to ensure that the sampling systems function properly and the responsibility of the Project Quality Assurance Manager to confirm that appropriate data quality checks and documentation is implemented to confirm the final quality of collected data. During twice weekly on-site inspections UK project personnel confirm through visual inspection that the sampling system conforms to the sampling system design specifications. The actual performance of the sampling system is confirmed during Internal Technical System Audits conducted between each flock of birds (approximately every 52 days).

Verification. Verification of individual fan flow rates will occur at the end of each flock removal from the broiler houses. Following bird removal from the houses and prior to fan calibration each fan is visually inspected to confirm that it has been pressure washed and that belts (on belt driven fans) are adjusted to the correct tension. During the between flock checks, all aspects and parts of the fan calibration will be checked and verified by following the QC.

Verification. Verification of the sampling system occurs through routine twice-weekly and between flock checks. The twice-weekly check inspects the functioning of sampling instruments. The sample lines and data lines are visually checked. (The output from all instruments and operation of the sampling system components are checked daily). During the between flock checks, all aspects and parts of the sampling system are checked and verified by following the QC.

Sampling System Validation. The data from routine visit and between flock audits will be used to validate the sampling system and to ensure that the sampling system meets the objective of the project as described in Section 6 – Project Task Description.

23.2 Analytical Procedures

Section 15 details the requirements for the analytical methods. The methods include acceptance criteria (Sections 15 and 16) for important components of the procedures, along with suitable codes for characterizing each sample's deviation from the procedure.

Verification. The Quality Assurance Manager conducts audits to ensure the analytical method specifications mentioned in the QAPP are being followed. The audits will include checks on the identity of litter samples collected between flocks. Deviations from the analytical procedures will be noted in audit finding forms and corrected using the procedures described in Section 21.

Validation. Similar to the validation of sampling activities, the review of data from lab blanks, calibration checks, laboratory duplicates and other laboratory QC that are described in Sections

15 and 16 can be used to validate the analytical procedures. Acceptable precision and bias in these samples indicate that the analytical procedures are adequate. Any data that indicates unacceptable levels of bias or precision or a tendency (trend on a control chart) will be flagged and investigated as described in Section 21. Any discovery of inappropriate analytical procedures will trigger corrective action.

23.3 Quality Control

Sections 15 and 16 detail the requirements for the QC during sampling collection, handling, and analysis, which include analyses of check standards, calibration and accuracy check. For each specified QC check, the procedure, acceptance criteria, and corrective action are specified.

Verification. As mentioned in the above sections, both internal and external audits will be performed to ensure the QC method specifications mentioned in the QAPP are being followed.

Validation. Validation activities of many of the other data collection phases mentioned in this subsection use the quality control data to validate the proper and adequate implementation of that phase. Therefore, validation of QC procedures will require a review of the documentation of the corrective actions that will be taken when QC samples failed to meet the acceptance criteria, and the potential effect of the corrective actions on the validity of the routine data.

23.4 Calibration

When calibration problems are identified, any data produced between the suspect calibration event and any subsequent recalibration will be flagged to alert data users. Sections 16 and 17 detail the calibration activities and requirements for the critical pieces of equipment for the air emission monitoring.

Verification.

As mentioned in the above sections, both internal and external technical systems audits will be performed to ensure the calibration specifications and corrective actions mentioned in the QAPP are being followed. Deviations from the calibration procedures will be noted in audit finding forms and corrected using the procedures described in Section 21.

Validation.

Similar to the validation of sampling activities, the review of calibration data that are described in Sections 15 and 16, can be used to validate calibration procedures. Calibration data within the acceptance requirements would lead one to believe that the sample collection measurement devices are operating properly. Any data that indicates unacceptable levels of bias or precision or a tendency (trend on a control chart) will be flagged and investigated. Validation would include the review of the documentation to ensure corrective action will be taken as prescribed in the QAPP.

23.5 Data Reduction and Processing

When calibration problems are identified, any data produced between the suspect calibration event and any subsequent recalibration will be flagged to alert data users. Sections 16 and 17 detail the calibration activities and requirements for the critical pieces of equipment for the air emission monitoring.

<u>Verification.</u> As mentioned in the above sections, both internal and external technical systems audits will be performed to ensure the data reduction and processing activities mentioned in the QAPP are being followed.

<u>Validation.</u> As part of the audits of data quality, discussed in Section 20, a number of sample IDs, chosen at random will be identified. All raw data files, including the following will be selected:

- Electronic data (recorded by DAQ system and computer)
- Routine check
- Calibration -the calibration information represented from that sampling period
- Sample handling/custody
- Corrective action

Data post processing

24.0 Verification and Validation Methods

Many of the processes for verifying and validating the measurement phases of the emission data collection have been discussed in Section 23. If these processes, as written in the QAPP, are followed, the DQOs should be achieved. However, exceptional field events may occur, and it is expected that some of the QC checks will fail to meet the acceptance criteria.

Information on problems that could affect the integrity of data is identified in the form of flags (Appendix I). It is important to determine what caused these out of range indications in the data. In some cases there may be a unique event occurring and the data may truly represent measures parameters and simply be outside of the expected range. In other cases out of range data may be due to equipment that is out of calibration or that has failed. The review of this raw data and their associated QC data will be verified and validated in a routine report on the basis of calibration data. The routine report and calibration data is the most efficient entity for verification/validation activities. It is assumed that if measurement uncertainty can be controlled within acceptance criteria, at calibration level, then the overall measurement uncertainty will be maintained within the precision and bias DQOs.

24.1 Verification

After a one-day data set is downloaded to the ISU computer, a review will be conducted for completeness, correctness, conformance/compliance of the environmental and concentration data against the QC standard, instrument operational conditions and broiler house normal operating conditions. All data is evaluated using a program specifically developed for this task (MAEMU v1.2, developed by using Visual Basic), running on an ISU computer for this project. The program reviews the data for data outliers and data outside of acceptance criteria. These data are flagged appropriately. The acceptance criteria, listed in Table 24.1, is set up in the program and is used to determine if individual data or data from a particular instrument has been flagged. These flagging criteria can be varied due variations in expected data ranges due to seasonal differences and bird growth. Verification of measurement data is conducted in three parts, one for the environmental condition measurement value, the second for the air sample measurements and the third for fan operational parameters.

Temperature, relative humidity, barometric pressure and static pressure readings are inspected first. Any reading out of the normal operation range is flagged appropriately and UK field personnel are notified and asked to make an on-site inspection to determine the reason for out of range data (e.g., malfunction of sensors or true out of range reading). The following correction actions are performed if the on-site visit determines that are required to address the issue.

- ➢ The gas analyzers, INNOVA, API 101E, and VIG, are routinely challenged (weekly) with calibration gases. If the recent reading of one gas does not meet the QC standard, the data collected between current site visit and the last site visit where the unit met the QC criteria will be flagged. For example, the NMHC reading is 2.8 ppm when 3 ppm propane cal-gas is injected, the difference, 0.2 ppm is larger than 5% of cal-gas concentration (0.15 ppm). In this case all NMHC readings since the last calibration will be flagged with "CVN". In addition, the gas-concentration will be flagged if the reading is out of the analyzer operation range. For instance all NMHC data would be flagged with "OVN" if the NMHC reading exceeds 10 ppm.

- The TSP, PM_{10} and $PM_{2.5}$ operational readings from TEOMs are reviewed based on the routine leak test and operation range. If the main flow rate of TEOM with a TSP head is not in the range, 0.98 to 1.02 L/min, a flag "OTF" will be recorded.

A separate flag data set will be created and flags of individual data will be filed. Based on the data flags, the daily completeness of each variable will be derived by using following equation:

$$\text{Completeness} = \frac{N_{total} - N_{flag}}{N_{total}} \times 100$$

After calculating completeness and data flagging, the program will create a daily verification form to summarize the flags and completeness for environment variables, air pollutants and fan operation data. The flagged data will not be used for daily air emission calculation.

Daily emissions for each pollutant are calculated based upon the data flag status (i.e. only data that has not been flagged is used) and a daily emission report is generated, which includes a summary table for individual gas emission, flags and completeness of the pollutant. If any flag is detected by the program, a flag notification email will be sent to all PIs for addressing and solving the problem(s). This daily report will be posted on a secured web-site and PIs (Burns, Xin, Gates or Hoff) will review it within 2 working days. All the data points with flags is inspected and the reason addressed. Also, the verified daily emission data is summarized on a flock basis.

24.2 Validation

Data is internally validated by the Quality Assurance Manager (Lara Moody), data processing operators (Hong Li) and all PIs. The daily air emission reports are reviewed as well as the other routine reports, field calibration data and lab record.

The data validation includes the following four steps:

- Review all the routine field visit reports and calibration report to ensure QC standard is met, if not the corresponding data will be invalidated.

- Review data verification records, including data flags, daily emission reports; if the flagged data meets the QC standard, these data points will revalidated and the data processing program will be rerun.
- Summarize data and QC deficiencies if the data quality was not met and evaluate the impact on overall data quality
- Develops data validation reports quarterly.

A checklist of criteria and items to evaluate during each stage of data review is listed in Table 24.1. In cases where any of the criteria and checks can be automated using the post processing program, random checks should still be done to ensure that the auto-check is working properly. If errors or problems are identified through any of the following checks, corrective action, appropriate to the problem, should be taken (e.g., reanalysis, data qualification, troubleshooting, or documentation).

Table 24.1 Verification and Validation data flags and action

Requirement	**Data Range**	**Acceptance criteria**	**Flag**	**Action**
Temperature	32^{o}F ~ 105 ^{o}F	> 105 ^{o}F < 32^{o}F	OET	Reanalysis/ Confirmation by on-site visit / calibrate / replace Thermocouple/document
Relative humidity	0~100 %	>100% < 0	OEH	Reanalysis/ Confirmation by on-site visit / calibrate / replace RH Sensor/document
Barometric pressure	900~1050 kpa	>1050 < 900	OEB	Reanalysis/Confirmation by on-site visit / calibrate / replace Barometric pressure sensor/document
Static pressure	-0.05 ~ 0.5 inch Water	>0.25 < -0.02	OEP	Reanalysis/Confirmation by on-site visit / calibrate / replace Static pressure sensor/document
Fan current switch	ON/OFF	OFF (all the time)	FCS	Reanalysis/Confirmation by on-site visit / replace Fan Current Switch/document
Temperature	<±1^{o}F (Checking)	>±1^{o}F	OCT	Reanalysis/Confirmation by on-site visit / replace Thermocouple/document
Relative humidity	<±5 % of Standard (Checking)	>±5 %	OCH	Reanalysis/Confirmation by on-site visit / Calibration/document
Barometric pressure	<±5 % of Standard (Checking)	>±5 %	OCB	Reanalysis/Confirmation by on-site visit/ Calibration/document
Static pressure	<±5 % of Standard	>±5 %	OCP	Reanalysis/Confirmation by on-

	(Checking)			site visit / Calibration/document
NH_3	<±5 % of Standard	>±5 %	CIA	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
CO_2	<±5 % of Standard	>±5 %	CIC	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
H_2S	<±5 % of Standard	>±5 %	CHS	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
Non-Methane Hydrocarbon (NMHC)	<±5 % of Standard	>±5 %	CVN	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
Methane	<±5 % of Standard	>±5 %	CVM	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
Total Hydrocarbon (THC)	<±5 % of Standard	>±5 %	CVT	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
H_2S measurement range	0~100 ppb	> 100 < 0	OHS	Reanalysis/Confirmation by on-site visit / Calibration/document
NMHC measurement range	0-10 ppm	> 10 < 0	OVN	Reanalysis/Confirmation by on-site visit / Calibration/document
Methane measurement range	0-100 ppm	> 100 < 0	OVM	Reanalysis/Confirmation by on-site visit / Calibration/document
THC measurement range	0-100 ppm	> 100 < 0	OVY	Reanalysis/Confirmation by on-site visit / Calibration/document
TSP flow	0.98~1.02 LPM (<0.15 leak check)	> 1.02 < 0.98 (>0.15 leak)	OTF	Data qualification Reanalysis/Confirmation by on-site visit / Leak check & correction/document
TSP measurement range	0~100 mg/m^3	> 100 < 0	OTR	Reanalysis/Confirmation by on-site visit / Instrument Inspection
PM10 flow	0.98~1.02 LPM (<0.15 leak check)	> 1.02 < 0.98 (>0.15 leak)	OPF	Data qualification Reanalysis/Confirmation by on-site visit / Leak check & correction/document
PM10 measurement range	0~50 mg/m^3	> 50 < 0	OPR	Reanalysis/Confirmation by on-site visit / Instrument Inspection/document
PM2.5 flow	0.98~1.02 LPM (<0.15 leak check)	> 1.02 < 0.98 (>0.15 leak)	OMF	Data qualification Reanalysis/Confirmation by on-site visit / Leak check & correction/document
PM2.5 measurement range	0~20 mg/m^3	> 20 < 0	OMR	Reanalysis/Confirmation by on-site visit / Instrument Inspection/document

25.0 Reconciliation with User Requirements

Section 7 – Quality Objectives and Criteria for Measurement Data describes the DQOs set forth for this project to assure data representativeness, completeness, comparability, and accuracy. Section 23 – Data Review, Verification, and Validation Requirements and Section 24 – Verification and Validation Methods describe the requirements and methods used in this project to determine the data representativeness, completeness, comparability, and accuracy that will aid in meeting the DQOs. The DQO for data completeness is to obtain valid emissions data for no less then 75% of the scheduled sampling for each pollutant. The DQO sets the Measurement Performance Criterion for daily emission rates at an uncertainty of less than 10%. The emission rate uncertainty for each pollutant is calculated as per section 7.4 at the end of each flock. Uncertainties for fan flow can be calculated at the end of each flock by comparing fan calibrations from the beginning and end of the flock cycle. Pollutant measurement uncertainties can be calculated on a weekly basis based on the calibration gas challenge that is completed for each instrument on a weekly basis. This allows an emissions rate uncertainty to be calculated for each pollutant by week at the end of each flock following the post flock calibration of fans.

The steps to perform the Data Quality Assessment are provided below:

1. Review the DQOs provided in Section 7 and the sample design process detailed in Section 11 – Sample Process Design
2. Conduct a preliminary review of the data
    a. Uncover potential limitations to using the data, to reveal outliers, and to explore the basic structure of the data (processing, reviewing, and sharing the preliminary data included in Section 24)
    b. Look for anomalies in recorded data, missing values, and any deviation from standard operating procedure
3. Perform statistical analysis of the preliminarily accepted data
    a. Base statistical test selection on the primary objective (to determine representative broiler house gaseous and particulate emission rates (kg bird^{-1} day^{-1}))
4. Verify assumptions of the statistical tests
    a. Assumptions include those associated with the development of the DQOs
        i. DQO is based on performance criteria and component error analysis
        ii. Data used for the statistical computation of an emission rate must meet the 75% completeness standard defined in the DQOs (Section 7)
5. Draw conclusions from the data
    a. Determine if an statistical assumptions were violated
    b. Use the statistical analysis to determine representative emission rates

Data is provided to the end users (Tyson and EPA decision makers) in the Final Emissions Report delivered in the 4th quarter of 2007. The report will include a section describing the steps taken to meet the DQOs and descriptions of the data provided. Data provided will include all acceptable raw data (acceptable as determined by the validation and verification methods in

Section 24) and the statistical analysis used to draw conclusions about the results. Possible limitations to the data will be described in the report. The report will also provide a description of the facilities where the data was collected to describe for end users what systems this data is representative of.

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Appendix A: SOP of Information Required from Tyson and Information for the Producer

Measurements to be Taken

1. Inside and outside temperature and relative humidity.
2. Fan status (on/off) and airflow rate.
3. Operation of lights, feeders.
4. Static pressure difference between inside and outside the barn.
5. Inside and outside ammonia and carbon dioxide concentrations.

Measurement Duration

Continuous monitoring of two barns for 12 months, beginning January 2006.

Measurement Logistics

Gas samples are collected using flexible FEP tubes, at three locations in each barn. All gas samples and instrumentation equipment are housed in an 8 ft x 14 ft MAEMU positioned adjacent to the barn. This MAEMU will serve as a shelter for measurement instruments.

Project staff visits the site once a week, or more often as needed. This is required to check equipment status, calibrate sensors, and to make sure everything is working as planned. Most of this time is spent in the instrumentation trailer and not the barns, although some time needs to be spent in the barns to change sample line filters, TEOM filters, exchange TEOM inlet heads, and to check sensors. Strict adherence to biosecurity as per Section 1.7 will be followed.

Barn Modifications

In order to introduce the sensor wires and gas sampling lines into the barns, two 4-in PVC pipes connect the MAEMU to each barn. These pipes house data lines and air sample lines, and are buried.

Requirements for Tyson and Collaborating Producer

Tyson is required to provide the university the following information about each barn:

1. Animal diet, feed consumption, inventory and body weight
2. Production outputs, marketed birds and birds mortality
3. Record of litter removals
4. Record of cleaning operations
5. Record of animal movements in and out of the barn
6. Record of water consumption
7. Advance notification of any alteration in production schedules and methods.
8. Record of equipment failures, (e.g., ventilation fans, inlet control)
9. Power failures
10. Temperature set points
11. Operation of lights

Appendix B: SOP of Gas Sampling System

Vacuum pumps (P1-P4) with *Teflon* wetted parts are used to deliver air from the sampling locations via solenoids and a manifold (M1), and transport the air stream to another manifold (M2), which connects to the gas analyzer. Teflon or Teflon coating is used in all wetted parts of the sampling system (pump, solenoid valves, manifold, and tubing). Four pairs of 2-way solenoid valves (S1-S8) in the air sampling system located in sampling lines are controlled by the DAQ system and control unit to allow measurements of gas concentrations by automatic gas sampling from four locations (figure 1). To avoid the malfunction of solenoid valves due to overheating, solenoid cool boards are used to drive these solenoid valves. When the control module sends the signal to the cool boards, the cool boards will provide full power (12 VDC) on the solenoids during the first 100 ms and then cut the power to approximately half (5 VDC) and hold it. The cool boards solve the overheating problem of the solenoid valves (Figure 2). Individual supply pumps with 16 L/min delivering capacity are used to continuously draw air from each of the sampling locations. The sampling train is designed such that a sample will be drawn from all four sampling points continuously unless a sampling point is note being analyzed. When this occurs, the flow will be bypassed through the normally open solenoid valve (P5-P8). This arrangement is designed to minimize the residence time and thus greatly reduce sample-to-sample purging time. When a sampling stream is selected, the corresponding normal close valve will open and the normal open valve will close; and the selected gas stream will flow from the sample inlet via the tubing through the manifolds (M1 and M2). The internal pump of the gas analyzers draws air from manifold M2. The gas sampling system is designed such that all solenoid valves, manifolds and associated connections are under positive pressure. Using this positive pressure approach if a leak were to develop on the gas sampling control board at any of these components, it would not impact the integrity of the gas sample.

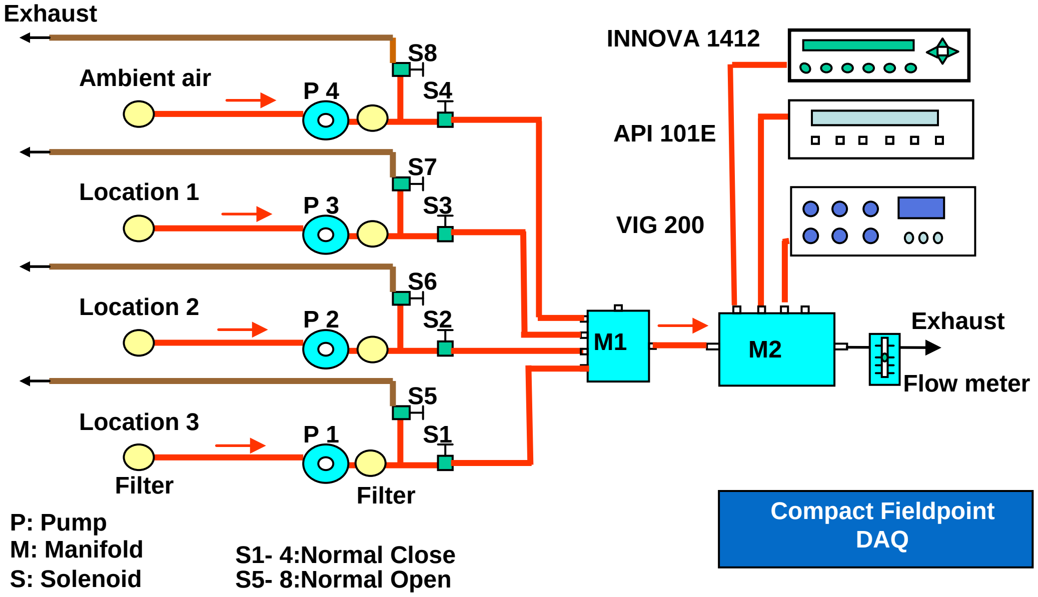

Figure 1. Schematic of sampling system configuration. (The analyzers have internal pumps.)

When needed sampling lines are heated with heat trace or heat tape to prevent in-line condensation, temperature of the sampling line and thus, power input of the heat trace or tape, is continuously monitored and regulated through the DAQ and control system.

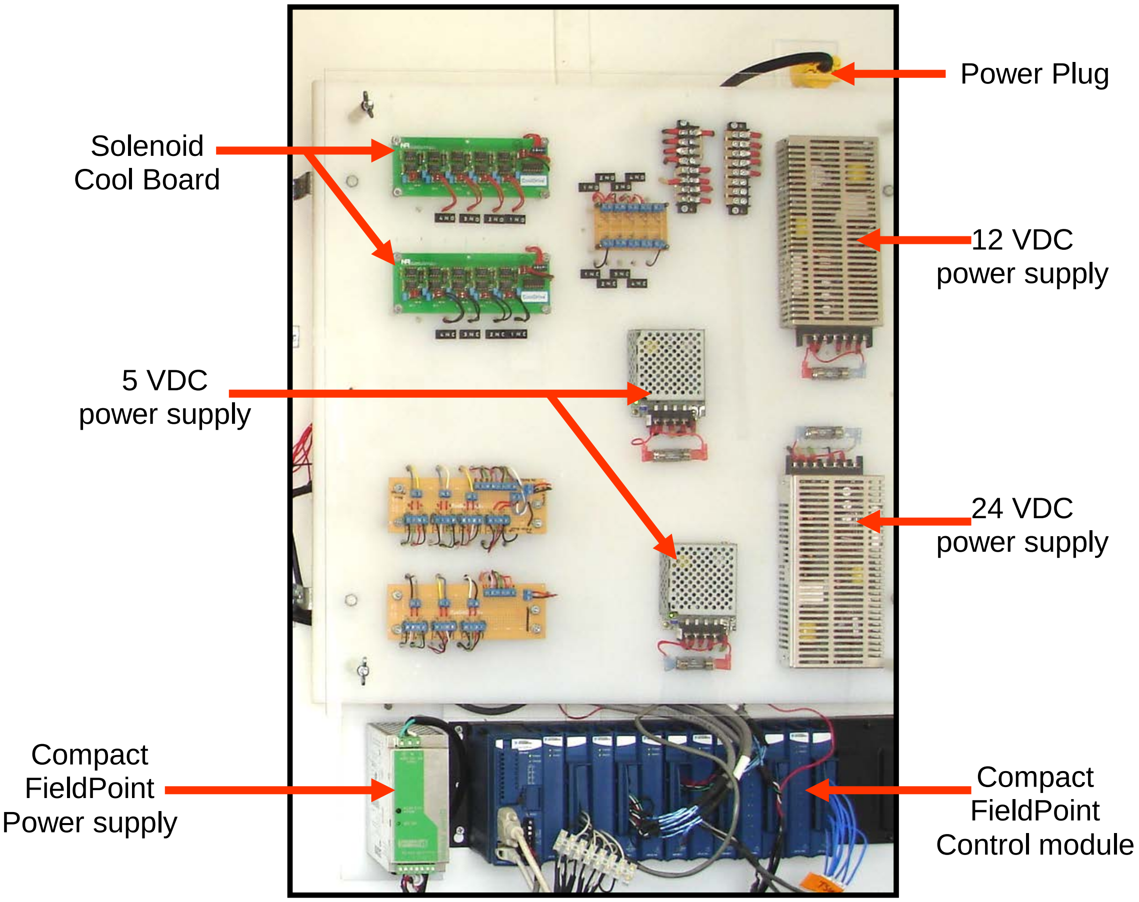

Figure 2. Electronic board and control modules for the sampling system

Two pleated paper filters are used to exclude insects and other coarse particulates, as well as a 47-mm diameter, in-line *Teflon* PFA filter holder housing a 47-mm diameter, *Teflon* PTFE-laminated polypropylene membrane filter with 20-μm pore size, is installed at the sampling end of each gas sampling tube to remove airborne particulate from the sampled air. Another 5-μm pore size PTFE filter is installed right after the vacuum pump to provide double protection. Both in-house sample filters are changed weekly (Figure 3).

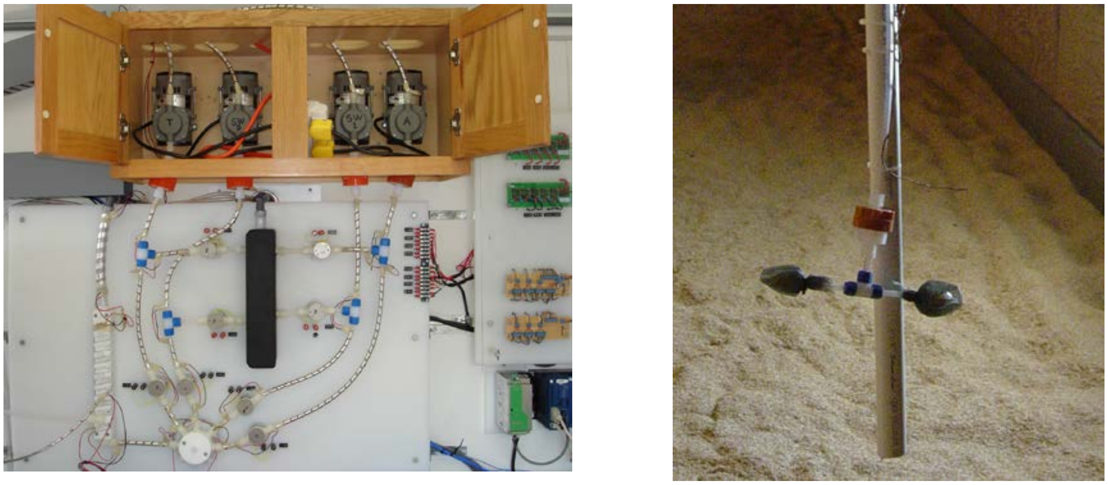

Figure 3. Photographical views of the air sampling system

Appendix C: SOP of Field Estimation of Ventilation Capacity Using FANS

Field Estimation of Ventilation Capacity Using FANS

Introduction

A device for in-situ exhaust fan airflow capacity measurement, referred to as the Fan Assessment Numeration System (FANS) device, previously developed and constructed at the USDA-ARS Southern Poultry Research Laboratory, was refined and constructed by University of Kentucky (Gates et al., 2004[1]). FANS measures the total airflow rate of a ventilation fan by integrating the velocity field obtained from an array of five propeller anemometers used to perform a real-time traverse of the airflow entering ventilation fans of up to 122-cm (48-in) diameter. This SOP provides instructions on installation of the program and operation of the FANS analyzer, and helps in producing high quality measurements.

Data Acquisition Computer

Before using the FANS analyzer, it is necessary to prepare a computer with the necessary hardware to link with the FANS analyzer and software to control and record data. For this, a Keithley DriverLINX card, and the WildCat Anemometer Program (Anemometer2.exe) is needed. *The installation procedures that follow were provided by Ken Casey of the University of Kentucky, and distributed with each FANS unit manufactured.*

Installing Keithley DriverLINX and Anemometer Program

1. Close down all background applications of the computer to be installed.
2. Insert Keithley Card into PCMCIA.
3. Insert the Keithley DriverLINX CD and run the autostart program with command “setup.exe”
4. After the installation window appears, click *“Install DriverLINX”*
5. Click *“Install Drivers”* – c:\Program Files\DrvLINX4
6. and follow directions for registration, use defaults
7. Click “Install Interfaces” – same procedures as step a
8. Be sure to select all options (three of them)
9. Use default folder
10. Click *“Install Documentation”* – use default folder
11. Click *“Back”*, *“Exit”*, and *“Done”*
12. Your computer will be restarted
13. Once restarted, a screen should come up for hardware configuration
14. Follow step 2. Plug & Play should install drivers

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[1] Gates, R.S., K.D. Casey, H. Xin, E.F. Wheeler and J.D. Simmons. 2004. Fan Assessment Numeration System (FANS) design and calibration specifications. Transactions of the ASAE, 47(5):1709-1715.

15. Wait some time for response
16. Afterwards – click *"continue"*, follow directions
17. Probably, click *"configure"*
18. Under hardware configuration
19. Assign logical device number (the default – probably 0)
20. Leave all other values at default, click *"OK"*, and close window
21. Remove Keithley Card, wait about 10 seconds
22. Reinsert card, click "*Start*", "*Programs*", "*DriverLINX*", "*Test Panels*"
23. Run the AIO Panel
24. If it says "No Driver loaded" – reboot, ignore the rest of installer and restart AIO Panel.
25. You should be ready to run
26. You may need to tweak in "*DriverLINX Configuration Panel"*
27. Copy *Anememeter2.exe* and *Anememeter2.mdb* from floppy disc supplied into your directory

FANS Analyzer Unit
In order to ensure the FANS analyzer is operating properly, test both manual and software control as follows:

1. Supply the FANS analyzer with power.
2. The right-most toggle switch should be in up position.
3. Toggle left-most switch up and down, holding for a few seconds at a time to ensure that the motor is moving the anemometers properly.
4. After successful manual operation, test the "motor up" and "motor down" functions on the computer screen to determine if software has functional control.

If all is working properly, initiate a data collection traverse with no airflow and without anemometer propellers installed to establish the zero offset airflow correction. Then place the individual propellers onto the unit. The propellers cannot be installed at the traverse end positions due to limited space; therefore the traverse bar must be moved at least six inches from the top or bottom. Make sure that the number of the propeller and of the open-vane anemometer match (there are five in all – numbers are marked on both).

Operation. The fan to be tested should be turned on and warmed up for at least 10 minutes. A fan is tested over the normal operating range of building static pressure (SP) difference. At least four SPs are tested covering a range from slightly below to slightly above the normal building operating range. After the FANS is positioned at a chosen fan, a static pressure (SP) is set. Once SP has stabilized, two FANS traverses are run in quick succession. If the two runs differ by more than 2%, another traverse is performed. For lower range airflows, a 3% difference between traverses is acceptable. All tests are done when the house has no birds present so that any ventilation condition could be evaluated without jeopardizing bird comfort and well-being.

Moving and Positioning. A cart is helpful to aid in moving the FANS unit down the length of a long poultry house and positioning it in front of a fan. A hydraulic lift can be added to provide easy height adjustment of the 80-pound FANS unit to match the test fan height. Moving and positioning is best done with two workers. Complications with FANS setup include the need to move knee braces, water lines and electrical outlets in certain facilities. Each of these situations and other anomalies require special attention and can add substantial time to each setup.

Sealing FANS to Fan Housing. Sealing the FANS to the wall and/or fan housing is critical to accurate measurement, and can take the bulk of the setup time in moving the FANS from one fan to the next. A special gasket created from open-cell pipe insulation placed over ½-in PVC pipe and positioned between the FANS frame and the wall has been successfully used to provide a tight seal and reduce the need for extensive taping. The FANS is positioned against this gasket and two ratchet straps are used to draw the FANS unit tightly against the gasket and wall. Duct tape is used to seal any remaining gaps or cracks.

Fan housings that project through the wall into the interior space can prevent the FANS unit from being placed against the wall and thus present special challenges. For these situations, a 6-inch extension of the FANS frame, constructed of polystyrene and the same dimensions as the FANS frame, has been used to seal against the above mentioned pipe insulation gasket.

Duct Transition to Smaller Fan. Measurement accuracy is not affected by use of a transition to measure smaller diameter fans. A lightweight collapsible duct (blue polystyrene R-3) can be used to connect the FANS unit, with square opening of about 52 in, to 36 in or smaller fans. Gaps are sealed with duct tape. The duct is 48 inches long, which is about 1.3 fan diameters of the smaller fan, with one to two diameters length considered acceptable. Setup time for the duct is even longer than for the sealing method descried in the previous section for testing larger fans. Wherever possible, the FANS unit should be used directly without a transition, simply to save time.

Measuring Larger Ventilation Fans. Measurement accuracy is affected by use of a transition to measure larger diameter fans. Available literature (Gates et al., 2004) suggests that there is a penalty associated with forcing airflow through the FANS unit and into a fan whose approach aperture exceeds that of the FANS. It is recommended that each model of fan be independently tested in a certified fan test facility, with and without the FANS unit, to assess the degree of penalty. Ventilation fans of 48 inches or smaller have not been shown to be affected by this issue.

Streamlining Data Collection. Once the crew is practiced at setting up and operating the FANS at different static pressures, a complete setup and test for 4 or 5 static pressures can be accomplished in 1 to 1 ½ hours per fan in a broiler barn. The approximate time required for each fan test is as follows. About 7 minutes is needed for two consecutive FANS traverses plus data notation time, although more than 2 traverses are sometimes required. Changing and stabilizing each static pressure setting requires less than 5 minutes, but with even minor complications this can exceed ten minutes. For example, end doors and all inlets need to be opened to get a zero SP reading and then closed again to get the other SP settings. These FANS traverses are preceded by 10 to 20 minutes of FANS positioning and about 10 minutes of sealing the FANS to the fan housing. If a transition duct is used for a 36-inch fan, then 40 to 50 minutes is needed to assemble and seal a pre-cut duct between the FANS and the fan housing. More time is needed if the duct is fabricated from scratch.

Walkie-talkie radios are used so that the person adjusting static pressure in the control room can communicate with the person(s) running the FANS unit. Often these two people are out of sight of each other. The radios eliminate disruptive yelling and miscommunications. The FANS unit operator can tell the SP control person when tests are completed. Likewise, the SP control person can indicate when the test SP is adjusted and steady in order to start the test.

Appendix D: SOP of INNOVA 1412 Photoacoustic Multi-gas Monitor

INNOVA 1412 Photoacoustic Multi-gas Monitor

Description and Principle of Operation

The photoacoustic multi-gas monitor (INNOVA 1412, Innova AirTech Instruments, Denmark) is a highly accurate, reliable and stable quantitative gas monitoring system. It uses a measurement system based on the photoacoustic infra-red detection method, and is capable of measuring almost any gas that absorbs infra-red light. Gas selectivity is achieved through the use of optical filters. By installing up to five of these filters in the 1412, it can measure the concentration of up to 5 component gases and water vapour in any air sample. Although the detection limit is gas dependent, it is typically in the ppb region. The accuracy of these measurements is ensured by the 1412's ability to compensate for temperature and pressure fluctuations, water vapour interference and interference from other gases known to be present. Reliability of measurement results can be ensured by regular self-tests, which the 1412 performs.

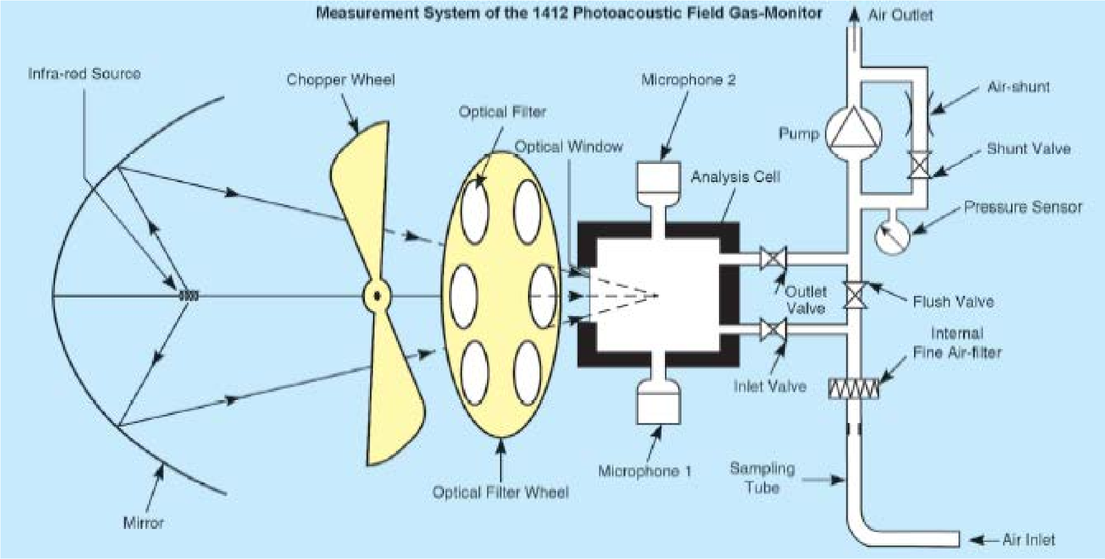


Figure 1. Measurement System of the 1412

An interior pump draws air from the sampling point through the air-filter to flush out the "old" air in the measurement system and replace it with a "new" air sample. The "new" air sample is hermetically sealed in the analysis cell by closing the inlet and outlet valves (Figure 1). Light from an infra-red light source is reflected off a mirror, passed through a mechanical chopper, which pulsates it, and then through one of the optical filters in the filter wheel. The gas being monitored, causes the temperature of the gas to increase selectively absorbs the light transmitted by the optical filter. Because the light is pulsating, the gas temperature increases and decreases, causing an equivalent increase and decrease in the pressure of the gas (an acoustic signal) in the closed cell. Two microphones mounted in the cell wall measure this acoustic signal, which is directly proportional to the concentration of the monitored gas present in the cell. The filter wheel turns so that light is transmitted through the next optical filter, and the new signal is measured. The number of times this is repeated is dependent upon the number of gases being measured. The response time is down to approximately 13 s for one gas or water vapour, or approximately 40 s if five gases and water vapour are measured. The NH_3's full scale is adjustable up to 2000 ppm. It has a lower detectable limit of 60 ppb.

The INNOVA 1412 multi-gas analyzer is specified with 1-second sampling integration time and fixed flushing time: 2 seconds for the chamber and 3 seconds for the tubing; and the response time for one single sampling cycle with NH_3, carbon dioxide and dew-point temperature measurements is approximately 22 sec. The response time of the analyzer to step changes in gas concentrations was tested (figure 2). The analyzer was challenged with two NH_3 calibration span gases, 22.8 ppm and 60.8 NH_3 respectively in a N_2 balance (±2% accuracy) (Matheson Gas Products, Inc., Montgomeryville, PA) at flow rates of 8 L/min through two 80 ft long individual sampling lines. At the beginning of the test, the two sampling lines were full of N_2 gas. During the first two sampling cycles, the time taken for the readings to change from 0 ppm (N_2 gas) to 22.8 ppm was 10 cycles (220 s), and the time taken for the readings to change from 22.8 ppm (span gas) to 60.8 ppm was also 10 cycles (220 s). After the first two span gas changes, the time taken for the readings to change from 22.8 to 66.8 ppm or from 60.8 to 22.8 ppm within ± 2% difference was 4 cycles (88 sec).The reason of 10 cycles required for the initial two changes was to purge the N_2 gas in the sampling lines. Once the sampling lines were full of the span gases, the NH_3 analyzer had a faster response time. It implied that separate sampling line should be used for each sampling location and air sample should be drawn continuously. Similarly, the time taken for the readings to change from 22.8 ppm to zero air was greater than 10 cycles when sampling lines were purged by zero gas. Thus, the results indicated that an 88-s sampling time (4 cycles) for the NH_3 analyzer would be sufficient to achieve 97% or better of the concentration value.

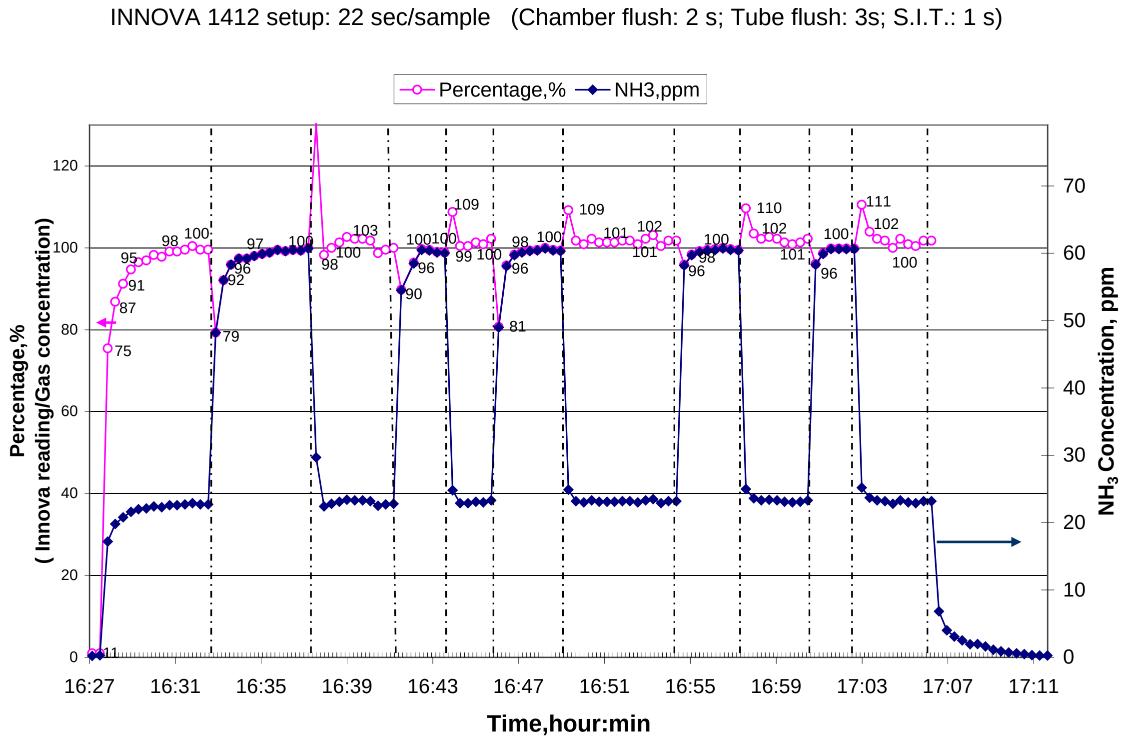


Figure 2 . Response of INNOVA 1412 intermittent exposure of 22.8, 60.8 ppm NH_3 (N_2 balance) and ambient air.

Warming Up the Monitor

The infra-red light source is very hot and the temperature in the analysis cell thus increases as calibration measurements procedure. Conditions within the cell tend to stabilize more quickly once the temperature inside the analysis cell is 15°C above the ambient room temperature. A period of 30 – 40 min is suggested to warm up the analysis cell before a calibration task is started. This will reduce the time required for calibration.

The Basic Calibration Set-up

The general equipment required to perform the calibration is shown in Figure 3. The sampling tubing to the VIG 200 will be disconnected and plugged. All the solenoid valves around the manifold (M1) will be close by using the manual control in the LabView 7 program. The tubing from the gal-gas cylinder will be connected to the flow meter which is mounted on the side of the instrument rack and connected to the sampling manifold (M2).

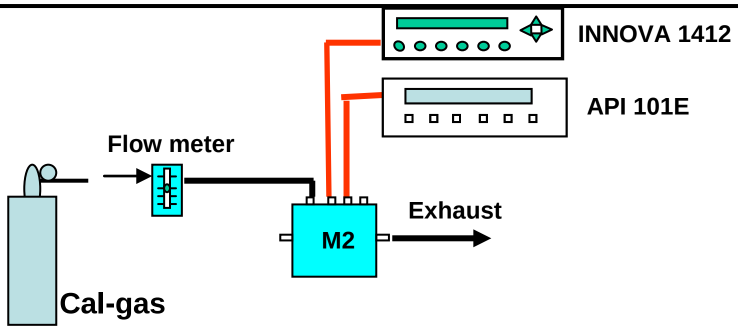


Figure 3. General equipment required for a calibration task

Calibration

Producing a Supply of Clean, Wet Air

Bubble zero-gas through a thermostatically controlled water-bath to produce a supply of clean, wet air to the Monitor during humidity interference calibration of the filters (see Figure 4).
The temperature of the water bath should be at least 2°C **below** the ambient temperature of the room where calibration is to be performed.

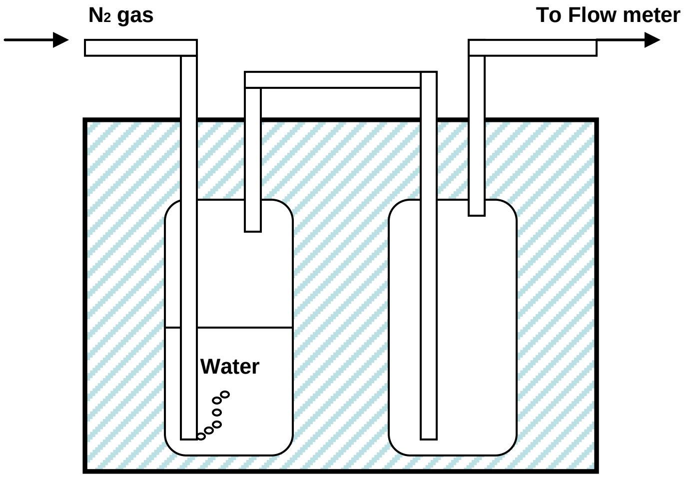


Figure 4. Schematic diagram of the equipment necessary to produce a supply of clean, wet air.

Setting the communication parameters

The communication parameters necessary for the monitor to communicate with the Gas Monitoring Software 7304 are shown below:

Baud rate	9600
Stop bits	1
data bits	7
Parity	Even
Hardwire mode	leased line
Handshake type	Hardwire

To prevent communication errors, the text line terminator, print data log and print error log must be set as shown below:

Text line Terminator	CR-LF

Print Data Log	**NO**
Print Error Log	NO

Setup→ CONFIGURATION→System→General→Test→ Self test→Yes→Print Data Log→NO→Print Error Log→NO

Calibration Gases

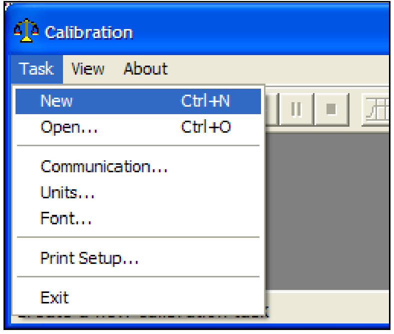
Zero air, CO_2 in N_2 and NH_3 in N_2 are used to calibrate the instrument. The certified calibration gases will consist of zero air (Acid Rain CEM zero), CH_4 in N_2 (EPA Protocol, ±2 % accuracy), Propane in N_2 (EPA Protocol, ±2 % accuracy), CO_2 in N_2 (EPA Protocol, ±2 % accuracy), NH_3 in nitrogen (Title 5 ammonia per EPA Conditional Method 27E, ±2% accuracy).

Zero and Span Calibration Procedure for Analyzer Only

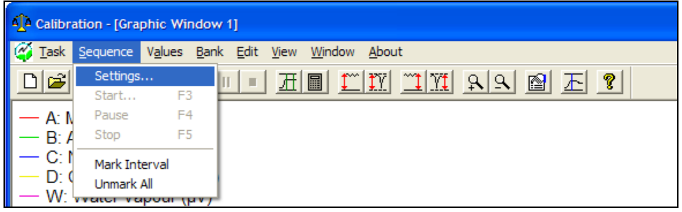
- Change the setting of 1412 communication parameters.
- Turn off the 1412 and disconnect 1412 with the Compact Fieldpoint module.
- Reconnect the 1412 to the COM1 port of the PC.
- Turn on the 1412.
- Open the Calibration program and create a new calibration task.
- Detach the air inlet tube from the existing sampling manifold. Close the pipe adapter of the sampling manifold with a cap or plug.
- Attach the 1412 to a calibration manifold.

Zero (N_2) Gas Calibration

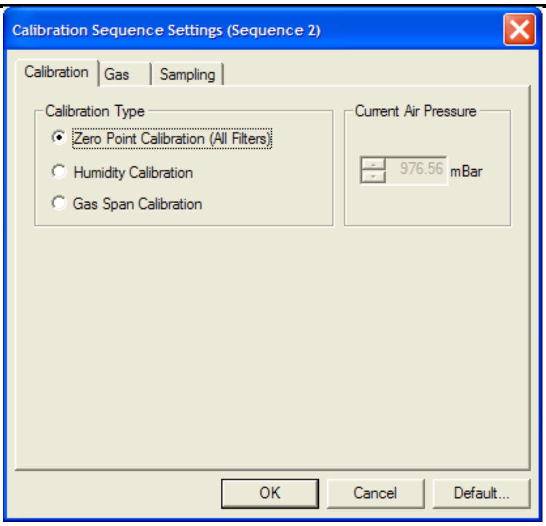
1. Open the Calibration program and create a **New** task.



2. Type in the desired task name (TYSON ##_MMDDYYYY) and click **OK**.
3. Pull down the **Sequence** menu. Click **Settings**.



4. Click on the Calibration index-card, if it is not already at the front.

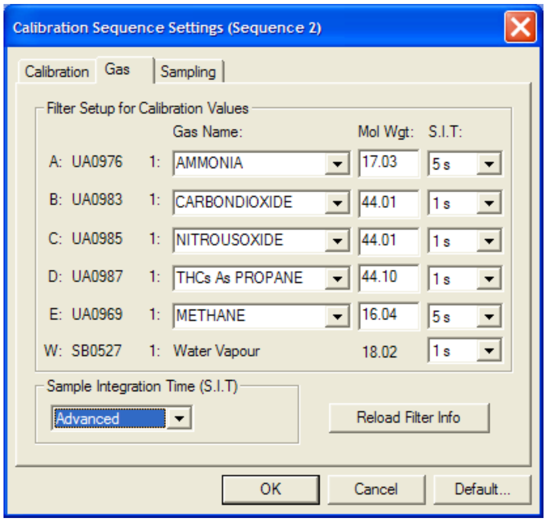


Calibration Type

● Zero Point Calibration (All Filters)
○ Humidity Calibration
○ Gas Span Calibration

Current Air Pressure: 976.56 mBar

5. Click to select **Zero point** radio-button.
6. Click on the Gas index-card and click in the Sample Integration Time field, and select the desired time: 5 s for Ammonia, 1s for CO_2, 1s for Nitrous oxide (N_2O), 1s for propane and 5s for CH_4.

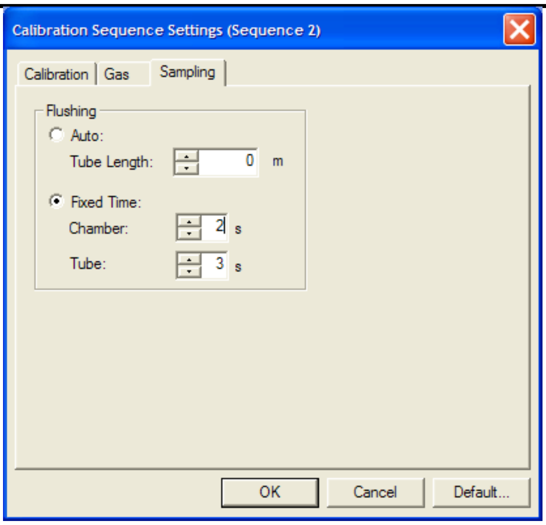


Filter Setup for Calibration Values

			Gas Name:	Mol Wgt:	S.I.T:
A:	UA0976	1:	AMMONIA	17.03	5 s
B:	UA0983	1:	CARBONDIOXIDE	44.01	1 s
C:	UA0985	1:	NITROUSOXIDE	44.01	1 s
D:	UA0987	1:	THCs As PROPANE	44.10	1 s
E:	UA0969	1:	METHANE	16.04	5 s
W:	SB0527	1:	Water Vapour	18.02	1 s

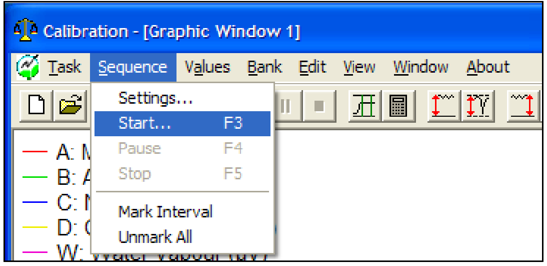
Sample Integration Time (S.I.T): Advanced

7. Click on the Sampling index-card and set the flushing time to desired time: Fixed time, 2 s for Chamber and 3 s for Tube.

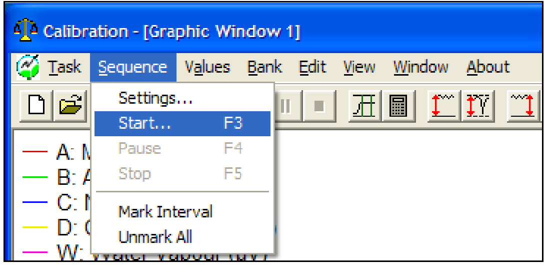


Flushing
○ Auto:
Tube Length: 0 m
● Fixed Time:
Chamber: 2 s
Tube: 3 s

8. When all the settings are correct, click on **OK**.
9. Pull down the **Sequence** menu and click on **Start.**

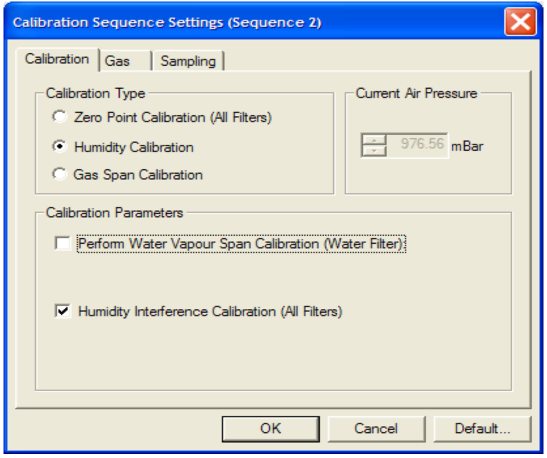


10. Insert the 1/4” ID tubing (from N_2 gas regulator) to the flow meter mounted on the side of the instrument rack; then open the regulator valve to allow gas flow. Zero gas is now flowing from the cylinder to the 1412.
11. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra zero air to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
12. Record time and analyzer display in lab notebook.
13. Close regulator and remove Zero gas tubing.
14. Pull down the **Sequence** menu and click on **Stop** after display is stabilized (typically 10 to 15 minutes).



Humidity Calibration

1. Pull down the **Sequence** menu. Click **Settings**.
2. Click on the Calibration index-card, if it is not already at the front.
3. Click to select **Humidity Calibration**.



Calibration Type
○ Zero Point Calibration (All Filters)
● Humidity Calibration
○ Gas Span Calibration

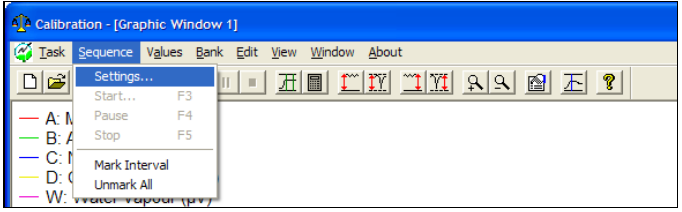
Current Air Pressure
976.56 mBar

Calibration Parameters
☐ Perform Water Vapour Span Calibration (Water Filter)
☑ Humidity Interference Calibration (All Filters)

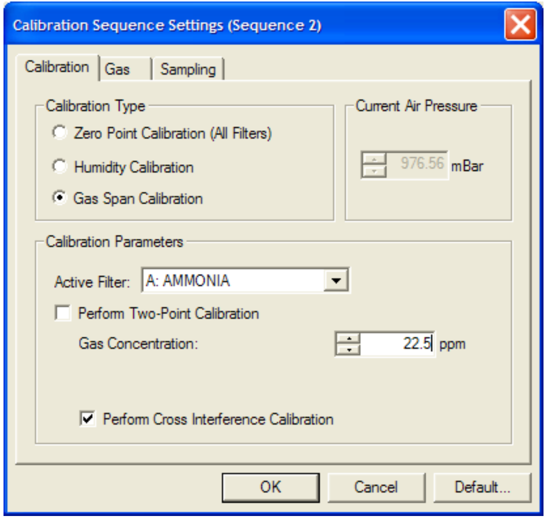
4. Only Select “**Humidity Interference Calibration (All Filters)**”. **Do not** select “Perform Water Vapor Span Calibration”.
5. Click on the Gas index-card and click in the Sample Integration Time field, and select the desired time as above.
6. When all the settings are correct, click on **OK**.
7. Pull down the **Sequence** menu and click on **Start**.
8. Connect a water bath device between the zero gas regulator and the flow meter mounted on the side of the instrument rack; then open the regulator valve to allow gas flow. Zero gas is now flowing from the cylinder to the 1412.
9. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra zero air to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
10. Record time and analyzer display in lab notebook.
11. Close regulator and main valve and remove zero gas tubing.
12. Pull down the **Sequence** menu and click on **Stop** after display is stabilized (typically 10 to 15 minutes).

Span Gas Calibration (NH_3)

1. Pull down the **Sequence** menu. Click **Settings**.



2. Click on the Calibration index-card, if it is not already at the front.
3. Click to select **Gas Span Calibration** radio-button.



Calibration Type
○ Zero Point Calibration (All Filters)
○ Humidity Calibration
● Gas Span Calibration

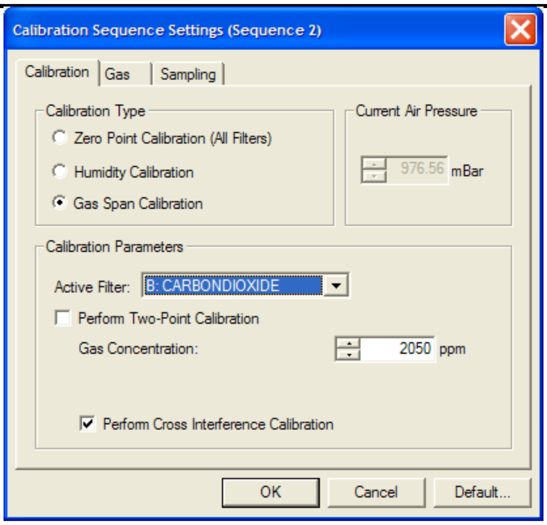
Current Air Pressure
976.56 mBar

Calibration Parameters
Active Filter: A: AMMONIA
☐ Perform Two-Point Calibration
Gas Concentration: 22.5 ppm
☑ Perform Cross Interference Calibration

4. Click in the Active filter field Ammonia and select the **Ammonia**, and check **Perform Cross Interference Calibration** and input the concentration of NH_3 gas.
5. Click on the Gas index-card and click in the Sample Integration Time field, and select the desired time as above.
6. When all the settings are correct, click on **OK**.
7. Pull down the **Sequence** menu and click on **Start**.
8. Insert the 1/4” ID tubing (from the NH_3 gas cylinder) to the flow meter mounted on the side of the instrument rack; then open the regulator valve to allow gas flow. NH_3 gas is now flowing from the cylinder to the 1412.
9. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra gas to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
10. Record time and analyzer display in lab notebook.
11. Close regulator and main valve and remove tubing from the NH_3 gas cylinder.
12. Pull down the **Sequence** menu and click on **Stop** after display is stabilized (typically 10 to 15 minutes).

Span Gas Calibration (CO_2)

1. Pull down the **Sequence** menu. Click **Settings**.
2. Click on the Calibration index-card, if it is not already at the front.
3. Click to select **Gas Span Calibration** radio-button.
4. Click in the Active filter field Ammonia and select the **Carbon Dioxide**, and check **Perform Cross Interference Calibration** and input the concentration of CO_2 gas.


Calibration Sequence Settings (Sequence 2)

Calibration Type
○ Zero Point Calibration (All Filters)
○ Humidity Calibration
● Gas Span Calibration

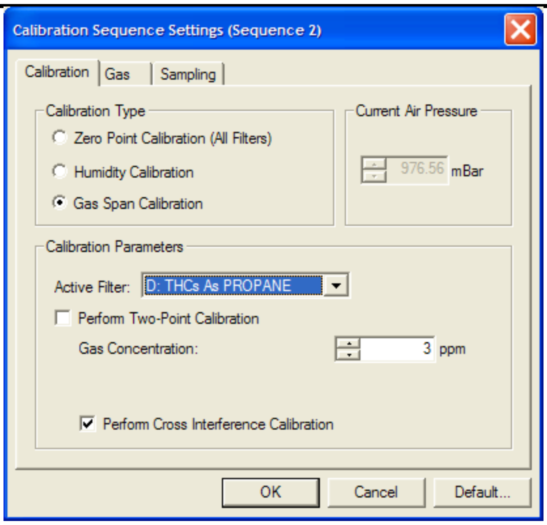
Current Air Pressure: 976.56 mBar

Calibration Parameters
Active Filter: B: CARBONDIOXIDE
☐ Perform Two-Point Calibration
Gas Concentration: 2050 ppm
☑ Perform Cross Interference Calibration

5. Click on the Gas index-card and click in the Sample Integration Time field, and select the desired time.
6. When all the settings are correct, click on **OK**.
7. Pull down the **Sequence** menu and click on **Start**.
8. Connect the 1/4" ID tubing (from the CO_2 gas cylinder) with a Nafion tubing, and then connect to the manifold; then open the regulator valve to allow gas flow. CO_2 gas is now flowing from the cylinder to the 1412.
9. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra gas to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
10. Record time and analyzer display in lab notebook.
11. Close regulator and main valve and remove tubing from the CO_2 gas cylinder.
12. Pull down the **Sequence** menu and click on **Stop** after display is stabilized (typically 10 to 15 minutes).

Span Gas Calibration (Propane)

13. Pull down the **Sequence** menu. Click **Settings**.
14. Click on the Calibration index-card, if it is not already at the front.
15. Click to select Gas Span Calibration radio-button.
16. Click in the Active filter field Ammonia and select the **THC (propane)**, and check **Perform Cross Interference Calibration** and input the concentration of Propane gas.



Calibration Type
○ Zero Point Calibration (All Filters)
○ Humidity Calibration
● Gas Span Calibration

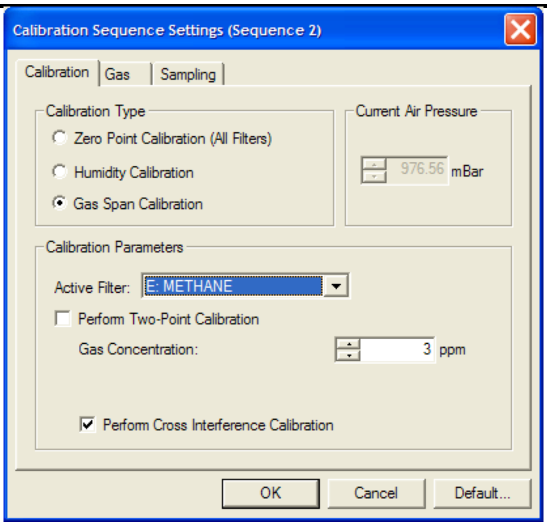
Current Air Pressure
976.56 mBar

Calibration Parameters
Active Filter: D: THCs As PROPANE
☐ Perform Two-Point Calibration
Gas Concentration: 3 ppm
☑ Perform Cross Interference Calibration

17. Click on the Gas index-card and click in the Sample Integration Time field, and select the desired time.
18. When all the settings are correct, click on **OK**.
19. Pull down the **Sequence** menu and click on **Start**.
20. Connect the 1/4” ID tubing (from the Propane gas cylinder) to the flow meter mounted on the side of the instrument rack; then open the regulator valve to allow gas flow. Propane gas is now flowing from the cylinder to the 1412.
21. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra gas to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
22. Record time and analyzer display in lab notebook.
23. Close regulator and main valve and remove tubing from the Propane gas cylinder.
24. Pull down the **Sequence** menu and click on **Stop** after display is stabilized (typically 10 to 15 minutes).

Span Gas Calibration (CH_4)

25. Pull down the **Sequence** menu. Click **Settings**.
26. Click on the Calibration index-card, if it is not already at the front.
27. Click to select Gas Span Calibration radio-button.
28. Click in the Active filter field Ammonia and select the **CH_4 (Methane)**, and check **Perform Cross Interference Calibration** and input the concentration of methane gas.



Calibration Sequence Settings (Sequence 2)

Calibration | Gas | Sampling

Calibration Type
○ Zero Point Calibration (All Filters)
○ Humidity Calibration
● Gas Span Calibration

Current Air Pressure
976.56 mBar

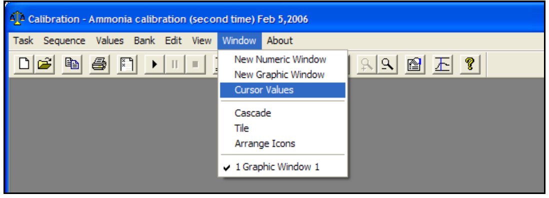
Calibration Parameters
Active Filter: E: METHANE
☐ Perform Two-Point Calibration
Gas Concentration: 3 ppm
☑ Perform Cross Interference Calibration

29. Click on the Gas index-card and click in the Sample Integration Time field, and select the desired time.
30. When all the settings are correct, click on **OK**.
31. Pull down the **Sequence** menu and click on **Start**.
32. Connect the 1/4” ID tubing (from the Methane gas cylinder) to the flow meter mounted on the side of the instrument rack; then open the regulator valve to allow gas flow. Propane gas is now flowing from the cylinder to the 1412.
33. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra gas to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
34. Record time and analyzer display in lab notebook.
35. Close regulator and main valve and remove tubing from the Methane gas cylinder.
36. Pull down the **Sequence** menu and click on **Stop** after display is stabilized (typically 10 to 15 minutes).

Calculating Calibration Factors

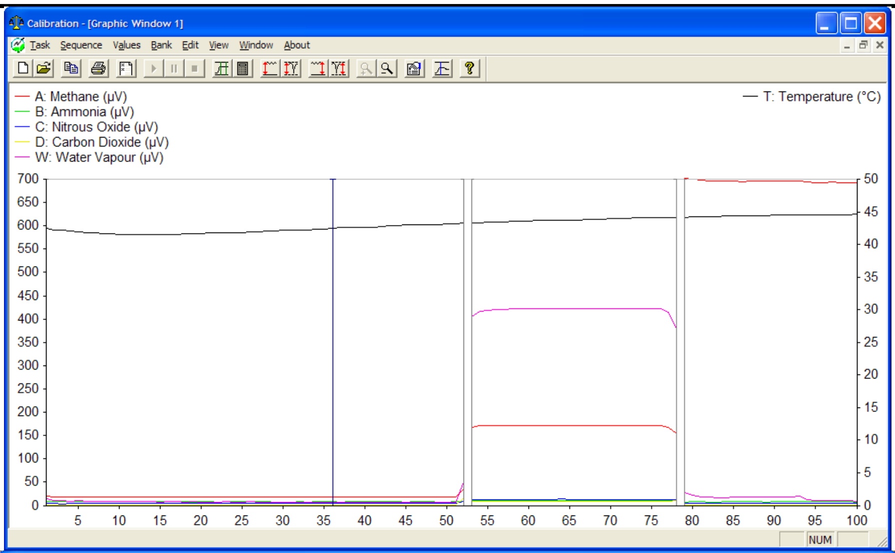
With the raw measurement data displayed on screen:

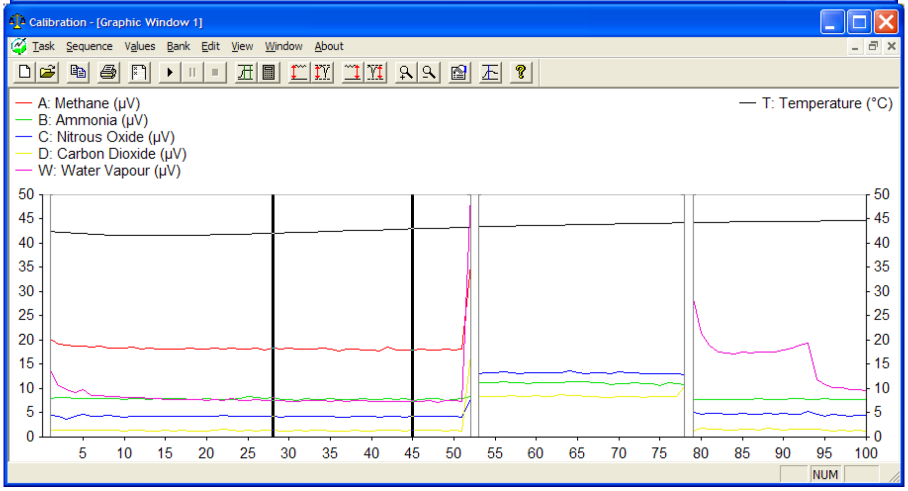
1. Open the Cursor Values dialogue.



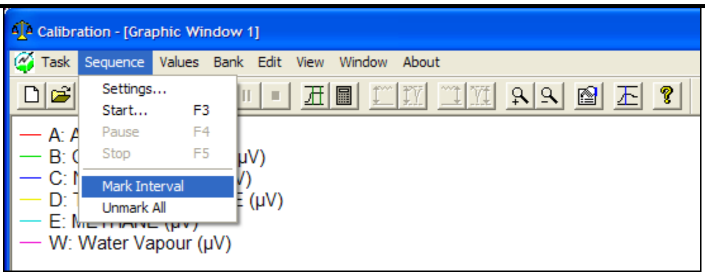
Calibration - Ammonia calibration (second time) Feb 5,2006

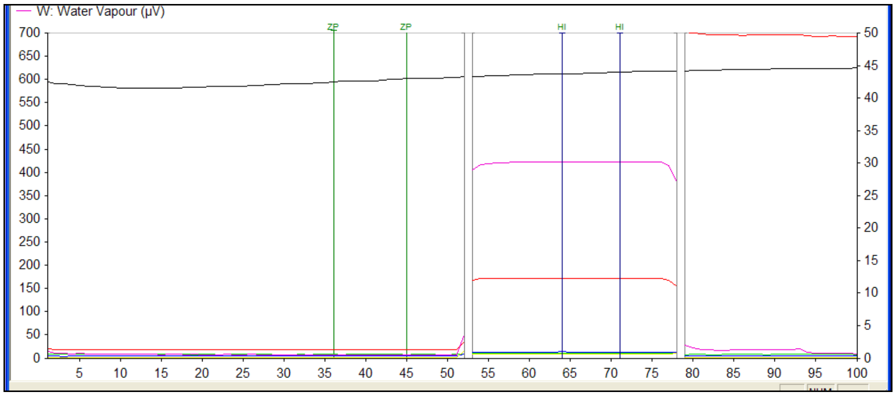
2. Use two cursors and the statistical data are displayed in the Cursor Values dialogue to locate a suitable range of data. All values in the select interval should be very stable and the temperature should be above 40 ^{o}C.



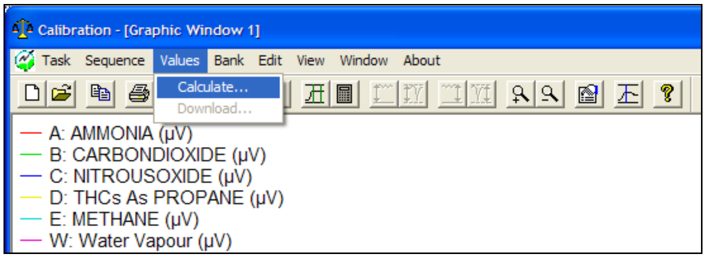


3. When you have the desired region between the cursors, pull down the **Sequence** menu and click on **Mark Interval**. The two cursors are replaced by a pair of green lines. These lines have markings at the end of them, which show the type of calibration data lying between the lines. The markings are:
   ZP: shows a zero point calibration
   HI: shows a humidity interference calibration
   SHA: shows a span calibration (filter A)
   SHB: shows a span calibration (filter B)
   SHC: shows a span calibration (filter C)
   SHD: shows a span calibration (filter D)
   SHE: shows a span calibration (filter E)





4. Select and mark all the intervals for every calibration.
5. Pull down the **values** menu and click on **calculate.**



6. When the calculation(s) is complete a Calculation Finished dialogue is displayed.

To download the calculated values

1. Pull down the **Values** menu. Click on **Download** and the Download dialogue is displayed.
2. Select the **Zero Point** index card
3. Set ticks in the NH_3, CO_2, Propane and Methane and Water Vapor check boxes.
4. Repeat steps 2 and 3 in the **Humidity** and **Gas** index cards.
5. Click on **OK**. The calibration factors are now downloaded to the monitor.

Post Calibration

a. Check and close main valves on all cylinders
b. Calibration of the 1412 monitor is complete
c. Turn off the 1412 and disconnect 1412 with the PC.
d. Reconnect the 1412 with compact Fieldpoint and turn on the 1412.
e. Set the filter sampling integration time back to original setup: 1 s for each filter.

Setup→Configuration→Filters→Filter A→YES→1s S.I.T→Filter B→YES→1s S.I.T→Filter C→YES→1s S.I.T→Filter D→YES→1s S.I.T→Filter E→YES→Water Filter→ YES→1s

6. The communication parameters necessary for the monitor to communicate with the compact Fieldpoint are shown below:

Baud rate	9600
Stop bits	2
data bits	7
Parity	Even
Hardwire mode	Leased line
Handshake type	Hard wired

Print data log and print error log must be set as shown below:

Text line Terminator	CR-LF
Print Data Log	**Yes**
Print Error Log	No

Setup→ CONFIGURATION→System→General→Test→ Self test→Yes→Print Data Log→Yes→Print Error Log→NO

Routine Checking

Zero and Span Check Procedure for Analyzer Only

- Detach the air inlet tube from the existing sampling manifold. Close the pipe adapter of the sampling manifold with a cap or plug.
- Attach the 1412 to a calibration manifold.

<u>Zero Gas Check</u>

a. Insert the 1/4” ID tubing (from the NH_3 gas cylinder) into the manifold connected to the valve; then open the regulator valve to allow gas flow. Zero gas is now flowing from the cylinder to the 1412.
b. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra zero air to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
c. Close regulator and remove tubing from the zero gas cylinder after display is stabilized (typically 5 to 10 minutes).

<u>Span Gas Check (NH_3)</u>

1. Insert the 1/4” ID tubing (from the NH_3 gas cylinder) into the manifold connected to the valve; then open the regulator valve to allow gas flow. NH_3 gas is now flowing from the cylinder to the 1412.
2. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold).

This provides a little extra gas to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.

3. Close regulator and main valve and remove tubing from the NH3 gas cylinder after display is stabilized (typically 5 to 10 minutes).

Span Gas Check (CO_2)

1. Connect the 1/4" ID tubing (from the CO_2 gas cylinder) with a Nafion tubing, and then connect to the manifold; then open the regulator valve to allow gas flow. CO_2 gas is now flowing from the cylinder to the 1412.
2. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra gas to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
3. Close regulator and main valve and remove tubing from the CO2 gas cylinder after display is stabilized (typically 5 to 10 minutes).
4. Reattach the filters to the existing gas sampling system.
5. Check and close main valves on all cylinders.

Span Gas Check (CH_4)

1. Insert the 1/4" ID tubing (from the CH_4 gas cylinder) into the manifold connected to the valve; then open the regulator valve to allow gas flow. CH_4 gas is now flowing from the cylinder to the 1412.
2. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra gas to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
3. Close regulator and main valve and remove tubing from the CH_4 gas cylinder after display is stabilized (typically 5 to 10 minutes).
4. Reattach the filters to the existing gas sampling system.
5. Check and close main valves on all cylinders.

Span Gas Check (N_2O)

1. Connect the 1/4" ID tubing (from the N_2O gas cylinder) with a Nafion tubing, and then connect to the manifold; then open the regulator valve to allow gas flow. N_2O gas is now flowing from the cylinder to the 1412.
2. Adjust regulator valve until vent airflow is about 2.5 L/min (read from bottom of ball of the vent monitoring flow meter installed in outlet of calibration manifold). This provides a little extra gas to the 1412 and keeps the pressure inside the manifold close to the atmospheric pressure.
3. Close regulator and main valve and remove tubing from the N_2O gas cylinder after display is stabilized (typically 5 to 10 minutes).
4. Reattach the filters to the existing gas sampling system.
5. Check and close main valves on all cylinders.

Manufacturer Contact Information

Innova AirTech Instruments (www.innova.dk)
Energivej 30 Tel.: (+45) 44 20 01 00 innova@innova.dk

DK-2750 Ballerup, Denmark Fax: (+45) 44 20 01 01

Reference:

1412 Photoacoustic Field Gas-Monitor Technical Document, INNOVA Air Tech Instruments.

Maintenance/Calibration Record Sheet for INNOVA 1412 Multi-gas Monitor

Date of Calibration: __________________ Calibrated by: __________________

Time	Items	Unit =	Notes
: :	Ambient pressure, (mm Hg)		
	Sample airflow (L/min)		
: :	Zero air applied	---	Cylinder P: ___ psi
: :	NH_3 Reading		
: :	CO_2 Reading		
	N_2O Reading		
	CH_4 Reading		
	Propane Reading		
: :	CO_2 (______ ppm) applied (With Nafion Tubing)	---	Cylinder P: ___ psi
: :	CO_2 Reading		
: :	NH_3 (______ ppm) applied	---	Cylinder P: ___ psi
: :	NH_3 Reading		
: :	CH_4 (______ ppm) applied	---	Cylinder P: ___ psi
	CH_4 Reading		
: :	Propane (______ ppm) applied	---	Cylinder P: ___ psi
	Propane Reading		
: :	N_2O (______ ppm) applied	---	Cylinder P: ___ psi
	N_2O Reading		
: :	New Calibration	Yes/No	
: :	Zero air applied		
: :	Zero humidity air applied		
: :	NH_3 applied		
: :	CO_2 applied (With Nafion Tubing)		
: :	Propane applied		
: :	CH_4 applied		
: :	N_2O applied		
: :	Download to Bank	Yes/No	
: :	Time switch off	---	
: :	Connect analyzer back to sampling system.		
Note:			

Appendix E: SOP of Temperature and Humidity Measurement

Temperature Measurements

Type T thermocouple is used to measure house temperature by compact Fieldpoint thermocouple module:
Maximum Temperature Range:
Thermocouple Grade
– 200 to 350°C.
Extension Grade
– 60 to 100°C.
Limits of Error
Standard: 1.0°C or 0.75% Above 0°C.
Special: 0.5°C or 0.4%.
A water bath and two precision ASTM mercury-in-glass thermometers (-8 to 32 °C and 25 to 55 °C, 0.1 °C precision) are used for calibration.

Humidity Measurements

HMW61U Humidity Transmitter

Electrical Cable Connection

+RH	-RH	
○	○	○
Red	White	Black

Measurement Instructions

The probe of the transmitter should always point downwards when installed.

Supply voltage:	10 … 35 VDC (RL = 0 Ω)
	20 … 35 VDC (RL = 500 Ω)
RH range:	0 …100% (Output 4…20mA)

Two-point humidity calibration

Two-point calibration can be performed using saturated salt solutions in controlled conditions (HMK15 or HMK13B). Please, refer also to the calibrator manual.

Greenspan's calibration table with output values according to the scale

Temperature	C	15	20	25	30	35
	F	59	68	77	86	95
LiCl	%RH	*)	11.3	11.3	11.3	11.3
4...20mA	mA		5.81	5.81	5.81	5.81
NaCl	%RH	75.6	75.5	75.3	75.1	74.9
4...20 mA	mA	16.1	16.08	16.05	16.02	15.98

1. Leave the calibrator and the probe for at least 1 hour in the same space so that their temperatures have time to equalize.
2. Open the transmitter cover, and loosen the tightening screw of the probe. Then, pull out the probe (Figure 3).
3. Unscrew the plastic probe cover and the filter.
4. Insert the probe into the measurement hole of the LiCl salt chamber.
5. Wait for 10-20 minutes.
6. Check the temperature and read the closest corresponding RH value in the calibration table (Table 1).
7. Adjust the output signal with calibration trimmer (RH OFFS ET, Figure 2) to the value given in the calibration table (Table 1).
8. Insert the probe into the measurement hole of the NaCl chamber.
9. Wait for 10 - 20 minutes.
10. Check that the reading corresponds within the desired accuracy to the reading given in the calibration table. If not, adjust the reading with the calibration trimmer (RH GAIN, Figure 2).
11. Check again the reading at the first point and repeat the procedure if necessary.
12. After completing the calibration, screw the probe cover and the filter on.

Manufacturer Contact Information

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Reference

HMW61U/Y Humidity Transmitter Operating Manual, March 2000.

HMK15 Humidity Calibrator

Introduction

The functioning of the HMK15 is based on the fact that certain salt solutions generate a certain relative humidity in the air above them. The salt solutions suitable for the HMK15 calibrator are lithium chloride LiCl (11% RH), magnesium chloride $MgCl_2$ (33% RH), sodium chloride NaCl (75% RH) and potassium sulphate K_2SO_4 (97% RH). For calibration, the sensor head is inserted into a salt chamber containing a saturated salt solution. The probe/transmitter reading is then adjusted to the correct value. Calibration is usually performed at least at two different humidities to ensure the sensor accuracy over the entire humidity range (0-100 % RH).

Description of the solutions

Salt Name	**RH**	**Usage**
LiCl	11%	Used as the dry end reference
$MgCl_2$	33%	Used as a check point if calibration is performed at more than two points.
NaCl	75%	Used as the wet end reference for probes measuring in applications with normal humidities.
K_2SO_4	97%	Used as the wet end reference for probes measuring in applications with very high humidities.

NOTE: **Never add water to dry LiCl salt.**
LiCl is harmful when swallowed; the solution is also corrosive.
If the LiCl solution is used or stored in temperatures below +18 C, its equilibrium humidity changes permanently.

Solution Preparation Procedure

1. Take the calibrator out of the box. Open the transit cover of the chamber. Remove the measurement cover from the chamber holder and press the transit cover on the holder.
2. Pour ion exchanged water into the chamber; the required amounts are given below.

LiCl	14 ml of water
$MgCl_2$	3 ml of water
NaCl	10 ml of water
K_2SO_4	10 ml of water

3. Sprinkle the contents of a salt package in small quantities into the chamber, stirring constantly. When measuring with the measurement cup, make sure that the cup is clean and dry. Rinse and dry the cup after every use.

LiCl	15 g or 18 ml
$MgCl_2$	30 g or 30 ml
NaCl	20 g or 15 ml
K_2SO_4	30 g or 20 ml

4. When all salt has been sprinkled into the chamber, the saturated salt solution should have the ratio of 60-90% undissolved salt to 10-40% liquid.
5. Close the chamber with the chamber cover. Fasten the salt chamber on the base plate and close the measurement holes with rubber plugs. Make sure that chamber covers and plugs are carefully closed.
6. Write the preparation date on a sticker and mark the chamber with it.
7. Allow approximately 24 hours for stabilization before use.

Notices for Avoiding Errors Introduced by Temperature Difference

Usually, the errors during humidity calibration are due to temperature differences. In the laboratory, the calibrator should be stored in the part of the room where the temperature is most stable and the calibrator must be kept out of direct sunlight and away from localized heat sources.

Handle the probe as little as possible. Do not hold the salt chamber or other parts of the calibrator in your hand during calibration as they warm up and cause errors in the readings.

During calibration, the thermometer is inserted into the 13.5 mm hole of a salt chamber. Press it downwards until it passes the O-rings. The thermometer is correctly in place when you can feel a resistance while pressing it downwards.

When the thermometers are not in use or the calibrator is transformed from one place to another, place the thermometer in holders.

Calibration procedure

(If the probe/transmitter is checked against several humidity references, the checking must first be made at the dry end.)

1. Leave the HMK15 calibrator and the probe at the calibration site for at least 30 minutes before starting the calibration in order to let the probe temperature stabilize to the room temperature.
2. In the temperature range of 25-30 °C, lithium chloride humidity changes only very slightly, thus it is not necessary to use the thermometer. However, we may use it to ensure that the sleeve is in the correct place.
3. Take off the grid or filter protecting the sensor. Insert the probe into a suitable hole of the LiCl salt chamber. Press it downwards till it passes through the O-rings. Wait until the humidity reading stabilizes; this will take about 10-30 minutes. The shorter the time the hole stays open before inserting the probe; the shorter the stabilization time required.
4. Read the salt chamber temperature from the thermometer; then read the closest humidity value from the Greenspan's calibration table. Adjust the dry end to the correspond value given in the table.
5. Then use the NaCl as the wet reference. If calibrating probes that are being used for a long time in high humidities (90-100RH). Use the K_2SO_4 as the wet reference.
6. Then repeat steps 4-6 for the wet reference. Note that in high humidities the risk for errors increases and the stabilization time should be longer (about 20-40 min).

Greenspan's calibration table

°C	LiCl	$MgCl_2$	NaCl	K_2SO_4
0	*	33.7±0.3	75.5±0.3	98.8±1.1
5	*	33.6±0.3	75.7±0.3	98.5±0.9
10	*	33.5±0.2	75.7±0.2	98.2±0.8
15	*	33.3±0.2	75.6±0.2	97.9±0.6
20	11.3±0.3	33.1±0.2	75.5±0.1	97.6±0.5
25	11.3±0.3	32.8±0.2	75.3±0.1	97.3±0.5
30	11.3±0.2	32.4±0.1	75.1±0.1	97.0±0.4
35	11.3±0.2	32.1±0.1	74.9±0.1	96.7±0.4
40	11.2±0.2	31.6±0.1	74.7±0.1	96.4±0.4
45	11.2±0.2	31.1±0.1	74.5±0.2	96.1±0.4
50	11.1±0.2	30.5±0.1	74.4±0.2	95.8±0.5

Transportation Instructions

1. Turn the protective sleeve on the thermometer and place the thermometer in the holder.
2. Replace chamber covers with transit covers. Press the chamber covers on vacant chamber holders for transportation.
3. During transportation, keep the chamber as upright as possible.
4. The closer the transportation temperature is to the temperature of the calibration site, the shorter the stabilization time will be. If the transportation is below 18°C, the LiCl should transport separately to keep the solution warm.
5. When the calibrator is at the calibration site, remove the transit covers and fasten the chamber covers on salt chambers.
6. Clean the transit covers with a damp cloth and press them on vacant chamber holders.
7. Repeat the calibration procedures.

Quality control

Depending on the frequency of use and the general operating conditions, the salt solutions should be replaced after about 6-12 months. A visual check should be performed at intervals of 2-3 months. There must be a minimum of approximately 10% of undissolved salt at the bottom of the chamber and the salt must be clean.

Note: LiCl may crystallize on the surface. But it may still have solution under the surface. In such case, stir the solution and check the next day.

For correct calibration, it is essential that salt chambers are tightly closed. Check the O-rings at each salt replacement. If they are damaged, replace with new ones.

Operating temperature range is 0-50°C.

Accuracy of salt solution humidities

Lithium chloride LiCl	±1.0%RH + Greenspan's uncertainty
Magnesium chloride $MgCl_2$	±1.0%RH + Greenspan's uncertainty
Sodium chloride NaCl	±1.4%RH + Greenspan's uncertainty
Potassium sulphate K_2SO_4	±1.5%RH + Greenspan's uncertainty

Accuracy of the thermometer

With mercury	±0.3°C
With red capillary liquid	±1°C

Manufacturer Contact Information

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Reference

HMK15 Humidity Calibrator Operating Manual, June 1998.

Table 1. Maintenance log

Data	Operator	Sensor SN#	Reason (salt replacement or other maintenance)

Table 2. Salt solution checks

Data	Operator	Sensor SN#	LiCl	$MgCl_2$	NaCl	K_2SO_4

Appendix F: SOP of Differential static pressure transmitters

Differential static pressure transmitters

The purpose of differential pressure measurements is to monitor operation of the ventilation system and to aid in the calculation of fan airflow. Barn static pressure is monitored continuously in the barns near the exhaust fans using a differential pressure transmitter (Setra Part No. 264) with a range of 0-125 Pa and an accuracy of ±1 Pa.

GENERAL INFORMATION

Setra Systems 264 pressure transducers sense differential or gauge (static) pressure and convert this pressure difference to a proportional high level analog output for both unidirectional and bidirectional pressure ranges. Two standard output versions are offered: A voltage output of 0 to 5 VDC or a current output of 4 to 20 mA.

MECHANICAL INSTALLATION

1. Media Compatibility

Model 264 transducers are designed to be used with air or non-conducting gases. Use with liquids or corrosive gases will damage the unit.

2. Environment

The operating temperature limits of the 264 are 0°F to +175°F (-18°C to +79°C).
The compensated temperature range is 0°F to +150°F (-18°C to +65°C).

3. Pressure Fittings

The Model 264 is designed to be used with 3/16” I.D. push-on tubing. Both the positive (high) pressure port and the reference (low) pressure port are located on the front of the unit, labeled “HIGH” and “LOW” respectively. For best results (shortest response times), 3/16” I.D. tubing is suggested for tubing lengths up to 100 feet long, 1/4” I.D. for tubing lengths up to 300 feet, and 3/8” I.D. for tubing lengths up to 900 feet.

ELECTRICAL INSTALLATION

If the Model 264 is supplied with the optional Conduit Enclosure, access the electrical terminations by removing the cover. The Model 264 is a two-wire loop-powered 4 to 20mA current output unit and delivers rated current into any external load of 0 to 800 ohms. These terminals have the designation of + and - The current flows into the + terminal and returns back to the power supply through the - terminal. The power supply must be a DC voltage source with a voltage range between 9 and 30 measured between the + and - terminals. The unit is calibrated at the factory with a 24 VDC loop supply voltage and a 250 ohm load.

CALIBRATION

The 264 transducer is factory calibrated and should require no field adjustment. Generally, the mounting position will have a zero shift effect on ranges below 1” WC. Whenever possible, any zero and/or span offsets should be corrected by software adjustment in the user’s control system. However, both zero and span adjustments are accessible either on the front of the unit or by removing the optional conduit enclosure. The 264 transducer is calibrated in the vertical position at the factory.

1. **Current Output Zero Adjustment**

   While monitoring the current output between the + and - terminals, and with both pressure ports open to atmosphere, the zero may be adjusted by turning the zero adjustment screw. The factory settings are 4mA (0.16mA) for unidirectional pressure ranges and 12mA (0.16mA) for bidirectional ranges.

2. **Current Output Span Adjustment**

   Span or full scale output adjustments should only be performed by using an accurate pressure standard (electronic manometer, digital pressure gauge, etc.) with at least comparable accuracy to the 264 transducer (1% FS). With full range pressure applied to the high pressure port (reference port open to atmosphere), the span may be adjusted by turning the SPAN adjustment screw. The factory settings are 20mA (0.16mA) for unidirectional and bidirectional pressure ranges.

The pressure sensor will be shunted to calibrate zero and compared with an inclined manometer at various span pressures. Static pressure taps will be constructed to minimize effects of air movement from wind on the measurement.

Model 264 low differential pressure transducer specifications

Electrical Output Current	4 to 20 mA
Accuracy	±1% FS
Type of Pressure	Very Low Differential
Pressure Ranges	0 to 0.5 in. WC (0-150 pa)
Media	Typically air or similar non-conducting gases

Manufacturer Contact Information

Setra Systems, Inc.
159 Swanson Road
Boxborough, MA 01719-1304
Tel (978) 263-1400
Toll Free (800) 257-3872

Maintenance/Calibration Sheet for Setra 264

Site________

Data	Operator	Location	Sensor SN#	Note

Appendix G: SOP of Compact Fieldpoint Modules and LabView Programs

Compact Fieldpoint Modules

Compact Fieldpoint network controller and Compact Fieldpoint A/O modules (National Instruments Corporation) are used as the data acquisition system (table 1):

Table1. Descriptions of compact Fieldpoint modules

Serial NO.	Description	Qty
cFP-2020	LabView 7 Real-Time/Ethernet Network Module	1
cFP-DO-400	8- channel Digital Output Module	1
cFP-AI-110	8- channel 16 Bit Analog Input Module (mA, mV, V)	4
cFP-AI-112	16- channel 16 Bit Analog Input Module (V)	1
cFP-CTR-500	8-channel Counter Input Module	1
cFP-TC-120	8-channel 16 Bit Thermocouple Input Module (TC, mV)	1

All the data signals from the instruments will be connected to and recorded by the compact Fieldpoint controller and modules. Data columns and their corresponding sensor connections will be arranged as shown in Table 2.

Table 2. Data file and sensor arrangement.

Data Col	File heading	Sensor/controller	Range	DAC hardware	Ch#	Signal or EV
1	Date & Time	---		---	---	PC clock
2	Smpl loc#	---		---	---	LabVIEW
3	NH_3,ppm	INNOVA 1412		cFP-2020		ASCII
4	CO_2,ppm	INNOVA 1412		cFP-2020		ASCII
5	dP, ºC	INNOVA 1412		cFP-2020		ASCII
6	SP1, Pa	Setra P sensor	0-125 pa	cFP-AI-110-1	0	4-20 mA
7	SP2, Pa	Setra P sensor	0-125 pa	cFP-AI-110-1	1	4-20 mA
8	RH1, %	HMW61U #1	0-100 %	cFP-AI-110-1	2	4-20 mA
9	RH2, °C	HMW61U #2	0-100 %	cFP-AI-110-1	3	4-20 mA
10	RHo, °C	HMW61U #2	0-100 %	cFP-AI-110-1	4	4-20 mA
11	Flow, L/min	Flow meter	0-10 L/min	cFP-AI-110-1	5	0-5V
12	Baro, bar	Barometric pressure sensor	800-1100 mbar	cFP-AI-110-1	6	4-20 mA
13	H_2S,ppb	API 101E	1000 ppb	cFP-AI-110-1	7	0-10 VDC
14	SW1, VDC	Side wall fan #1	0-3.8VDC	cFP-AI-110-2	0	0-10VDC
15	SW2, VDC	Side wall fan #2	0-3.8VDC	cFP-AI-110-2	1	0-10 VDC
16	SW3, VDC	Side wall fan #3	0-3.8VDC	cFP-AI-110-2	2	0-10 VDC

17	SW4, VDC	Side wall fan #4	0-3.8VDC	cFP-AI-110-2	3	0-10 VDC
18	Tunnel1, VDC	Tunnel fan #1	0-3.8VDC	cFP-AI-110-2	4	0-10 VDC
19	Tunnel2, VDC	Tunnel fan #2	0-3.8VDC	cFP-AI-110-2	5	0-10 VDC
20	Tunnel3, VDC	Tunnel fan #3	0-3.8VDC	cFP-AI-110-2	6	0-10 VDC
21	Tunnel4, VDC	Tunnel fan #4	0-3.8VDC	cFP-AI-110-2	7	0-10 VDC
22	Tunnel5, VDC	Tunnel fan #5	0-3.8VDC	cFP-AI-110-3	0	0-10 VDC
23	Tunnel6, VDC	Tunnel fan #6	0-3.8VDC	cFP-AI-110-3	1	0-10 VDC
24	Tunnel7, VDC	Tunnel fan #7	0-3.8VDC	cFP-AI-110-3	2	0-10 VDC
25	Tunnel8, VDC	Tunnel fan #8	0-3.8VDC	cFP-AI-110-3	3	0-10 VDC
26	Tunnel9, VDC	Tunnel fan #9	0-3.8VDC	cFP-AI-110-3	4	0-10 VDC
27	Tunnel10, VDC	Tunnel fan #10	0-3.8VDC	cFP-AI-110-3	5	0-10 VDC
28	Poly1, ppm	Polytron I_1 NH_3 sensor	0-100ppm	cFP-AI-110-3	6	4-20 mA
29	Poly2, ppm	Polytron I_2 NH_3 sensor	0-100ppm	cFP-AI-110-3	7	4-20 mA
30	T1, °C	Thermocouple #1		cFP-TC-120-1	0	
31	T2, °C	Thermocouple #2		cFP-TC-120-1	1	
32	T3, °C	Thermocouple #3		cFP-TC-120-1	2	
33	To, °C	Thermocouple outside		cFP-TC-120-1	3	
34	Tl, °C	Thermocouple_sample line		cFP-TC-120-1	4	
35	T6, °C	Thermocouple #6		cFP-TC-120-1	5	
36	T7, °C	Thermocouple #7		cFP-TC-120-2	6	
37	T8, °C	Thermocouple #8		cFP-TC-120-3	7	
38	TSP MC	TEOM	0-100 mg/m^3	cFP-AI-112	0	0-10 VDC
39	TSP Filer load	TEOM	0-100%	cFP-AI-112	1	0-10 VDC
40	TSP Main flow	TEOM	0-1L/min	cFP-AI-112	2	0-10 VDC
41	PM10 MC	TEOM	0-50 mg/m^3	cFP-AI-112	3	0-10 VDC
42	PM10 Filter load	TEOM	0-100%	cFP-AI-112	4	0-10 VDC
43	PM10 Main flow	TEOM	0-1L/min	cFP-AI-112	5	0-10 VDC
44	PM2.5 MC	TEOM	0-20 mg/m^3	cFP-AI-112	6	0-10 VDC
45	PM2.5 Filer load	TEOM	0-100%	cFP-AI-112	7	0-10 VDC
46	PM2.5 Main flow	TEOM	0-1L/min	cFP-AI-112	8	0-10 VDC
47	Total HC	VIG200	0-100 ppm	cFP-AI-112	9	0-10 VDC
48	Methane	VIG200	0-100 ppm	cFP-AI-112	10	0-10 VDC
49	Non-Methane	VIG200	0-10 ppm	cFP-AI-112	11	0-10 VDC
50	GC status	VIG200	ON/OFF	cFP-AI-112	12	0-10 VDC
51	Reserved			cFP-AI-112	13	0-10 VDC
52	Water flow	AMCO	0-65355	cFP-CTR-500	1	Pulse
53	Non-CH_4 ,ppm	INNOVA 1412		cFP-2020		ASCII
54	CH_4 ,ppm	INNOVA 1412		cFP-2020		ASCII
55	N_2O,ppm	INNOVA 1412		cFP-2020		ASCII
		Solenoid 1		cFP-DO-400-1	0	12 VDC
		Solenoid 2		cFP-DO-400-1	1	12 VDC
		Solenoid 3		cFP-DO-400-1	2	12 VDC

Solenoid 4	cFP-DO-400-1	3	12 VDC
Solenoid 5	cFP-DO-400-1	0	12 VDC
Solenoid 6	cFP-DO-400-1	1	12 VDC
Solenoid 7	cFP-DO-400-1	2	12 VDC
Solenoid 8	cFP-DO-400-1	3	12 VDC

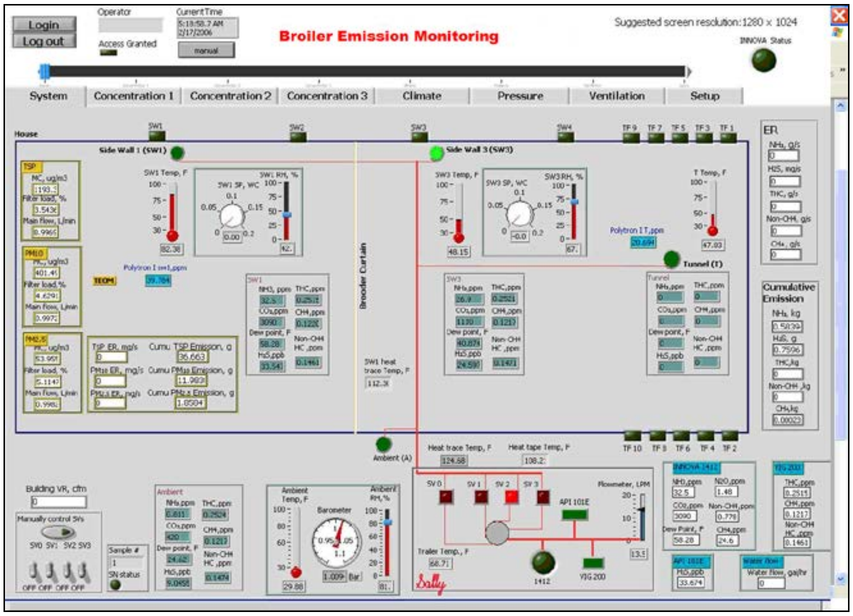
The above A/O module will be connected to or controlled by an embedded DAQ program running in the cFP-2020 stand alone controller.

1. Data Acquisition and Control System

The data acquisition system consists of a PC and Compact Fieldpoint (National Instruments Corporation (NI), Austin, TX) which is a data acquisition and automation controller composed of rugged I/O modules and intelligent communication interfaces. A real-time DAQ program developed using LabVIEW 7 software (National Instruments, Corporation, Austin, TX) is used to acquire data, automate sampling location control, display real-time data, and deliver data and system operation status (figure 1). The DAQ program consists of two sub-programs: an embedded program running in the CFP-2020 network module for collecting raw signals and controlling sampling location; a PC-based program running in the on-site project computer for data post-processing and data publishing on the webpage. The embedded program can stand-alone run and send out data and alarm email.

Electronic relative humidity transmitters (Vaisala Model HMW 61U) with a measurement range of 0.8 -100% and corresponding analog output of 4-20 mA are used to monitor RH in the houses. Type T thermocouples are used to monitor indoor and outdoor air temperature at the air sampling locations. Two 0 to 125 pa (0 to 0.5 inch WC) differential pressure transducers (Setra Model 264, Boxborough, MA) with analog output of 4-20 mA are used to measure building static pressure in both brooding and non-brooding portions of the production houses. Barometric pressure sensors (WE100, Global Water Instrumentation, Inc., Gold River, CA) with analog output of 4-20 mA are used for measuring atmospheric pressure. All the sensors with 4-20 mA analog output are powered by a 24 VDC power supply (100W) and connected directly to the analog input modules (cFP-AI-110, NI). The type T thermocouples are attached to a cFP-TC-120 thermocouple input module. The 14 fan current switches are individually connected to a 150 Ω resistor and powered by a 5 VDC power supply. The voltage signals across the resistors are connected to the analog input modules (cFP-AI-110, NI). The voltage signals from the API 101E and VIG 200 are connected to the analog input modules (cFP-AI-112, NI). Air sampling solenoid valves are controlled through cFP-DO-400 (NI) digital output module (Figure 2).

The INNOVA 1412 is connected to the Compact FieldPoint via a RS232 cable. At the end of every sampling cycle, the INNOVA 1412 communicates with the Compact FieldPoint and sends the results in ASCII code and starts the next sampling cycle. The Compact FieldPoint records each the start time of each sampling cycle and counts the number of sampling cycles at each sampling location. Data for fan operation status and other environment variables are collected by the Compact FieldPoint controller and measurement I/O modules at 1- or 2-s intervals, and processed to 30-sec averages. Real-time ventilation rates are calculated based on the real-time fan operation status and building static pressure. All the real-time readings of the instruments are recorded and displayed on the front panel of the program. Using Labview 7, the front panel can be published as a web page, and viewed in real-time and controlled from a remote location, through internet. The recorded data are stored daily to the on-site PC and backed up by a remote computer via a satellite high-speed internet connection. The stored data are also automatically transmitted through an email sever on a daily basis to provide redundant data transfer. Figure 3 shows the flow of the DAQ system.



CurrentTime 5:18:58.7 AM 2/17/2006

TSP
MC, ug/m3 193.3
Filter load, % 3.543
Main flow, L/min 0.996

PM10
MC, ug/m3 401.4
Filter load, % 4.629
Main flow, L/min 0.997

PM2.5
MC, ug/m3 53.95
Filter load, % 5.114
Main flow, L/min 0.998

TSP ER, mg/s 0
Cumu TSP Emission, g 36.663
PM10 ER, mg/s 0
Cumu PM10 Emission, g 11.983
PM2.5 ER, mg/s 0
Cumu PM2.5 Emission, g 1.8504

SW1 Temp, F 82.38
SW1 SP, WC 0.00
SW1 RH, % 42.
Polytron I sw1,ppm 39.784

SW1
NH3, ppm 32.5
THC,ppm 0.251
CO2,ppm 3090
CH4,ppm 0.122
Dew point, F 58.28
Non-CH4 HC ,ppm 0.1461
H2S,ppb 33.54

SW1 heat trace Temp, F 112.3

SW3 Temp, F 48.15
SW3 SP, WC -0.0
SW3 RH, % 67.
Polytron I T,ppm 20.694
T Temp, F 47.03

SW3
NH3,ppm 26.9
THC,ppm 0.2521
CO2,ppm 1130
CH4,ppm 0.1217
Dew point, F 40.874
Non-CH4 HC ,ppm 0.1471
H2S,ppb 24.59

Tunnel
NH3,ppm 0
THC,ppm 0
CO2,ppm 0
CH4,ppm 0
Dew point, F 0
Non-CH4 HC ,ppm 0
H2S,ppb 0

ER
NH3, g/s 0
H2S, mg/s 0
THC, g/s 0
Non-CH4, g/s 0
CH4, g/s 0

Cumulative Emission
NH3, kg 0.5839
H2S, g 0.7596
THC,kg 0
Non-CH4 ,kg 0
CH4,kg 0.00023

Heat trace Temp, F 124.68
Heat tape Temp, F 108.2
Trailer Temp., F 68.71
Flowmeter, LPM 13.5

Building VR, cfm 0
Manually control SVs
SV0 SV1 SV2 SV3
OFF OFF OFF OFF
Sample # 1
SN status

Ambient
NH3,ppm 0.611
THC,ppm 0.2524
CO2,ppm 420
CH4,ppm 0.1217
Dew point, F 24.62
Non-CH4 HC ,ppm 0.1474
H2S,ppb 9.0458

Ambient Temp, F 29.88
Barometer 1.009 Bar
Ambient RH,% 81.

INNOVA 1412
NH3,ppm 32.5
N2O,ppm 1.48
CO2,ppm 3090
Non-CH4,ppm 0.779
Dew Point, F 58.28
CH4,ppm 24.6

VIG 200
THC,ppm 0.2515
CH4,ppm 0.1217
Non-CH4 HC ,ppm 0.1461

API 101E
H2S,ppb 33.674

Water flow
Water flow, gal/hr 0

Figure 1. A snapshot of the DAQ software front panel for real-time monitoring of air emissions from animal houses

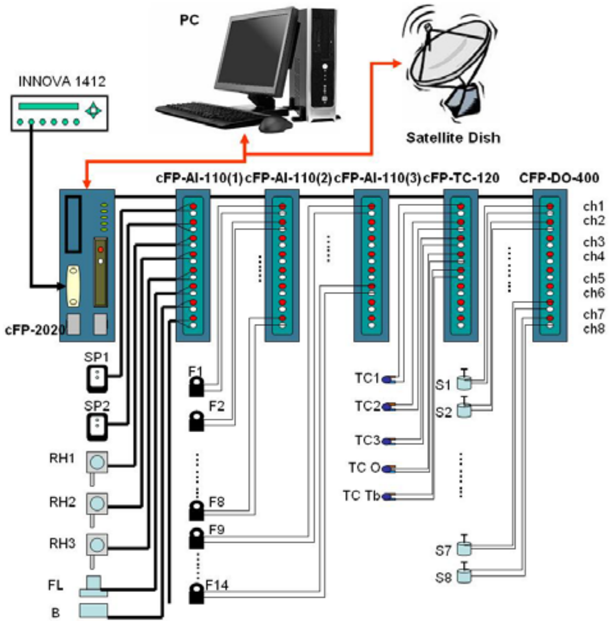


Figure 2. Schematic of the DAQ system

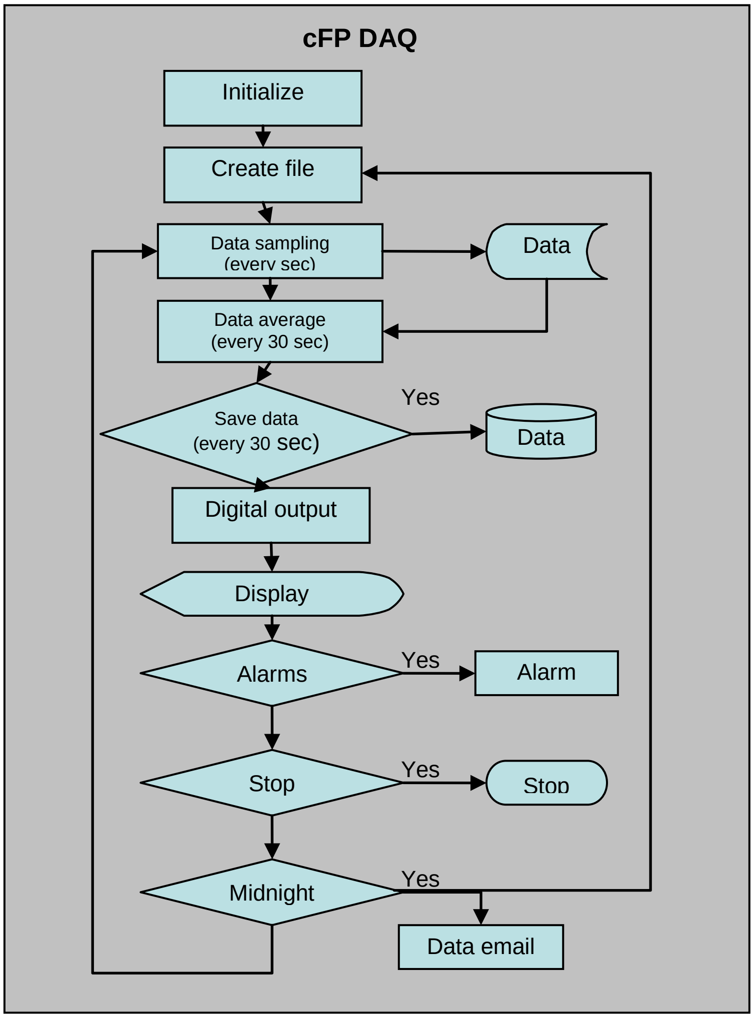


Figure 3. Flow chart of the DAQ program

Finally, the data is processed to calculate the NH_3 emission rate (ER).

Testing and Running the DAQ Program at Initial Operation

Bugs and Suggestions

Bugs found in the DAQ program and suggestions of improvement can be directed by email or phone call to Iowa State University. Upgraded DAQ program files will be sent from Iowa State University to the test computer via internet connection.

Manufacturer Contact Information

National Instruments Corporation
11500 N Mopac Expwy
Austin, TX 78759-3504

Tel: (800) 531-5066
Fax: 512-683-8411

Reference

cFP-DO-400, cFP-AI-110, cFP-AI-112, cFP-CTR-500, cFP-TC-120, FieldPoint Operating Instructions, October, 2002.
cFP-20xx and cFP-BP-x User Manual, April 2004.

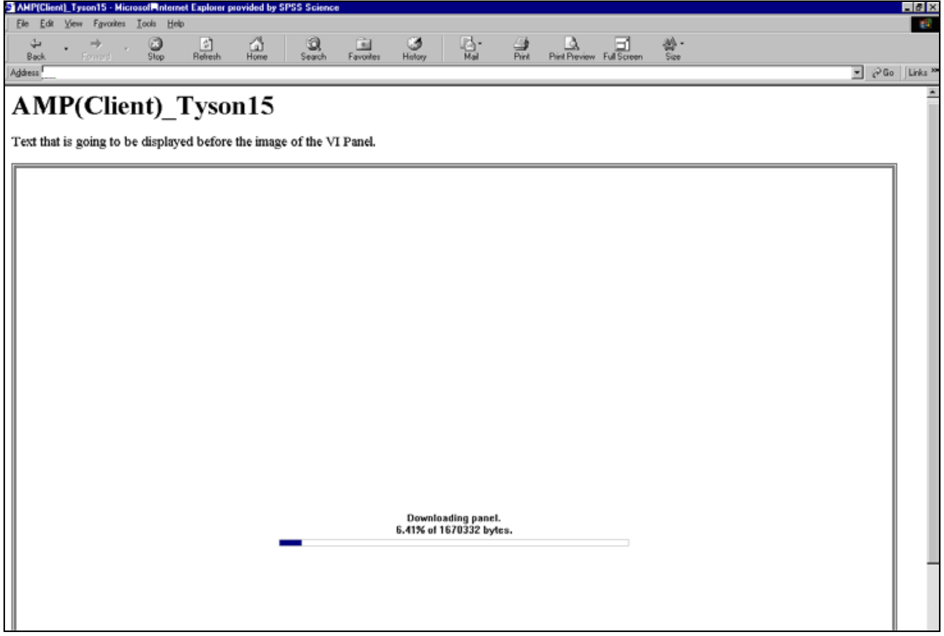
Appendix H: SOP of Using Remote Panel of Southeast Broiler Emission Monitoring Program (Client)

1. View the front panel remotely (Fig.1-2)

Before you start, make sure you have downloaded and run the free software on your computers: ftp://ftp.ni.com/support/labview/windows/runtime/7.1/LVRunTimeEng.exe .
Enter the following URLs into ***Address*** or URL field at the top of the Web browser ***Internet Explorer***:

http://XXX.XXX.XXX.XXX/t15.htm
http://XXX.XXX.XXX.XXX /t33.htm

The plug-in displays the remote panel in the Web browser window.



AMP(Client)_Tyson15

Text that is going to be displayed before the image of the VI Panel.

Downloading panel.
6.41% of 1670332 bytes.

Fig.1

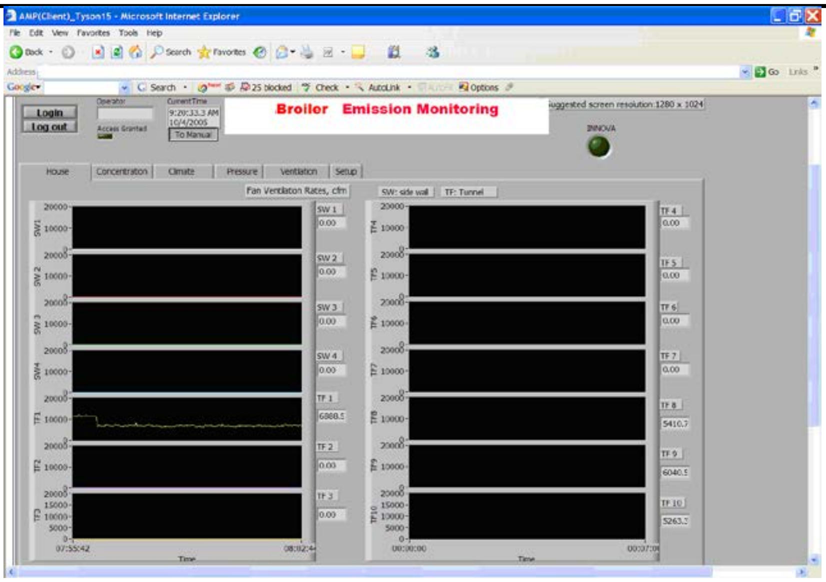


Fig.2

2. Receive access of control (Fig.3-5)

Request control by right-clicking anywhere on the remote panel window and selecting ***Request control of VI*** from the shortcut menu. A message will pop up: Control granted or Waiting for control. If multiple users request control, the control time limit is 300 sec. If control is granted, right-click anywhere and select ***Release control of VI*** for next user to control the remote panel.

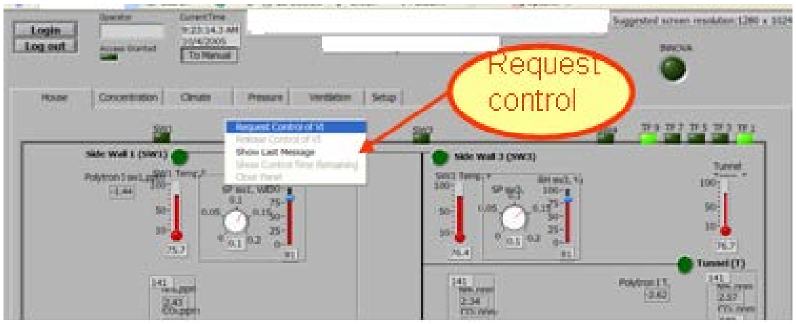
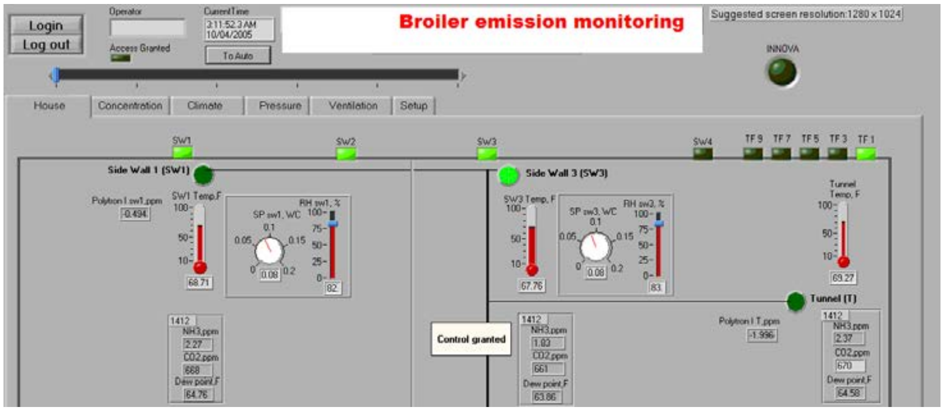
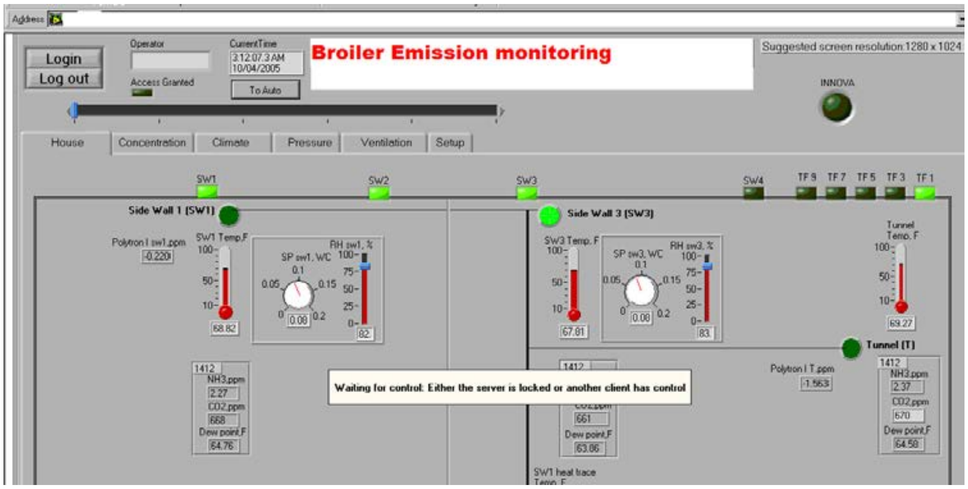


Fig.3



Control granted

Fig.4



Waiting for control: Either the server is locked or another client has control

Fig.5

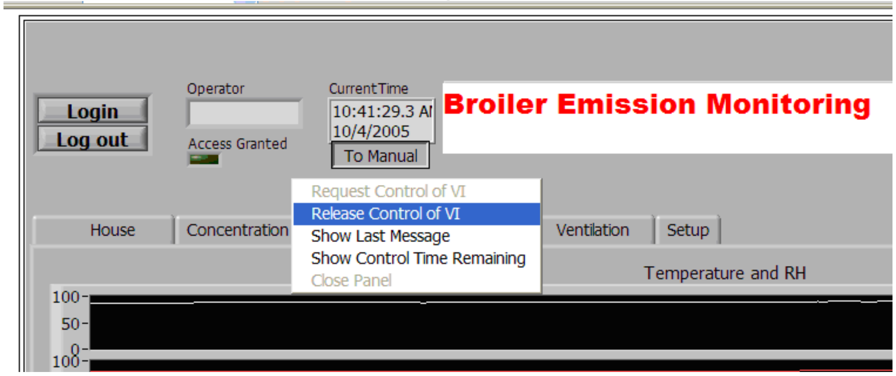


Fig.6

3. Manipulate the remote panel (Fig.7-109)

If the display switch button is ***To manual***, the five display tab will automatically rotate with 20-sec intervals. Click ***To manual*** and change the display to manual control. Click the slide control for desired display tab. Click ***Login*** for requesting change the setup of the program.

Fig.7

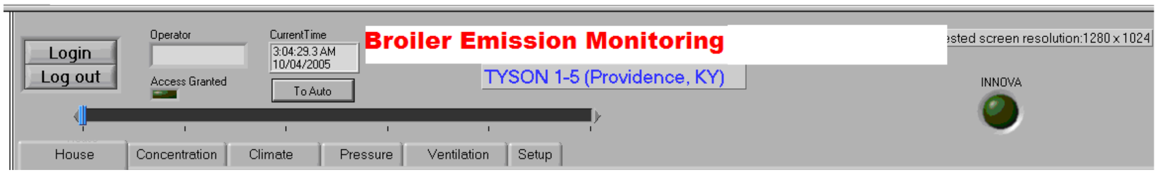


Fig.8

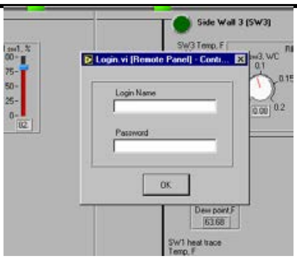
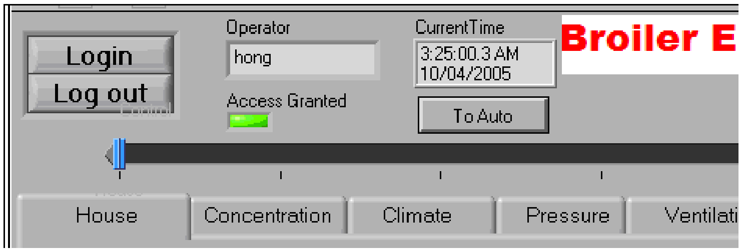


Fig.9


Operator: hong

CurrentTime: 3:25:00.3 AM 10/04/2005

Access Granted

Fig.10

4. Rules for manipulating the remote panel:

a) If you are a system administrator, please log out when you finish changing any setup. If not, please do not try to log in.

b) For other user's convenience, please release control of VI after you finish and change the display mode to automatic.

c) Please avoid keeping online too long time or running the remote panel all the time, it will slow down the internet service due to a limited daily throughput allowance.

d) Please email Hong Li your IP address if your computers have a static IP address. If your computers used DHCP, please give IP address range. If your computer connected to a router, which has a static IP, provide the router's IP.

e) The remote panels are only open for the specific IPs from ISU, UK, TYSON and your home. If you want to view it during travel, please let system administrator know in advance what time you want it to be open. So, the system administrator can open the servers for you. After that, I will close the unlimited access to keep out computers safe.

Appendix I: SOP of Data Management at ISU

The objectives of data management are to:

1. Ensure data security;
2. Provide convenient data retrieval;
3. Minimize labor and cost involved in data management, and
4. Minimize possible interference with the on-going data acquisition.

1. Data Store and Back-up

All original and final data will be reviewed and/or validated by technically qualified staff, and so documented in the program records. The documentation will include the dates the work was performed, the name of the reviewer(s), and the items reviewed or validated.
Corrections and additions to original data must be made as follows:

- After correction, original entries must remain legible (for manual corrections) or intact (for computerized corrections).
- The correction or addition must be readily traceable to the date and staff who performed the correction or addition.
- Corrections must be explained.

1.1 Measurement data file Creating and Storing

All the project specific program and data files will be saved in a single folder in the field computer:

C:\TYSON

Three subfolders will be under **C:\TYSON**:

a. **C:\ TYSON \AMP\Final Programs**

This folder stores DAQ program and hardware configuration files:
- OHSITE mmddyy.llb (DAQ program, of which part of the file name “mmddyy” records the month/date/year related version information)
- OHSITE.iak (configuration file of FieldPoint data acquisition hardware)

b. **C:\ TYSON\AMP \DAQfiles**

This folder stores program setting and calibration files that are all tab delimited:
- Heading&format.txt (defines the headings and format of the data in the recorded data files)
- Sampling sequence.txt (defines automatic air sampling locations and sequence)

- Analyzers.txt (stores gas analyzer ranges, correction coefficients, calibration gas concentrations, and calibration data)
- Settings.txt (stores configuration and settings of the temperature controller, etc.)

c. C:\ TYSON \Data\

This folder stores acquired measurement data files created by the LabView program. To facilitate the identification of data files from different sits, a project ID (two letters, “**B**” for the Tyson 1-5 site, “**D**” for the Tyson 3-3 site) is placed at the beginning of data file names.

Measurement signals from the sensors/analyzers and control signals are sampled every second. Sampled signals are averaged every 30 seconds and are saved in data file 1 (IDsyyyymmdd?.txt) and data file 2 (IDyyyymmdd?.txt, where “?” is a letter from "a" to "z"), respectively. Each time the program is started or when a new day begins at midnight, the two data files are created and saved in the "Data" folder. During DAQ program testing, if the program is started for 26 times during the same day, the “?” will be "z" and cannot go up further. If this happens, the "*z.txt" file in the "Data" folder will be cleaned in order to re-run the program.

As more and more data files are generated in the C:\ TYSON \Data\ folder, the folder becomes too big for backing up in a single CD. It is recommended that old data files be moved to a new folder **C:\ TYSON Data\.**

The project data files created by the embedded program running in the cFP-2020 control module will be saved in a compact flash memory card in the module:

d. D:\

There is no subfolder. This folder stores acquired measurement data files created by the LabView program. To facilitate the identification of data files from different sites, a project ID (two letters, “**A**” for the Tyson 1-5 site, “**B**” for the Tyson 3-3 site) is placed at the beginning of data file names.

Measurement signals from the sensors/analyzers and control signals are sampled every second. Sampled signals are averaged every 30 seconds and are saved in data file 1 (IDsyyyymmdd?.txt) and data file 2 (IDyyyymmdd?.txt, where “?” is a letter from "a" to "z"), respectively. Each time the program is started or when a new day begins at midnight, two data files are created and saved in the "Data" folder. During DAQ program testing, if the program is started for 26 times during the same day, the “?” will be "z" and cannot go up further. If this happens, the "*z.txt" file in the "Data" folder will be cleaned in order to re-run the program.

As more and more data files are generated in the D:\ folder, the folder becomes too big for backing up in a single memory card, so the data files will be downloaded from the memory card to the folder **C:\ Data** of the on-site computers and the older data files will be automatically deleted from the memory card.

1.2 Data Alarm, transfer and Back-up

Electronic data is stored on the on-site computer and downloaded daily with a scheduled time (2:00 p.m.) via a high-speed Internet connection to a dedicated project computer at ISU. The data is backed-up weekly to CDs on-site by the UK personnel and to an external hard drive at ISU. As the data redundant system, compact Fieldpoint stand-alone controller, records the electronic raw data in a compact flash memory and sends the data out by email via a high-speed Internet connection (see Appendix G) at midnight, daily. The emailed data, including the alarm emails from any critical on-site incident, power failure, out-of range and instrumentation failures, also are backed-up weekly to the project computer at ISU (Figure 1). For the precise data post process in the dedicated project computer, all the processed data is stored in the computer and backed-up to the external hard drive. In addition to computer storage, raw tables or graphs are printed out and stored in loose-leaf notebooks.

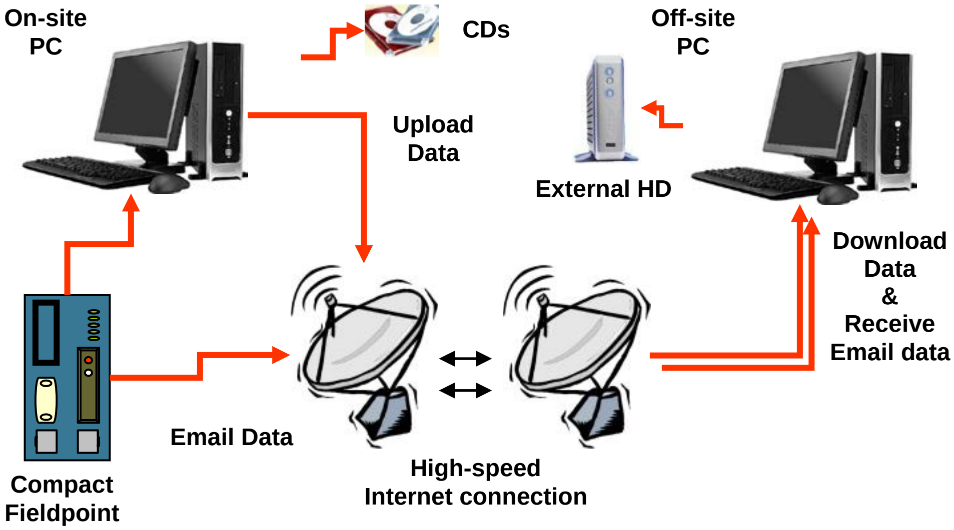


Figure 1. Flow chart of electronic data back up and store

Field test documentation and electronic data storage are maintained in accordance with standard operating procedures, including storage of all raw electronic data in ASCII file format for later analysis using commercially-available spreadsheet and statistical programs. A large portion of the data is also maintained electronically in the form of spreadsheets. All pollutants, temperature, pressure, RH and fan ON/OFF data is electronically stored and compiled in a manner that facilitates computation of hourly and daily averages.

Reports are prepared by qualified staff only from properly reviewed and validated data. All data is reported in units consistent with other measurements. Assumptions are clearly explained as to validity and limitations.

Accurate working files of all documentation, including logbook entries, original data, calculations, deviations from approved procedures, data uncertainties, assumptions, QA/QC results and external performance data, audits, and review, inspection, and validation are maintained by the principal investigator as appropriate until archived after the completion of the project. Project records are maintained in a systematic and logical form and adequately filed for rapid retrieval, accounted for and appropriately indexed.

1.3 Procedure

1. Arrange all project-relevant files together at an easily-found location under C: drive for backup and retrieval.
2. Arrange folder/file structure in the field PC based on file importance and file types. Each folder in the C: drive should be limited to 700 Mb size for easy backup in a single CD.
3. Make records of the LabView program settings and coefficients whenever there are changes. Most settings and coefficient data are recorded in the Settings.txt file. An alternative method is used to make screen shots of part of the LabView program including diagram and front panels that have been changed.
4. Use the LabView automatic email feature to email data files that LabView acquired daily to the campus at midnight.
5. Back up the project folder in the field computer on a CD every two weeks.
6. Back up the operating system when there are significant changes in the system. Store the backup CDs in a location other than the field lab.

2. Classification of data files (with level “1” being the most important)

Management of data files, and method and frequency of file backup depends on the importance of the files.

a. Unique files created before or during the project. These files, once lost, usually cannot be rebuilt. They include:
   - Measurement data
   - Calibration data
   - Field notes
   - Email messages
   - Image files (digital photos or computer screen shots) relevant to the project
b. Program files and system configurations created for the project. These files, once lost, will require extra time to rebuild or recover. They include:
   - LabView data acquisition and control program
   - Configuration files for data acquisition and control hardware (e.g., Compact Fieldpoint)
   - Firewall configurations, etc.
   - Email message rules
   - Favorites lists
c. Specific software and documents needed for the project. These files are provided by manufacturers. They can usually be obtained on the Internet or from the manufacturer

by request, but having them ready on the computer increases working efficiency. They include:

- Instrument manuals
- Software like compact Fieldpoint, INNOVA 1412 for windows, etc.

d. Operating system (installed and configured Windows) and installed commercial software, e.g., MS Office.

3. Data Post Processing

A data post processing program (MAEMU_v1.2) is developed by using Microsoft Visual Basic, which is embedded in Microsoft Excel (2003). The downloaded data from two sites are processed in two days after receiving the data. The daily emission rate for each pollutant is reported with the completeness of each pollutant. At the end of each flock, the flock emission data is reported based on the daily emission data for each pollutant.

3.1 Daily Emission Reporting

First, the original data is verified and validated by a data flagging procedure based on the routine check data and the flags are generated and stored in a separate worksheet, named “Flag”. Validation of measurement data requires two parts, one for the environment condition measurement value, and the second for the air sample measurement. Records of all invalid samples are filed. The information includes a brief summary of why the sample was invalidated along with the associated flags. This record is available on the post process, since all data is recorded. The flags are showed in the Table I.1. In the “Flag” worksheet, the “1” represents no flag and “0” represents a flag. For example, an “OET” flag shows in the summary table and “0” must be appearing in column “OET” of the “Flag” worksheet. Then, the data flag is tracked and the reason for this flag will be found out and the corresponding action will be performed. Here, the thermocouple sensors are inspected.

Table I.1 Verification and Validation data flags and action

Requirement	**Data Range**	**Acceptance criteria**	**Flag**	**Action**
Temperature	32°F ~ 105 °F	> 105 °F < 32°F	OET	Reanalysis/ Confirmation by on-site visit / calibrate / replace Thermocouple/document
Relative humidity	0~100 %	>100% < 0	OEH	Reanalysis/ Confirmation by on-site visit / calibrate / replace RH Sensor/document
Barometric pressure	900~1050 kpa	>1050 < 900	OEB	Reanalysis/Confirmation by on-site visit / calibrate / replace Barometric pressure sensor/document
Static pressure	-0.05 ~ 0.5 inch Water	>0.25 < -0.02	OEP	Reanalysis/Confirmation by on-site visit / calibrate / replace Static pressure sensor/document
Fan current switch	ON/OFF	OFF (all the time)	FCS	Reanalysis/Confirmation by on-site visit / replace Fan Current Switch/document
Temperature	<±1°F (Checking)	>±1°F	OCT	Reanalysis/Confirmation by on-site visit / replace Thermocouple/document
Relative humidity	<±5 % of Standard (Checking)	>±5 %	OCH	Reanalysis/Confirmation by on-site visit / Calibration/document
Barometric pressure	<±5 % of Standard (Checking)	>±5 %	OCB	Reanalysis/Confirmation by on-site visit/ Calibration/document
Static pressure	<±5 % of Standard (Checking)	>±5 %	OCP	Reanalysis/Confirmation by on-site visit / Calibration/document
NH_3	<±5 % of Standard	>±5 %	CIA	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
CO_2	<±5 % of Standard	>±5 %	CIC	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
H_2S	<±5 % of Standard	>±5 %	CHS	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
Non-Methane Hydrocarbon (NMHC)	<±5 % of Standard	>±5 %	CVN	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
Methane	<±5 % of Standard	>±5 %	CVM	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
Total Hydrocarbon (THC)	<±5 % of Standard	>±5 %	CVT	Data qualification Reanalysis/Confirmation by on-site visit / Calibration/document
H_2S measurement range	0~100 ppb	> 100 < 0	OHS	Reanalysis/Confirmation by on-site visit / Calibration/document
NMHC measurement range	0-10 ppm	> 10 < 0	OVN	Reanalysis/Confirmation by on-site visit / Calibration/document

Methane measurement range	0-100 ppm	> 100 < 0	OVM	Reanalysis/Confirmation by on-site visit / Calibration/document
THC measurement range	0-100 ppm	> 100 < 0	OVY	Reanalysis/Confirmation by on-site visit / Calibration/document
TSP flow	0.98~1.02 LPM (<0.15 leak check)	> 1.02 < 0.98 (>0.15 leak)	OTF	Data qualification Reanalysis/Confirmation by on-site visit / Leak check & correction/document
TSP measurement range	0~100 mg/m^3	> 100 < 0	OTR	Reanalysis/Confirmation by on-site visit / Instrument Inspection
PM10 flow	0.98~1.02 LPM (<0.15 leak check)	> 1.02 < 0.98 (>0.15 leak)	OPF	Data qualification Reanalysis/Confirmation by on-site visit / Leak check & correction/document
PM10 measurement range	0~50 mg/m^3	> 50 < 0	OPR	Reanalysis/Confirmation by on-site visit / Instrument Inspection/document
PM2.5 flow	0.98~1.02 LPM (<0.15 leak check)	> 1.02 < 0.98 (>0.15 leak)	OMF	Data qualification Reanalysis/Confirmation by on-site visit / Leak check & correction/document
PM2.5 measurement range	0~20 mg/m^3	> 20 < 0	OMR	Reanalysis/Confirmation by on-site visit / Instrument Inspection/document

After all data is flagged, validated values are used for the emission calculation based upon the emission calculation equation in Section 11. The daily average, standard deviation, maximum, and minimum values for each pollutant concentration, ventilation rate, temperature, relative humidity and pressure are calculated and summarized in the “Results “worksheet. The final daily cumulative emission of each pollutant with the data flag will be summarized in the “Summary” worksheet. The daily emission report files are saved and backed up by following the flock number and bird age manner. The folder, “C:\Tyson\Processed data\”, is used to store all the post processed data.

3.2 Flock Emission Reporting

After each flock, the daily emissions of each pollutant during the whole flock period are summarized with the completeness of daily emission. If the daily completeness of one pollutant is less than 75%, the daily emission data for this pollutant is invalidated and marked. Summary tables and charts are generated for each flock bird. The folder, “C:\Tyson\Data Reports\”, is used to store all the post processed data.

Appendix J: SOP of Reporting and Calculation of Contaminant Concentrations, Ventilation and Emissions

This SOP gives instructions for calculating and reporting gas (ammonia, carbon dioxide, hydrogen sulfide, non-methane hydrocarbon) and dust (PM2.5, PM10, TSP) concentrations and barn emission rates.

Concentration Defined

Concentration is broadly defined as the fraction of a constituent of interest contained within a sample. Concentration of gaseous contaminants are generally reported in volumetric, mass-based, or mixed units (see next section). Concentrations of particulates can be provided as number of particles in a sample, or mass of particulates in a certain size range in a mass of sample gas.

Gaseous Contaminants -Units of Measurement[2]

Concentration of gaseous contaminants may be expressed in volumetric, mass-based, or mixed units fractions. The first two are dimensionless except for any scale factor, whereas mixed units fractions are typically expressed as mass of contaminant per unit volume of sample mixture, e.g. mg m^{-3}.

Volumetric concentration is generally expressed in parts per million (ppm) or parts per billion (ppb), defined as the parts of contaminant per million or billion parts of air by volume (1000 ppb = 1ppm).

Mass-based concentration is expressed in either mg kg^{-1} or µg kg^{-1}, with the numerator referring to the mass of contaminant and the denominator to the mass of sample air.

Mixed-unit concentration is most convenient for this work, and is generally expressed as either mg m^{-3} or µg m^{-3}. While this is technically a mixed-unit expression for concentration, it is often called “mass concentration”, and we adopt this naming convention in this SOP. It is convenient because when multiplied by volumetric flow rate of air, an emission rate is directly determined.

Conversion between volumetric $[C]_V$ (ppm) and mass $[C]_M$ (mg m^{-3}) concentrations, assuming the mixture behaves as an ideal gas, is[1]:

$$[C]_V = 8.309T/(Mp)\,[C]_M \qquad (1)$$
$$[C]_M = 0.1204Mp/T \qquad (2)$$

where:

---

[2] Air Contaminants. Chapter 12. ASHRAE HOF. 2005. American Society of Heating Ventilation and Air-Conditioning Engineers, Atlanta GA.

p = sample mixture pressure, kPa
T = sample mixture temperature, K
M = relative molar mass of contaminant, dimensionless

Gaseous Contaminants – Standard Conditions

The relation between $[C]_M$ and $[C]_V$ for standard conditions of 25 °C and 101.325 kPa, is given by:

$$[C]_M = (M/24.45)\,[C]_V \qquad (3)$$

For ammonia, carbon dioxide, hydrogen sulfide and methane, the relative molecular masses are 17.03, 44.01, 34.08 and 16.04, respectively. From equation (3) the relation between standard concentration on mass and volumetric basis are:

$$[C]_{M,NH3} = 0.6965\,[C]_{V,NH3}$$
$$[C]_{M,CO2} = 1.8\,[C]_{V,CO2}$$
$$[C]_{M,H2S} = 1.3939\,[C]_{V,H2S}$$
$$[C]_{M,CH4} = 0.6560[C]_{V,CH4}$$

Gaseous Contaminants – Effects of Temperature and Pressure

A volumetric concentration measurement (ppm) taken at non-standard conditions may be converted to mass concentration (mg m^{-3}) by equation (2) for a given pressure, p, and absolute temperature, T.

Particulate Contaminants -Units of Measurement

Concentration of particulate contaminants may be expressed in mixed units (mass of particulate in a unit volume of sample air), or as a particle count per unit volume of sample air. If the latter is used, the particle count is understood to be within a particle size range, e.g. up to 2.5 µm or 10 µm (PM2.5 and PM10). Total suspended solids may be expressed as either particle count or particle mass per unit volume of sample air. In this SOP, we shall always use mixed units for particulate concentrations, i.e. mg m^{-3}.

Ventilation Rates – Units of Measurement

Fan ventilation rates (standard $m^3\ s^{-1}$, or $sm^3\ s^{-1}$) for each running fan are determined from building static pressure difference (SP, Pa) and the calibration equation for the fan, as follows:

$$Q_{FAN} = a + b\ SP$$

where the parameters a,b are different for each fan and are obtained from regression of the FANS calibration data explained elsewhere in this SOP.

Building ventilation rate, Q'_o, is determined by summing all fans that are running at any time. In the event that large spatial variations are noted, building ventilation rate can be broken into representative amounts near each sampling location, typically two values in the broiler housing, e.g. $Q'o_1$ and $Q'o_2$.

The relations between actual (Q), moist standard (Q'), and dry standard (Q'') volumetric flow rates are:

$$Q'' = (1-W)Q' = (1-W)\,Q(p/p')(T'/T) \qquad (4)$$

where:

W = humidity ratio of air, kg H_2O per kg dry air
= $0.62198\ p / (p-p_v)$
p_v = water vapor pressure (kPa)
= $(rh/100)p_{v,sat}$
rh = air relative humidity, %
$p_{v,sat}$ = saturation water vapor pressure
p = actual pressure (kPa)
p' = standard pressure, 101.325 kPa
T = actual absolute temperature, K
T' = standard absolute temperature, K
Q = actual (moist) volumetric flow, $m^3\ s^{-1}$
Q' = moist standard volumetric flow, $sm^3\ s^{-1}$
Q'' = dry standard volumetric flow, $dsm^3\ s^{-1}$

Emission Rates – Units of Measurement

Emission rate (E) of a gaseous or particulate contaminant is expressed as a mass flow per unit time, e.g. g $NH_3\ s^{-1}$. It may be further refined on a per live-weight, per animal or per animal-unit basis. Consideration should be given to avoid expressing E on a time interval that is shorter than the minimum sampling frequency used to obtain the data. Thus for example, if several minutes are required to acquire concentration data then it is unrealistic to report E on a mass per second basis.

Emission Rates – Calculations

Emission rate (E) is difference in mass flow between all inlet and outlets, for the contaminant of interest. Mass flow of contaminant entering a building can be expressed as the background volumetric concentration $[C]_{Vi}$ multiplied by the incoming volumetric flow rate, Q_i. Similarly, the exhaust mass flow of contaminant is the product of exhaust volumetric concentration $[C]_{Vo}$ multiplied by the exhaust volumetric flow rate, Q_o. Note that volumetric flow rates Q_i and Q_o are typically not equal, since air density differences usually exist between inlet and outlets. Mass flow rate of ventilation air, M_i and M_o, are equal. Equation (4) expresses the general definition of emission rate:

$$E = Q'_o[C]_{Mo} - Q'_i\,[C]_{Mi} \qquad (5)$$

In equation (4), the volumetric flow rates Q'_o and Q'_i may be either actual flow rate, or standardized flow rates (either moist standard = $sm^3\ s^{-1}$ or dry standard = $dsm^3\ s^{-1}$). Moist standard conditions are most appropriate. The mass concentrations of outside and inside samples should be adjusted to standard temperature and pressure, as per equation (3).

In equation (5), the volume units used for volumetric flow rate (denominator) and mass concentration (denominator) must match. For example, non-standard moist air, standard moist air, or standard dry air would be the consistent units to use. Further, typically Q'_o is measured (see SOP for airflow measurement), but Q'i must be computed from continuity:

$$Q_i/\upsilon_i = Q_o/\upsilon_o$$

or,

$$Q'i = (\upsilon_i / \upsilon_o)\, Q'_o \qquad (6)$$

where υ_i , υ_o are inside air and outside air specific volumes, m^3 moist air per kg dry air. Specific volume may be calculated from air density (kg moist air per m^3 dry air, or kg ma per kg da) and humidity ratio W (kg H_2O per kg da), by:

$$\upsilon = (1+W) / \rho \qquad (7)$$

Summary of Measurements and Calculations for Emission Rate

Measurements required to compute E include:

1. Interior and exterior air state points: dry-bulb temperature, relative humidity
2. Interior and exterior mass volumetric concentrations
3. Building static pressure differences, and atmospheric pressure

Intermediate calculations to compute E include:

1. Interior and exterior saturation and partial water vapor pressure, humidity ratio, air density, specific volume (from equations 4 and 7)
2. Exhaust standard ventilation rate, Q'_o (from FANS calibration and measured static pressure)
3. Incoming standard volumetric ventilation rate, Q'_i (from equation 6)

Combining equations (4)-(7), compute emission rate E from:

$$E = Q'_o\, ([C]_{Mo} - (\upsilon_i / \upsilon_o)\, [C]_{Mi}) \qquad \text{(mg contaminant s}^{-1}\text{)}$$
(8)

Adjust E time basis to reflect issues described in next section.

Concentration Data Extraction, Averaging and Interpolation

Gas Concentration Extraction and Averaging

When analyzing each of the house air samples, four 30-second measurement cycles by the ammonia analyzer will be performed to ensure attainment of 97% or better of the expected concentration value. If fans at all three sampling locations are running, the time interval of a complete sampling cycle will be 120 x 3 = 360 s. If SW3 and/or TF1 are not running, their sample analysis will be skipped, and the sampling will go back to SW1 or fresh/background air. Airflow rates corresponding the measured concentrations will be used in the calculation of the overall house emission rate. Since compositions of the background air are much more stable than the house air, it will be sampled only once every 2 hours. Due to the larger step change in ammonia concentration between the house air and background air, a longer sampling time (i.e., 5 minutes) will be used to allow full stabilization of the analyzer readings. Only the concentration readings at the end of the sampling cycle will be considered as valid measurements.

Gas Concentration Interpolation

When there is only 1 valid reading per location during a 360 sec sampling cycle. To account for potential concentration changes during this period, linear interpolation between the two adjacent readings of the same location will be performed to determine the concentrations in between.

Complete Data Sets

To avoid errors introduced into calculated average values due to partial data days that result in biased time weights, only complete-data days (CDD) that include over 75% valid data should be used for calculating average daily means (ADM). Similarly, hourly averages should be reported only if over 75% of the data during that hour is valid and monthly averages are reported only if over 75% of the days are valid.

Quantity Names and Terminology

Reading: One data point read by LabVIEW. It is not necessarily recorded by LabVIEW.
Data record: A single data point recorded in data files by the LabView data acquisition program. A data record consists of an average of 1-s readings collected over the data recording interval. LabVIEW takes a reading every second and write a data file. LabVIEW also records an average of 30 readings every 30 s and records that in another data file.

Daily mean: Average of all valid and interpolated data records during CDD.
Average daily means (ADM): Average of valid daily means. It can be obtained over a month, a season or a year.
Overall test mean: Average of all valid data over the entire test.

Appendix K: SOP of Model 101E UV Fluorescence H_2S Analyzer

Introduction

The M101E UV Fluorescence H_2S Analyzer is a microprocessor controlled analyzer that determines the concentration of hydrogen sulfide (H_2S), in a sample gas drawn through the instrument. It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the sample chamber where the H_2S in the sample gas is converted into SO_2 which is then exposed to ultraviolet light causing the SO_2 to become excited (SO_2*). As these SO_2* molecules decay back into SO_2 they fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO_2 present in the sample chamber and by inference therefore the amount of H_2S present in the sample gas.

The M101E H_2S analyzer is basically a SO_2 analyzer with a $H_2S \rightarrow SO_2$ conversion stage inserted into the gas stream before the sample gas enters the sample chamber. The H_2S to SO_2 converter receives sample gas from which the SO_2 has been removed by a scrubber. Once the naturally occurring SO_2 is removed from the sample gas, the special converter changes the H_2S in the sample stream to SO_2 using a high-temperature catalytic oxidation.
The chemical process is:

$$2H_2S + 3O_2 \longrightarrow 2H_2O + 2SO_2$$

The physical principle of the M101E's measurement method relies on the fluorescence that occurs when Sulfur dioxide (SO2) is excited by ultraviolet light with wavelengths in the range of 190 nm - 230 nm. This reaction is a two-step process.
The first stage occurs when SO2 molecules are struck by ultraviolet photons of the appropriate wavelength (19 nm - 230 nm). The SO_2 retains some excess energy that causes one of the electrons of the SO_2 molecule to move to a higher energy orbital state. In the case of the Model 101E, a band pass filter between the source of the UV light and the affected gas limits the wavelength of the UV light to approximately 214 nm.

$$SO_2 + hv_{214nm} \xrightarrow{Ia} SO2*$$

The second stage of this reaction occurs after the SO_2 reaches its excited state (SO_2*). Because the system will seek the lowest available stable energy state, the SO_2* molecule quickly returns to wavelength of this fluoresced light is also in the ultraviolet band but at a longer (lower energy) wavelength centered at 330nm.

$$SO_2* \xrightarrow{kF} SO_2 + hv_{330nm}$$

The linearity of the API 101E was checked. Figure 1 shows the linearity results for the two analyzer (SN: 965 and 966) accuracy checks. For each check, a linear regression was calculated from API 101E response versus the nominal H2S gas standard concentration over the range of 0 to 500 ppb.

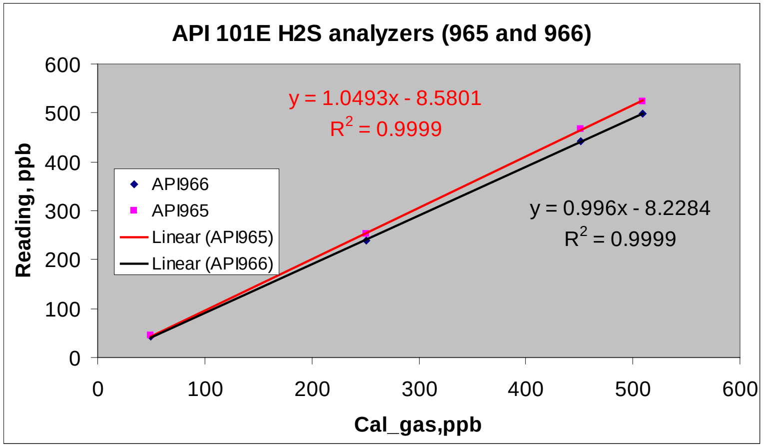
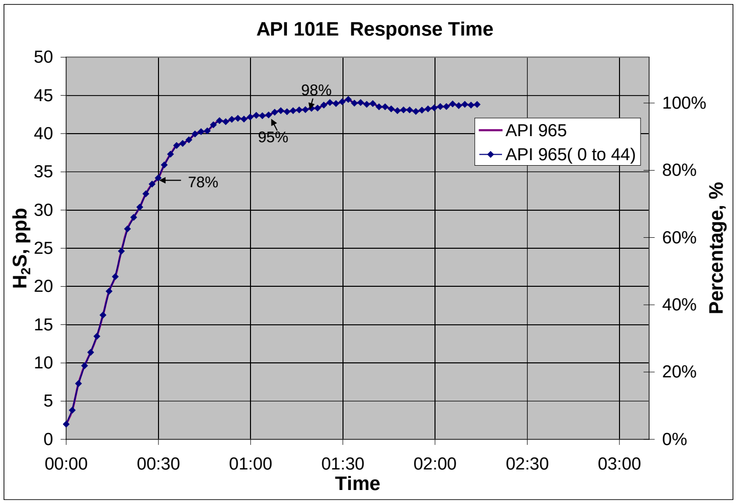


Figure 1. APl 101E Linearity Results

For 965, the slope of the regression line was 1.05, with an intercept of -8.58 and r^2 value of 0.9999. For 965, the slope of the regression line was 0.996, with an intercept of -8.23 and r^2 value of 0.9999. Over the range of concentrations tested (0 to 500 ppb H2S), the API 101E demonstrated a high degree of linearity.



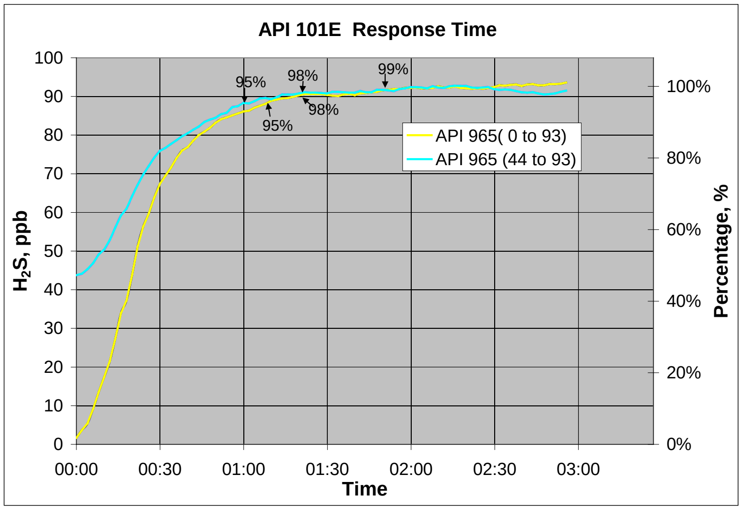


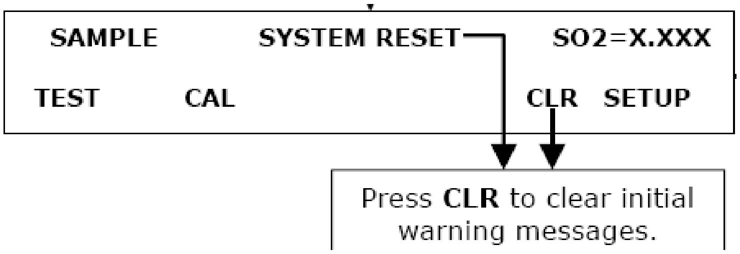
Figure 2. API response time

The response time of the analyzer to step changes in gas concentrations was tested (figure 2). The analyzer was challenged with two H_2S calibration span gases, 44 ppb and 93ppb H_2S respectively in a N_2 balance (±2% accuracy) (Matheson Gas Products, Inc., Montgomeryville, PA). Response time was determined from the amount of time required for the Model 101E to reach 95% of the change in response during the zero air to 44 ppb H2S span gas, 0 to 93 ppb and 44 to 93 ppb shown in Figure 2. The response time was approximately 75 seconds.

Start up

After electrical and pneumatic connections are made, turn on the power switch on the front panel. The exhaust and PMT cooler fans should start. The display should immediately display a single, horizontal dash in the upper left corner of the display. This will last approximately 30 seconds while the CPU loads the operating system.

Once the CPU has completed this activity it will begin loading the analyzer firmware and configuration data. During this process, string of messages will appear on the analyzer's front panel display:



Press **CLR** to clear initial warning messages.

The "fault", red LED will be blinking. Then push the "CLR" key to clear the "SYSTEM RESET" message. The M101E requires about 60 minutes warm-up time before reliable H_2S measurements can be taken.

If the warning messages persist after 60 minutes, investigate their cause using the troubleshooting guidelines in Chapter 11 of Manual.

Functional check

After the analyzer's components have warmed up for at least 30 minutes, verify that the software properly supports any hardware options that were installed.

Check to make sure that the analyzer is functioning within allowable operating parameters. Please check with the values listed in the manufactory data sheet with the operation manual. To view the current values of these parameters press the following key sequence on the front panel.

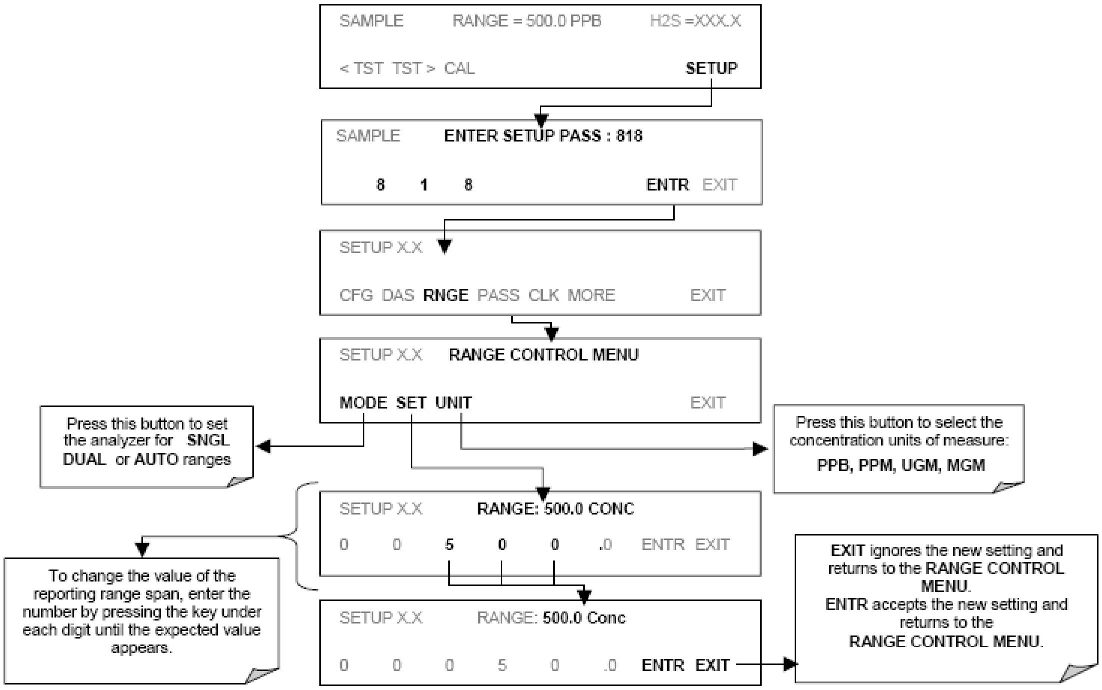
Changing the Sample Particulate Filter

The particulate filter should be inspected often for signs of plugging or excess dirt. It should be replaced according to the service interval in Table 9-1 of manual (every week) even without obvious signs of dirt. Filters with 1 and 5 µm pore size can clog up while retaining a clean look. We recommend handling the filter and the wetted surfaces of the filter housing with gloves and tweezers. Do not touch any part of the housing, filter element, PTFE retaining ring, glass cover and the O-ring with bare hands.

1. Turn OFF the analyzer to prevent drawing debris into the sample line.
2. Open the M101E's hinged front panel and unscrew the knurled retaining ring of the filter assembly.
3. Carefully remove the retaining ring, glass window, PTFE O-ring and filter element.
4. Replace the filter element, carefully centering it in the bottom of the holder.
5. Re-install the PTFE O-ring with the notches facing up, the glass cover, then screw on the hold-down ring and hand-tighten the assembly. Inspect the (visible) seal between the edge of the glass window and the o-ring to assure proper gas tightness.
6. Re-start the analyzer.

Calibration Procedure

Step one: Set/verify the analog output reporting range of the 101E.



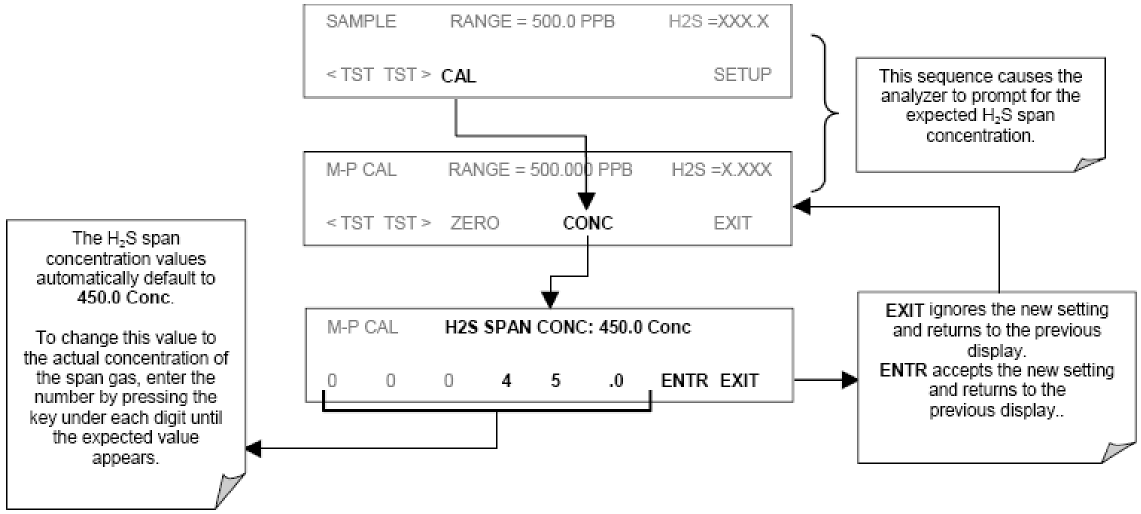
Press this button to set the analyzer for **SNGL DUAL** or **AUTO** ranges

Press this button to select the concentration units of measure: **PPB, PPM, UGM, MGM**

To change the value of the reporting range span, enter the number by pressing the key under each digit until the expected value appears.

EXIT ignores the new setting and returns to the **RANGE CONTROL MENU**.
ENTR accepts the new setting and returns to the **RANGE CONTROL MENU**.

Step two: Set the expected H_2S span gas concentration.



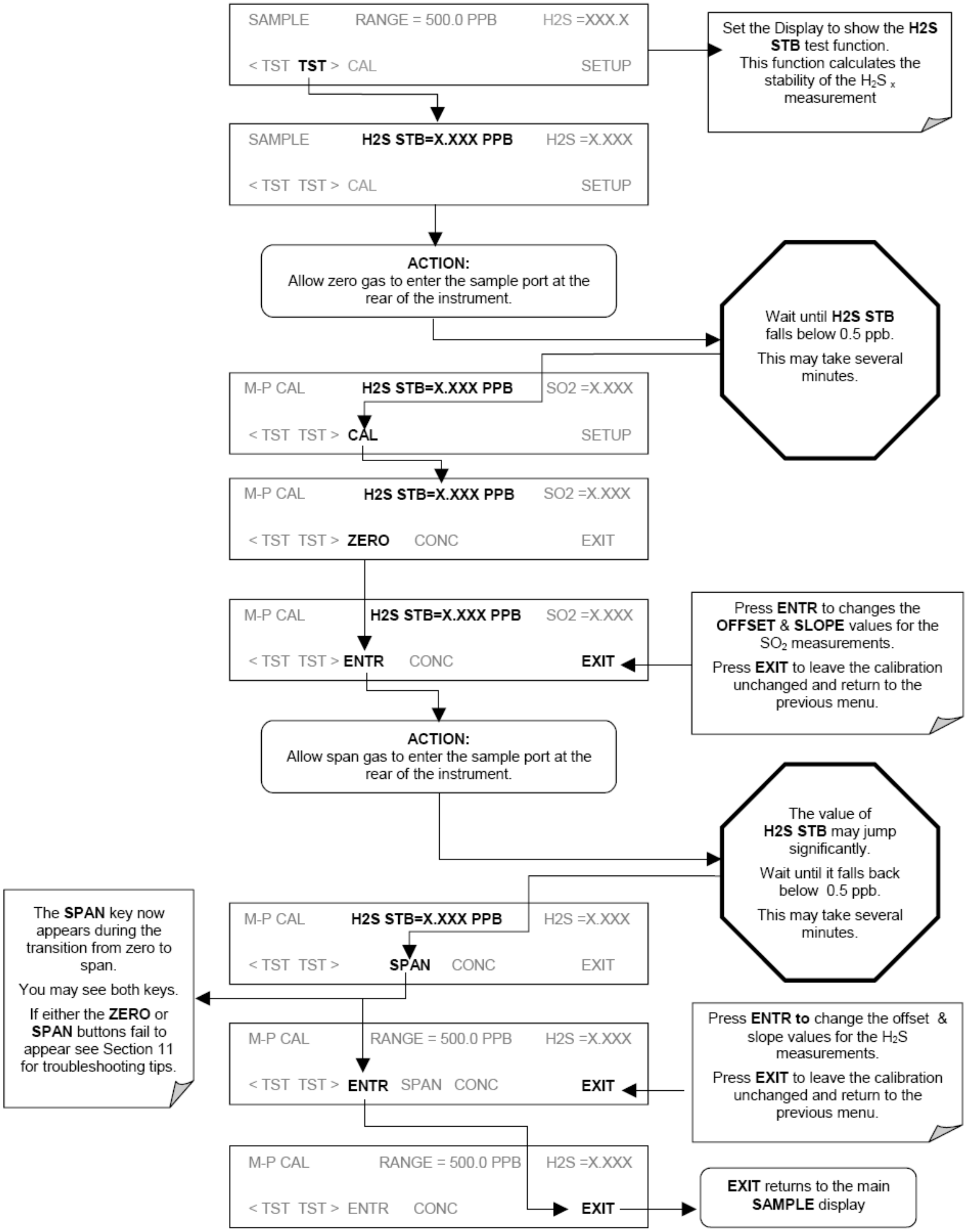
This sequence causes the analyzer to prompt for the expected H_2S span concentration.

The H_2S span concentration values automatically default to **450.0 Conc**.

To change this value to the actual concentration of the span gas, enter the number by pressing the key under each digit until the expected value appears.

EXIT ignores the new setting and returns to the previous display.
ENTR accepts the new setting and returns to the previous display..

Step three: Perform the zero/span calibration procedure:



Set the Display to show the **H2S STB** test function. This function calculates the stability of the H_2S_x measurement

ACTION:
Allow zero gas to enter the sample port at the rear of the instrument.

Wait until **H2S STB** falls below 0.5 ppb.

This may take several minutes.

Press **ENTR** to changes the **OFFSET** & **SLOPE** values for the SO_2 measurements.

Press **EXIT** to leave the calibration unchanged and return to the previous menu.

ACTION:
Allow span gas to enter the sample port at the rear of the instrument.

The value of **H2S STB** may jump significantly.

Wait until it falls back below 0.5 ppb.

This may take several minutes.

The **SPAN** key now appears during the transition from zero to span.

You may see both keys.

If either the **ZERO** or **SPAN** buttons fail to appear see Section 11 for troubleshooting tips.

Press **ENTR to** change the offset & slope values for the H_2S measurements.

Press **EXIT** to leave the calibration unchanged and return to the previous menu.

EXIT returns to the main **SAMPLE** display

Manufacturer Contact Information

TELEDYNE ADVANCED POLLUTION INSTRUMENTATION
9480 CARROLL PARK DRIVE
SAN DIEGO, CA 92121-5201
USA

Toll-free Phone:	800-324-5190
Phone:	858-657-9800
Fax:	858-657-9816
Email:	api-sales@teledyne.com
Website:	http://www.teledyne-api.com/

Reference:

INSTRUCTION MANUAL OF MODEL 101E UV FLUORESCENCE H2S ANALYZER , REV. A2 , 26 September, 2005

Maintenance/Calibration Record Sheet for API 101 E H_2S analyzer

Date of Calibration: ___________________ Calibrated by: ___________________

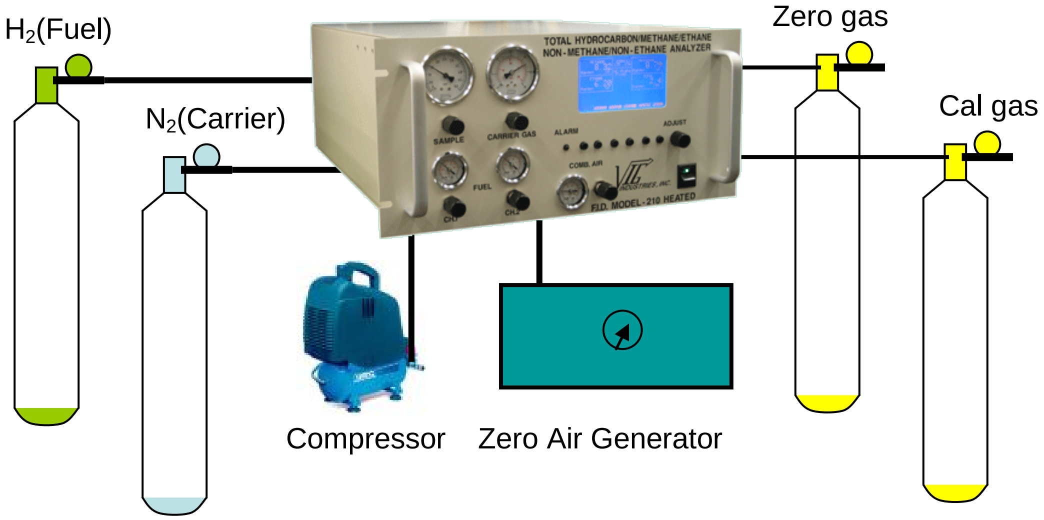
Time	Items	Unit =	Notes
: :	Ambient pressure, (mm Hg)		
	Sample airflow (L/min)		
: :	Zero air applied	---	Cylinder P: ___ psi
: :	H_2S Reading		
: :	H_2S (______ ppm) applied	---	Cylinder P: ___ psi
: :	H_2S Reading		
: :	New Calibration	Yes/No	
: :	Zero air applied		
	H_2S applied		
: :	Finish calibration	Yes/No	
: :	Time switch off	---	
: :	Connect analyzer back to sampling system.		
Note:			

Appendix L: SOP of VIG Model 200 (Methane/Non-methane/Total Hydrocarbon) Analyzer

Introduction

The methane/non-methane/total hydrocarbon analyzer VIG200 measures concentrations of a wide variety of hydrocarbons in gas mixtures and in air, and can separate the methane component from the non-methane component by using a GC column. This makes VIG-200 ideal for stack monitoring, laboratory or process control use. The model 200 uses column technology to separate methane and non-methane from total hydrocarbons (THC). When a small sample is fed though a column, the column separates each components of the THC one at a time, lightest first and heaviest last. The lightest hydrocarbon is methane. A small sample is sent through the column, wait for the methane to come out, measure the methane, and the rest of the sample is sent backward through the column, and measure the rest and call it non-methane. The measurement is achieved by the use of a FID (flame ionization detector) coupled with a very precise amplifier. The FID injects the gas into a hydrogen-based flame. The flame helps to break the electrons from their orbit, along with a high voltage surrounding the flame. The voltage forces the electrons to jump from the flame on to the electrode giving a measurable medium. The amplifier takes this information and makes it linear and in scale.

Installation



Fuel: Hydrogen (100%), Ultra High Purity Grade @ 18 psi.
Combustion Air: Hydrocarbon free, oil free, dry air @ 18 psi. (From Zero Air Generator)
Zero Air: Zero air Ultra High Purity Grade @ 9-10 psi.
Compressed air: Oil free, dry, Compressed air@ 55 psi. (From Air Compressor)
Calibration gas: Methane/Propane mixture balanced in air @ 9-10 psi.
Carrier gas: Nitrogen Ultra High Purity Grade @ 30 psi.

Startup

- Connect compressed air to the unit and set the incoming pressure to 55 psi.
- Press “Power” switch. Connect Nitrogen to the unit at the carrier gas port and set the carrier gas pressure on the front panel to 22 psi.
- Press any key to continue.
- Find the “Oven” key. If no, push the “More”.
- Set the desired oven temperature to 275^{o}F by turning front panel knob.
- Connect all required gases to the proper ports on the rear panel.
- Go the “Burner 1” and Burner 2”. Press the “Ignite”. Make sure that “Auto” is flashing. If not, press the “Auto” key.
- After the alarm lamp on the front panel goes out, check and adjust the fuel, combustion air, carrier gas and compressed air to the desired value in the **Table 1** on the **VIG 200 user manual**.

Warming Up the Monitor

A period of 6-hr is suggested to warm up the analyzer before a calibration task is started. This will reduce the time required for calibration.

Calibration

Before calibration, make sure the display and output values are the peak value.

- Press “Main” / “More” / “Menu” until “Modes” is displayed.
- Press “Modes”.
- Press “Peak” for Display and Output.
- On the front panel of the Labview program, click the “Manually control” and put all four SVs (solenoid valves) on “OFF”.

<u>Zero Gas Calibration</u>

15. Close regulator valve on the zero gas cylinder.
16. Open main valve on zero gas cylinder.
17. Insert the 1/4” ID tubing (from the gas cylinder) into the inlet of the flow meter mounting on the side of instruments rack.
18. Adjust regulator valve until vent airflow is about 5 L/min (read from bottom of ball of the vent monitoring flow meter). This provides a little extra zero air to the analyzers and keeps the pressure inside the manifold close to the atmospheric pressure.
19. Flow Zero gas for 2 minutes.
20. Press “Main” / “More” / “Menu” until “GC” is displayed and Press “GC”. Press “Single”.
21. Wait for about 3 minutes until the CH_4 and Residual analysis is finished.
22. If the CH_4 or Residual reading is not in the range of ± 0.1 ppm, the potentiometer needs to be adjusted.
    i. Press “Setup”.
    ii. Press “Methane” or “Residual” and Press “Zero”.

   iii. Turn the front panel knob. If the reading is larger than “0”, reduce the potentiometer value. If the reading is smaller than “0”, increase the potentiometer value.
   iv. Press Main” / “More” / “Menu” until “GC” is displayed and Press “GC”.

23. Press “Single”.
24. Wait for about 3 minutes until the CH4 and Residual analysis is finished.
25. Repeat steps 6-10 for both Methane and Residual until an acceptable zero reading is reached.
26. Press “Main” / “More” / “Menu” until “Modes” is displayed.
    i. Press “Modes”.
    ii. Press “Track” for Display.
    iii. Press “Main” / “More” / “Menu” until “GC” is displayed.
    iv. Press “GC” and Press “Setup”
    v. Press “Total”.
    vi. Press “Zero”.
    vii. Turn the front panel knob until the Total reading in the display window reads 0.0 ppm.
27. Close regulator and remove tubing from the zero gas cylinder.
28. Change the Modes display setup back to “Peak”.

<u>Span Gas Calibration</u>

1. Close regulator valve on the span gas cylinder.
2. Open main valve on span gas cylinder.
3. Insert the 1/4” ID tubing (from the gas cylinder) into the inlet of the flow meter mounting on the side of instruments rack.
4. Adjust regulator valve until vent airflow is about 5 L/min (read from bottom of ball of the vent monitoring flow meter). This provides a little extra span gas to the analyzers and keeps the pressure inside the manifold close to the atmospheric pressure.
5. Flow Span gas for 2 minutes.
6. Press “Main” / “More” / “Menu” until “GC” is displayed and Press “GC”. Press “Single”.
7. Wait for about 3 minutes until the CH4 and Residual analysis is finished.
8. If the CH4 or Residual reading is not in the range of span gas concentration ± 0.1 ppm, the potentiometer needs to be adjusted.
   i. Press “Setup”.
   ii. Press “Methane” or “Residual” and Press “Span”.
   iii. Turn the front panel knob. If the reading is larger than span gas concentration, reduce the potentiometer value. If the reading is smaller than span gas concentration, increase the potentiometer value.
   iv. Press Main” / “More” / “Menu” until “GC” is displayed and Press “GC”.
9. Press “Single”.
10. Wait for about 3 minutes until the CH_4 and Residual analysis is finished.

11. Repeat steps 6-10 for both Methane and Residual until an acceptable zero reading is reached.
12. Press “Main” / “More” / “Menu” until “Modes” is displayed.
    - i. Press “Modes”.
    - ii. Press “Track” for Display.
    - iii. Press “Main” / “More” / “Menu” until “GC” is displayed.
    - iv. Press “GC” and Press “Setup”
    - v. Press “Total”.
    - vi. Press “Span”.
    - vii. Turn the front panel knob until the Total reading in the display window reads 0.0 ppm.
13. Close regulator and remove tubing from the zero gas cylinder.
14. Change the Modes display setup back to “Peak”.
15. Press “Main” / “More” / “Menu” until “GC” is displayed and Press “GC”. Press “Auto”.
16. On the front panel of the Labview program, click the “Manually control” and close the manually control.

Manufacturer Contact Information

VIG Industries, Inc.
4051 East La Palma Ave., Suite C
Anaheim, California 92807-1751
Toll Free in the US: (800) 862 - 7844
Phone: (714) 632 - 8200
Fax: (714) 632 - 8201
Email: Service@vigindustries.com

Reference:

Manual of model 200 methane/non-methane/total hydrocarbon analyzer

Maintenance/Calibration Record Sheet for VIG 200

Date of Calibration: ___________________ Calibrated by: ___________________

Time	Items	Unit =	Notes
: :	Ambient pressure, (mm Hg)		
	Sample airflow (L/min)		
: :	Zero air applied	---	Cylinder P: ___ psi
: :	Total Reading		
: :	CH$_4$ Reading		
: :	Propane Reading		
: :	CH$_4$ (______ ppm) applied	---	Cylinder P: ___ psi
	CH$_4$ Reading		
: :	Propane (______ ppm) applied	---	Cylinder P: ___ psi
	Propane Reading		
: :	New Calibration	Yes/No	
: :	Zero air applied		
	Total adjustment: CH$_4$ adjustment: Propane adjustment:		
	Total Reading: CH$_4$ Reading: Propane Reading:		
: :	CH$_4$ applied		
	Total adjustment: CH$_4$ adjustment: Propane adjustment:		
	Total Reading: CH$_4$ Reading: Propane Reading:		
: :	Propane applied		
	Total adjustment: CH$_4$ adjustment: Propane adjustment:		
	Total Reading: CH$_4$ Reading: Propane Reading:		
: :	Finish calibration	Yes/No	
: :	Time switch off	---	
: :	Connect analyzer back to sampling system.		
Note:			

Appendix M: SOP of Tapered Element Oscillating Microbalance (TEOM) for TSP Measurement

Introduction

The TEOM instrument (TEOM 1400 Ambient Particulate (PM-10) Monitor) is a continuous PM monitoring device designated by USEPA as an equivalent method (EPA Designation No. EQPM-1090-079) for PM_{10} (≤ 10 μm aerodynamic diameter). The acronym TEOM stands for "Tapered Element Oscillating Microbalance," an inertial measurement technique that operates on changes in the resonant frequency of an oscillating element as a function of increases in particle mass collected on a filter attached to the element. Changes in the element's resonant frequency are sampled electronically in quasi-real time, providing both continuous and time-averaged measures of mass accumulation that are directly proportional to instantaneous and time-averaged mass concentrations in air, respectively. The device operates at an industry-standard, volume-controlled flow rate of 16.7 L/min so that it can be outfitted with a variety of commercially available pre-separator inlets suitable for measuring PM. **The unit is fitted with a TSP inlet head in this application.**

Switching Instrument on/off

Since the airflow is maintained at a constant volume, corrected for local temperature and barometric pressure, the operation of this monitor requires that the temperature and pressure sensors are connected for proper temperature and pressure readings and flow corrections.

Turn on unit

Supply power to the instrument by plugging in the power cord to 120 VAC, and pressing the power button on the front panel of the TEOM control unit. The main screen (four-line display) will soon appear after showing the name of the instrument. Turn on the pump to draw the sample streams by plugging in the power cord to 120 VAC. The monitor waits at least 30 min after being powered up to compute the first mass concentration data.

Turn off unit

Press the power button on the front panel of the TEOM control unit. The four-line display becomes blank. Turn off the vacuum pump by pressing the power button and disconnect the control unit from 120 VAC by unplugging the power cord.

Status Line on Main Screen

Whenever a status code other then "OK" is shown on the display, the instrument automatically turns on the "Check Status" light on the front of the control unit. The information displayed on the main screen includes status condition, operating mode, A/O 1 mode, RS-232 mode, protection, and time. For example, the screen will show the following line at time XX:XX:

```
OK     4+      51%    NU      XX:XX
```

Status condition

OK	Normal operation
M	No frequency signal
T	Temperature(s) outside of operational bounds
F	Flow(s) outside of operational bounds
X	Filter nearing capacity—exchange filter

Operating mode

1	Temperature/flow stabilization
2	Begin TM computation
3	TM computed, begin MR/MC computation
4	Normal operating mode
S	Set up mode
X	Stop all mode

A/O 1 mode

(Blank)	Analog output 1 normal definition
+	Analog output 1 used for status watch
XX%	Filter loading (percent)

RS-232 mode

N	None
P	Print online
R	R&P protocol
A	AK protocol
G	German network protocol
S	Storage to printer
F	Fast storage output

Protection

U	Unlocked
L	Low lock
H	High lock
XX:XX	Current time (24-hr format)

Using the Keypads and Software

User should refer to Section 4.5 of the operating manual and become familiar with the incorporated menu-driven software and keypads.

Filter Storage and Exchange

The measurements must be conducted with TEOM filter cartridges that are made of Teflon-coated glass fiber filter paper. Filters should be stored inside the sensor unit for easy access and to keep them dry and warm. Do not handle new filter with your fingers. Instead, use the filter exchange tool and follow the procedures given in the operating manual. Keep the sample pump running to facilitate filter exchange. Use the two pockets on the right side of the mass transducer (inside) to store the next two new TEOM filters, for pre-conditioning and removal of excessive moisture build-up prior to use.

System Operation after Power Failure

The system resets itself when power is regained, and enters the same mode as before. All operating parameters are maintained in the system's battery backed-up CMOS memory.

Setting Variables Stored in Data Logger

The <Step Screen> key toggles the instrument between the View Storage Screen and Set Storage Screen, or, pressing 09<Enter> can gain direct access to the Set Storage Screen from any screen. The first eight lines of the Set Storage Screen contain the titles of the variables currently being stored in the data logger (Program Register Codes listed in Appendix A of operating manual). The "Interval" variable defines the time (in seconds) between successive writings of data to the circular buffer.

Some popular program register codes:

Code	**Variable**	**Units**
008	Mass concentration	μg/m^3
009	Total mass	μg
035	Pressure drop	%
039	Current main flow	L/min
040	Current auxiliary flow	L/min
041	Status condition	code
057	30-min average mass concentration	μg/m^3
130	Current ambient temperature	^{o}C
131	Current ambient pressure	atm

Setting Analog Outputs

The instrument's three analog output channels are accessible from the identical 15-pin connectors on the front and back panels of the control unit. Details regarding the pin assignments and voltage (VDC) of outputs are given in the operating manual (Section 5.1). To bring up the Set Analog Output Screen, press <A/O>, or select "Set Analog Output" from Menu Screen, or press 04<Enter>.

Setting Sampling Average Time

The <Step Screen> key toggles the instrument to "Set Hardware", then press <Enter>. Press the "Data Stop" to start stetting the sampling average time.

Nomenclature

TM	Total mass

MR	Mass rate
MC	Mass concentration
A/O	Analog output
atm	atmosphere, 746 mBar

Calibration

Procedures are based on routine flow auditing, leak checking, and mass calibration verification. Since the TEOM monitor can be directly mass calibrated, it can be directly quality assured using a mass standard. All QA procedures should be coordinated with routine maintenance procedures to minimize down time.

Flow Audit

A flow audit adapter is provided and the procedures are outlined in the operating manual. Both the sample flow rate and total flow rate may be checked using the flow audit adapter with a capped nut for closing the flow splitter bypass line port. It is recommended that the volumetric flow rates be within ±7% of the set points. The United States Environmental Protection Agency (USEPA) requires a tolerance of ±10% for the total flow through the PM-10 inlet. If measured flows differ by more than the stated tolerances, recheck all settings, and perform the test again. Large errors in the flow may indicate other sources of error, such as a malfunctioning flow controller, a system leak, or improper temperature and pressure settings.

Leak Check

The leak check procedures are included in the operating manual (Section 7.6). The leak check should be performed with NO sample filter attached to the mass transducer, which will prevent accidental damage from occurring to the sample filter cartridge when exposed to the high pressure drop (vacuum) in the sample line that the leak check creates. Flow rates should indicate less than 0.15 L/min for the main flow and less than 0.65 L/min for the auxiliary flow with the end of the sample line closed, if not, systematically check plumbing for connector leaks.

Mass Calibration Verification

The mass transducer is permanently calibrated and never requires recalibration under normal use. However, the mass measurement accuracy of the instrument may be verified following procedures in the operating manual. R&P offers a mass calibration verification kit to help perform this procedure.

Maintenance

The lifetime of a **TEOM filter cartridge** depends on the nature and concentration of the particulate sampled, and the main flow rate setting (1, 2, or 3 l/min). The filter must be exchanged when the filter loading value (as shown on the status line of the main menu) **approaches 70%**. At a flow rate of 3 l/min, 100% filter loading generally corresponds to a total mass accumulation of approximately 3 to 5 mg of particulate. Filter lifetime at a main flow rate of 3 l/min is generally 21 days at an average PM-10 concentration of 50 $\mu g/m^3$. Flow splitter adapters for 1 and 2 l/min operation are available for use in areas with higher particulate concentrations.

The factory recommended schedule of periodic maintenance and the schedule to be adopted for use in livestock barns are as follows:

Maintenance item	**Factory**	**This Project**
Clean air inlet head	Upon filter exchange	Twice a Week
Replace TEOM filter cartridge	70% load	Weekly
Exchange in-line filters	6 mon. or when loaded	When loaded
Leak test	Annually	Every flock
Analog board calibration	Annually	Every 6 months

The TEOM TSP air inlet requires regular maintenance in livestock barns. The TEOM inlet itself should be cleaned weekly. In order to do this one must first push the <Data Stop> button on the keypad. Remove the dirty TEOM inlet and replace it with a clean inlet. The dirty TSP inlet will be taken back to work station for cleaning and ready for next inlet swap. For cleaning the dirty inlet, please see Manual **Appendix G: Inlet Maintenance**. Grease as needed to maintain a slight layer of Silicon Grease. Carefully replace the inlet unit, and return to the control unit of the TEOM system, and press the <Data Stop> button once more. This will prevent skewed data from being recorded. It will automatically begin recording in approximately 30 min.

Other Settings

Flow rate through sample inlet	16.7 L/min (1 m^3/hr)
Main flow rate	1 L/min
Temperature of sample stream	50 ^oC
Particulate concentration	< 5 $\mu g/m^3$ to several g/m^3
Standard Conditions	1 atm pressure, 20°C

Spare Parts and Consumables

Slow blow 2A, 250 V fuse
2A & 250 V in-line fuse, P/N 04003419
Box of 20 TEOM filter cartridges (TX40 media), P/N 57-000397-0020
Large bypass in-line filter, P/N 57-002758
Flow controller filter, P/N 30-003097

Manufacturer Contact Information

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Reference:
TEOM 1400 Operation manual

Appendix N: SOP of Tapered Element Oscillating Microbalance (TEOM) for PM10

Introduction

The TEOM instrument (TEOM 1400 Ambient Particulate (PM-10) Monitor) is a continuous PM monitoring device designated by USEPA as an equivalent method (EPA Designation No. EQPM-1090-079) for PM_{10} (≤ 10 μm aerodynamic diameter). The acronym TEOM stands for "Tapered Element Oscillating Microbalance," an inertial measurement technique that operates on changes in the resonant frequency of an oscillating element as a function of increases in particle mass collected on a filter attached to the element. Changes in the element's resonant frequency are sampled electronically in quasi-real time, providing both continuous and time-averaged measures of mass accumulation that are directly proportional to instantaneous and time-averaged mass concentrations in air, respectively. The device operates at an industry-standard, volume-controlled flow rate of 16.7 L/min so that it can be outfitted with a variety of commercially available pre-separator inlets suitable for measuring PM. **The unit is fitted with a PM_{10} inlet head in this application.**

Switching Instrument on/off

Since the airflow is maintained at a constant volume, corrected for local temperature and barometric pressure, the operation of this monitor requires that the temperature and pressure sensors are connected for proper temperature and pressure readings and flow corrections.

Turn on unit

Supply power to the instrument by plugging in the power cord to 120 VAC, and pressing the power button on the front panel of the TEOM control unit. The main screen (four-line display) will soon appear after showing the name of the instrument. Turn on the pump to draw the sample streams by plugging in the power cord to 120 VAC. The monitor waits at least 30 min after being powered up to compute the first mass concentration data.

Turn off unit

Press the power button on the front panel of the TEOM control unit. The four-line display becomes blank. Turn off the vacuum pump by pressing the power button and disconnect the control unit from 120 VAC by unplugging the power cord.

Status Line on Main Screen

Whenever a status code other then "OK" is shown on the display, the instrument automatically turns on the "Check Status" light on the front of the control unit. The information displayed on the main screen includes status condition, operating mode, A/O 1 mode, RS-232 mode, protection, and time. For example, the screen will show the following line at time XX:XX:

```
OK      4+      51%    NU      XX:XX
```

Status condition

OK	Normal operation
M	No frequency signal
T	Temperature(s) outside of operational bounds
F	Flow(s) outside of operational bounds
X	Filter nearing capacity—exchange filter

Operating mode

5	Temperature/flow stabilization
6	Begin TM computation
7	TM computed, begin MR/MC computation
8	Normal operating mode
S	Set up mode
X	Stop all mode

A/O 1 mode

(Blank)	Analog output 1 normal definition
+	Analog output 1 used for status watch
XX%	Filter loading (percent)

RS-232 mode

N	None
P	Print online
R	R&P protocol
A	AK protocol
G	German network protocol
S	Storage to printer
F	Fast storage output

Protection

U	Unlocked
L	Low lock
H	High lock
XX:XX	Current time (24-hr format)

Using the Keypads and Software

User should refer to Section 4.5 of the operating manual and become familiar with the incorporated menu-driven software and keypads.

Filter Storage and Exchange

The measurements must be conducted with TEOM filter cartridges that are made of Teflon-coated glass fiber filter paper. Filters should be stored inside the sensor unit for easy access and to keep them dry and warm. Do not handle new filter with your fingers. Instead, use the filter exchange tool and follow the procedures given in the operating manual. Keep the sample pump running to facilitate filter exchange. Use the two pockets on the right side of the mass transducer (inside) to store the next two new TEOM filters, for pre-conditioning and removal of excessive moisture build-up prior to use.

System Operation after Power Failure

The system resets itself when power is regained, and enters the same mode as before. All operating parameters are maintained in the system's battery backed-up CMOS memory.

Setting Variables Stored in Data Logger

The <Step Screen> key toggles the instrument between the View Storage Screen and Set Storage Screen, or, pressing 09<Enter> can gain direct access to the Set Storage Screen from any screen. The first eight lines of the Set Storage Screen contain the titles of the variables currently being stored in the data logger (Program Register Codes listed in Appendix A of operating manual). The "Interval" variable defines the time (in seconds) between successive writings of data to the circular buffer.

Some popular program register codes:

Code	**Variable**	**Units**
008	Mass concentration	μg/m^3
009	Total mass	μg
035	Pressure drop	%
039	Current main flow	L/min
040	Current auxiliary flow	L/min
041	Status condition	code
057	30-min average mass concentration	μg/m^3
130	Current ambient temperature	^{o}C
131	Current ambient pressure	atm

Setting Analog Outputs

The instrument's three analog output channels are accessible from the identical 15-pin connectors on the front and back panels of the control unit. Details regarding the pin assignments and voltage (VDC) of outputs are given in the operating manual (Section 5.1). To bring up the Set Analog Output Screen, press <A/O>, or select "Set Analog Output" from Menu Screen, or press 04<Enter>.

Setting Sampling Average Time

The <Step Screen> key toggles the instrument to "Set Hardware", then press <Enter>. Press the "Data Stop" to start stetting the sampling average time.

Nomenclature

TM	Total mass
MR	Mass rate
MC	Mass concentration
A/O	Analog output
atm	atmosphere, 746 mBar

Calibration

Procedures are based on routine flow auditing, leak checking, and mass calibration verification. Since the TEOM monitor can be directly mass calibrated, it can be directly quality assured using a mass standard. All QA procedures should be coordinated with routine maintenance procedures to minimize down time.

Flow Audit

A flow audit adapter is provided and the procedures are outlined in the operating manual. Both the sample flow rate and total flow rate may be checked using the flow audit adapter with a capped nut for closing the flow splitter bypass line port. It is recommended that the volumetric flow rates be within ±7% of the set points. The United States Environmental Protection Agency (USEPA) requires a tolerance of ±10% for the total flow through the PM-10 inlet. If measured flows differ by more than the stated tolerances, recheck all settings, and perform the test again. Large errors in the flow may indicate other sources of error, such as a malfunctioning flow controller, a system leak, or improper temperature and pressure settings.

Leak Check

The leak check procedures are included in the operating manual (Section 7.6). The leak check should be performed with NO sample filter attached to the mass transducer, which will prevent accidental damage from occurring to the sample filter cartridge when exposed to the high pressure drop (vacuum) in the sample line that the leak check creates. Flow rates should indicate less than 0.15 L/min for the main flow and less than 0.65 L/min for the auxiliary flow with the end of the sample line closed, if not, systematically check plumbing for connector leaks.

Mass Calibration Verification

The mass transducer is permanently calibrated and never requires recalibration under normal use. However, the mass measurement accuracy of the instrument may be verified following procedures in the operating manual. R&P offers a mass calibration verification kit to help perform this procedure.

Maintenance

The lifetime of a **TEOM filter cartridge** depends on the nature and concentration of the particulate sampled, and the main flow rate setting (1, 2, or 3 l/min). The filter must be exchanged when the filter loading value (as shown on the status line of the main menu)

approaches 70%. At a flow rate of 3 l/min, 100% filter loading generally corresponds to a total mass accumulation of approximately 3 to 5 mg of particulate. Filter lifetime at a main flow rate of 3 l/min is generally 21 days at an average PM-10 concentration of 50 μg/m^3. Flow splitter adapters for 1 and 2 l/min operation are available for use in areas with higher particulate concentrations.

The factory recommended schedule of periodic maintenance and the schedule to be adopted for use in livestock barns are as follows:

Maintenance item	**Factory**	**This Project**
Clean air inlet head	Upon filter exchange	Twice a week
Replace TEOM filter cartridge	70% load	Weekly
Exchange in-line filters	6 mon. or when loaded	When loaded
Leak test	Annually	Every flock
Analog board calibration	Annually	Every 6 months

The TEOM PM10 air inlet requires regular maintenance in livestock barns. The TEOM inlet itself should be cleaned weekly. In order to do this one must first push the <Data Stop> button on the keypad. Remove the dirty TEOM inlet and replace it with a clean inlet. The dirty PM 10 inlet will be taken back to work station for cleaning and ready for next inlet swap. For cleaning the dirty inlet, please see Manual **Appendix G: Inlet Maintenance**. Grease as needed to maintain a slight layer of Silicon Grease. Carefully replace the inlet unit, and return to the control unit of the TEOM system, and press the <Data Stop> button once more. This will prevent skewed data from being recorded. It will automatically begin recording in approximately 30 min.

Other Settings

Flow rate through sample inlet	16.7 L/min (1 m^3/hr)
Main flow rate	1 L/min
Temperature of sample stream	50 ^{o}C
Particulate concentration	< 5 μg/m^3 to several g/m^3
Standard Conditions	1 atm pressure, 20°C

Spare Parts and Consumables

Slow blow 2A, 250 V fuse
2A & 250 V in-line fuse, P/N 04003419
Box of 20 TEOM filter cartridges (TX40 media), P/N 57-000397-0020
Large bypass in-line filter, P/N 57-002758
Flow controller filter, P/N 30-003097

Manufacturer Contact Information

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Reference:
TEOM 1400 Operation manual

Appendix O: SOP of Tapered Element Oscillating Microbalance (TEOM) for PM2.5

Introduction

The TEOM instrument (TEOM 1400a Ambient Particulate (PM-10) Monitor) is a continuous PM monitoring device designated by USEPA as an equivalent method (EPA Designation No. EQPM-1090-079) for PM_{10} (≤ 10 µm aerodynamic diameter). The acronym TEOM stands for “Tapered Element Oscillating Microbalance,” an inertial measurement technique that operates on changes in the resonant frequency of an oscillating element as a function of increases in particle mass collected on a filter attached to the element. Changes in the element’s resonant frequency are sampled electronically in quasi-real time, providing both continuous and time-averaged measures of mass accumulation that are directly proportional to instantaneous and time-averaged mass concentrations in air, respectively. The device operates at an industry-standard, volume-controlled flow rate of 16.7 L/min so that it can be outfitted with a variety of commercially available pre-separator inlets suitable for measuring PM. **The unit is fitted with a $PM_{2.5}$ inlet head in this application.**

Switching Instrument on/off

Since the airflow is maintained at a constant volume, corrected for local temperature and barometric pressure, the operation of this monitor requires that the temperature and pressure sensors are connected for proper temperature and pressure readings and flow corrections.

Turn on unit

Supply power to the instrument by plugging in the power cord to 120 VAC, and pressing the power button on the front panel of the TEOM control unit. The main screen (four-line display) will soon appear after showing the name of the instrument. Turn on the pump to draw the sample streams by plugging in the power cord to 120 VAC. The monitor waits at least 30 min after being powered up to compute the first mass concentration data.

Turn off unit

Press the power button on the front panel of the TEOM control unit. The four-line display becomes blank. Turn off the vacuum pump by pressing the power button and disconnect the control unit from 120 VAC by unplugging the power cord.

Status Line on Main Screen

Whenever a status code other then “OK” is shown on the display, the instrument automatically turns on the “Check Status” light on the front of the control unit. The information displayed on the main screen includes status condition, operating mode, A/O 1 mode, RS-232 mode, protection, and time. For example, the screen will show the following line at time XX:XX:

```
OK    4+     51%   NU    XX:XX
```

Status condition

OK	Normal operation
M	No frequency signal
T	Temperature(s) outside of operational bounds
F	Flow(s) outside of operational bounds
X	Filter nearing capacity—exchange filter

Operating mode

9	Temperature/flow stabilization
10	Begin TM computation
11	TM computed, begin MR/MC computation
12	Normal operating mode
S	Set up mode
X	Stop all mode

A/O 1 mode

(Blank)	Analog output 1 normal definition
+	Analog output 1 used for status watch
XX%	Filter loading (percent)

RS-232 mode

N	None
P	Print online
R	R&P protocol
A	AK protocol
G	German network protocol
S	Storage to printer
F	Fast storage output

Protection

U	Unlocked
L	Low lock
H	High lock
XX:XX	Current time (24-hr format)

Using the Keypads and Software

User should refer to Section 4.5 of the operating manual and become familiar with the incorporated menu-driven software and keypads.

Filter Storage and Exchange

The measurements must be conducted with TEOM filter cartridges that are made of Teflon-coated glass fiber filter paper. Filters should be stored inside the sensor unit for easy access and to keep them dry and warm. Do not handle new filter with your fingers. Instead, use the filter exchange tool and follow the procedures given in the operating manual. Keep the sample pump running to facilitate filter exchange. Use the two pockets on the right side of the mass transducer (inside) to store the next two new TEOM filters, for pre-conditioning and removal of excessive moisture build-up prior to use.

System Operation after Power Failure

The system resets itself when power is regained, and enters the same mode as before. All operating parameters are maintained in the system's battery backed-up CMOS memory.

Setting Variables Stored in Data Logger

The <Step Screen> key toggles the instrument between the View Storage Screen and Set Storage Screen, or, pressing 09<Enter> can gain direct access to the Set Storage Screen from any screen. The first eight lines of the Set Storage Screen contain the titles of the variables currently being stored in the data logger (Program Register Codes listed in Appendix A of operating manual). The "Interval" variable defines the time (in seconds) between successive writings of data to the circular buffer.

Some popular program register codes:

Code	**Variable**	**Units**
008	Mass concentration	μg/m^3
009	Total mass	μg
035	Pressure drop	%
039	Current main flow	L/min
040	Current auxiliary flow	L/min
041	Status condition	code
057	30-min average mass concentration	μg/m^3
130	Current ambient temperature	^{o}C
131	Current ambient pressure	atm

Setting Analog Outputs

The instrument's three analog output channels are accessible from the identical 15-pin connectors on the front and back panels of the control unit. Details regarding the pin assignments and voltage (VDC) of outputs are given in the operating manual (Section 5.1). To bring up the Set Analog Output Screen, press <A/O>, or select "Set Analog Output" from Menu Screen, or press 04<Enter>.

Setting Sampling Average Time

The <Step Screen> key toggles the instrument to "Set Hardware", then press <Enter>. Press the "Data Stop" to start stetting the sampling average time.

Nomenclature

TM	Total mass
MR	Mass rate
MC	Mass concentration
A/O	Analog output
atm	atmosphere, 746 mBar

Calibration

Procedures are based on routine flow auditing, leak checking, and mass calibration verification. Since the TEOM monitor can be directly mass calibrated, it can be directly quality assured using a mass standard. All QA procedures should be coordinated with routine maintenance procedures to minimize down time.

Flow Audit

A flow audit adapter is provided and the procedures are outlined in the operating manual. Both the sample flow rate and total flow rate may be checked using the flow audit adapter with a capped nut for closing the flow splitter bypass line port. It is recommended that the volumetric flow rates be within ±7% of the set points. The United States Environmental Protection Agency (USEPA) requires a tolerance of ±10% for the total flow through the PM-10 inlet. If measured flows differ by more than the stated tolerances, recheck all settings, and perform the test again. Large errors in the flow may indicate other sources of error, such as a malfunctioning flow controller, a system leak, or improper temperature and pressure settings.

Leak Check

The leak check procedures are included in the operating manual (Section 7.6). The leak check should be performed with NO sample filter attached to the mass transducer, which will prevent accidental damage from occurring to the sample filter cartridge when exposed to the high pressure drop (vacuum) in the sample line that the leak check creates. Flow rates should indicate less than 0.15 L/min for the main flow and less than 0.65 L/min for the auxiliary flow with the end of the sample line closed, if not, systematically check plumbing for connector leaks.

Mass Calibration Verification

The mass transducer is permanently calibrated and never requires recalibration under normal use. However, the mass measurement accuracy of the instrument may be verified following procedures in the operating manual. R&P offers a mass calibration verification kit to help perform this procedure.

Maintenance

The lifetime of a **TEOM filter cartridge** depends on the nature and concentration of the particulate sampled, and the main flow rate setting (1, 2, or 3 l/min). The filter must be exchanged when the filter loading value (as shown on the status line of the main menu)

approaches 70%. At a flow rate of 3 l/min, 100% filter loading generally corresponds to a total mass accumulation of approximately 3 to 5 mg of particulate. Filter lifetime at a main flow rate of 3 l/min is generally 21 days at an average PM-10 concentration of 50 μg/m^3. Flow splitter adapters for 1 and 2 l/min operation are available for use in areas with higher particulate concentrations.

The factory recommended schedule of periodic maintenance and the schedule to be adopted for use in livestock barns are as follows:

Maintenance item	**Factory**	**This Project**
Clean air inlet head	Upon filter exchange	Twice a week
Replace TEOM filter cartridge	70% load	Weekly
Exchange in-line filters	6 mon. or when loaded	When loaded
Leak test	Annually	Every flock
Analog board calibration	Annually	Every 6 months

The TEOM PM2.5 air inlet requires regular maintenance in livestock barns. The TEOM inlet itself should be cleaned weekly. In order to do this one must first push the <Data Stop> button on the keypad. Remove the dirty TEOM inlet and replace it with a clean inlet. The dirty PM 2.5 inlet will be taken back to work station for cleaning and ready for next inlet swap. For cleaning the dirty inlet, please see Manual **Appendix G: Inlet Maintenance**. Grease as needed to maintain a slight layer of Silicon Grease. Carefully replace the inlet unit, and return to the control unit of the TEOM system, and press the <Data Stop> button once more. This will prevent skewed data from being recorded. It will automatically begin recording in approximately 30 min.

Other Settings

Flow rate through sample inlet	16.7 L/min (1 m^3/hr)
Main flow rate	1 L/min
Temperature of sample stream	50 ^{o}C
Particulate concentration	< 5 μg/m^3 to several g/m^3
Standard Conditions	1 atm pressure, 20°C

Spare Parts and Consumables

Slow blow 2A, 250 V fuse
2A & 250 V in-line fuse, P/N 04003419
Box of 20 TEOM filter cartridges (TX40 media), P/N 57-000397-0020
Large bypass in-line filter, P/N 57-002758
Flow controller filter, P/N 30-003097

Manufacturer Contact Information

Rupprecht & Patashnick Co., Inc.
25 Corporate Circle

Albany, NY 12203

Timothy Morphy
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Reference:
TEOM 1400 Operation manual

Appendix P: SOP of Barometric Pressure sensor

The purpose of Barometric Pressure measurements is for the correction of the emission calculations.

The sensor is a two-wire sensor using the red wire for power and the black wire for the output signal. Warning: Always connect the sensor with the power turned off.

The barometric pressure sensor may be stored without any special provisions. Place the sensor inside a bag to keep the sensor clean and store on a shelf or hang it on a wall.

Barometric Pressure will be monitored continuously outside of the houses using a WE100 with a range of 80,000 to 110,000 Pa and an accuracy of ± 300pa. One barometric static pressure sensor is required for each house.
The barometric pressure sensor will be compared and calibrated with a calibrated portable pressure sensor at various span pressures.

WE100 barometric pressure transducer specifications
Output: 4-20mA
Range: 800-1100 millibars
Accuracy: +1% of full scale
Operating Voltage: 10-36VDC
Current Draw: Same as sensor output
Warm Up Time: 3 seconds minimum
Operating Temperature: -40° to +55°C

<u>Calibration</u>

- Calibrate the sensor every year or at a different frequency if specified by the QAPP for a particular project.
- Calibrate the sensor system (sensor and data logger) against a Fortin Barometer.
- Follow the procedures for reading and adjusting the Fortin barometer documented.
- Read instantaneous measurements from data logger/sensor system at the time of each Fortin Barometer reading.
- Conduct six paired measurements over a two–day period, average mean of their respective readings are taken out and if this matches then it is calibrated.
- Record the results of the calibration on the sensor lab notebook form.
- If the mean difference between Fortin barometer and senor/data logger measurement is less than or equal to 4 hPa, then the sensor passes calibration and the drift will be back-corrected.
- If the mean difference is > 42 hPa, the barometer will be adjusted against a Fortin Barometer

Manufacturer Contact Information

Global Water
Instrumentation, Inc.
11257 Coloma Road
Gold River, CA 95670
T: 800-876-1172
F: (916) 638-3270

Appendix Q: SOP for Use of Rotem RSC-2 Scale System

References:

1. Rotem Poultry Scale System RSC-2 User Manual.
2. Scalenet Communications Program for RSC-2 User Manual.

Routine Check

1. Check scales for clearance between scales and litter. Optimum separation is 1 inch. Adjust scales as needed

Routine Download

1. Startup the computer notebook with USB-Serial Adapter connected.
2. Hookup Serial Communications between notebook and Rotem Serial Cable
3. Start up Rotem Scalenet Application
4. As soon as software establishes communications with Rotem Scales, the main screen will popup on the computer screen displaying the current growth day and if the scales are weighing.
5. On the application's pull down menu, click on "*Setup*", "*Farm Name*" to change to the current house name (i.e., Tyson 1-5) (This changes only the software data reference, not the data retained in the actual scale's database)
6. On the application's pull down menu, click on "*Setup*", "*Set Flock Number*" to verify current Project Flock Designation Number (i.e., 2). (This changes only the software data reference, not the data retained in the actual scales database)
7. Click on **Collect** icon button to start download of history file for the current flock. Save the download file as both a Rotem (*.his) and Excel (*.xls) file. Designate the files to be saved in the corresponding folder (….\House 1-5\ or ….\House 3-3\) on the computer notebook (C:\Documents and settings\Administrator\My Documents\Rotem Data\).
8. As soon as download is complete, close the Scalenet application, disconnect the communications cables, and turn off the computer
9. Repeat this process each visit. When downloading the file, overwrite the previous saved file.
10. At the end of the flock, email the final excel file (*.xls) to ISU for evaluation.

Between Flocks

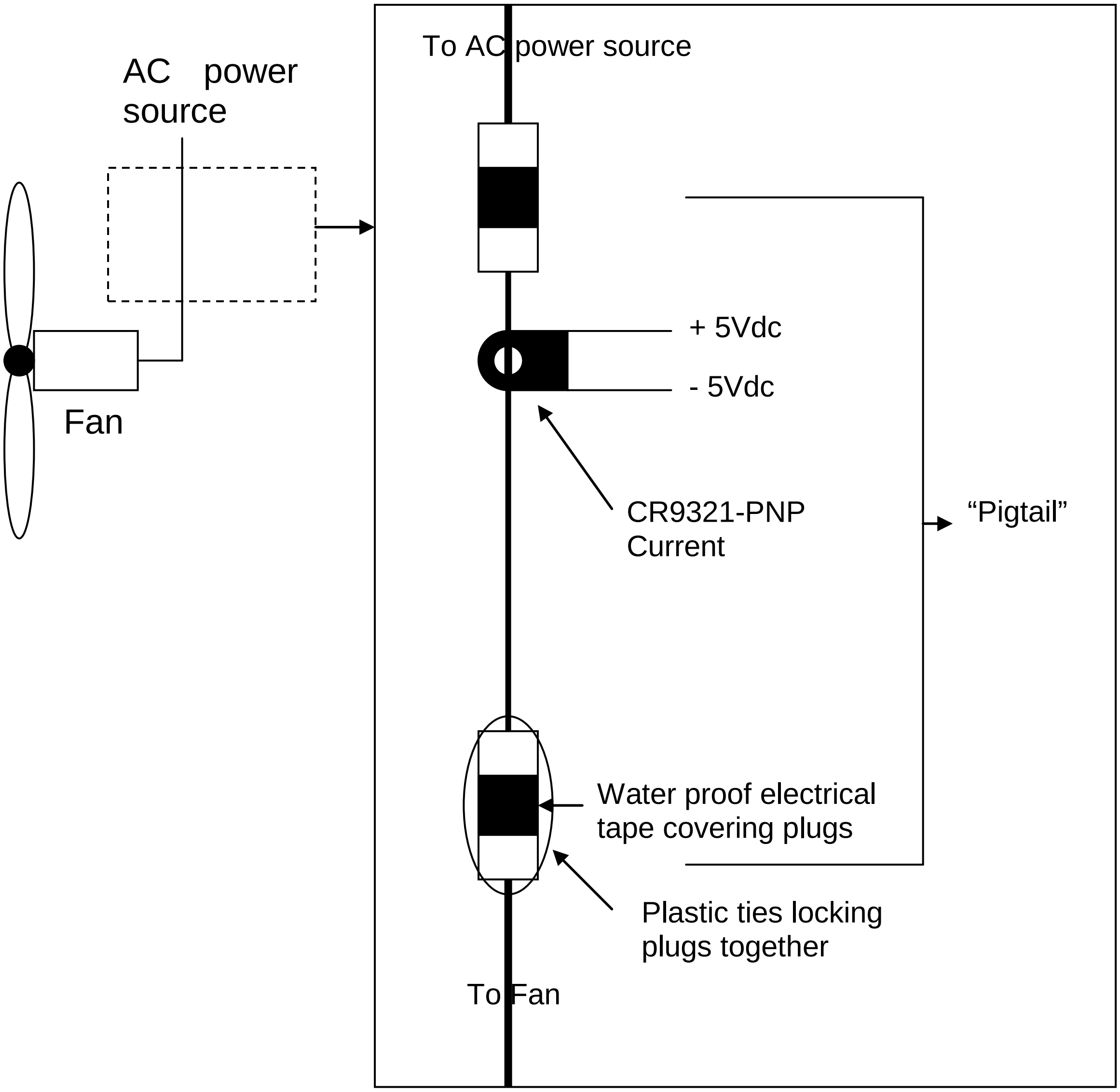
1. Immediately prior to bird catch, remove the scale platform from the load cell, clean, and store in a safe location.
2. Download the final flock weights and email the final excel file (*.xls) to ISU for evaluation.
3. Sometime prior to placement of the next flock, check the accuracy of the scales using known weights. Upon verification, remove the platform and store in a safe location.
4. Immediately after placement of the next flock birds, place the platform back on the load cell. Using the Scalenet application, click on the **Setting** icon button and reset the scales database. A different screen will appear. In the left column, click on "Growth Day" to

change the day to 1; click on “Flock Number” to change to the current flock number designation, and click on “Time” to verify the correct time with the computer time.

Appendix R: SOP for Fan Current Switch Application

Figure 1 shows the induction operated current switch (CS) (CR9321, CR Magnetics, St. Louis, MO) application in monitoring fan operational status. The CS is used in a "pigtail" which acts as a short extension cord. The "pigtail" is put in line between the fan motor and its AC power source. Water proof electrical tape is wrapped extensively around the plug connections to protect them from water and dust. The plugs are then "locked" together using multiple plastic ties as a deterrent to being separated. When AC current is present the CS returns a user defined amount of DC current to the MAEMU.

Figure 1. CS Application



Appendix S: Litter Sample Analytical Methods

Determination of manure pH:

Safety notes:

- Use lab coats, close-toed shoes and hand gloves.
- Mix liquid or semi-liquid manure thoroughly in the fume hood with the front panel pulled down.
- Do not immerse the pH electrode to the bottom of beaker

Equipment:

- pH meter
- 100 ml glass or plastic beakers
- Glass stirring rods
- Distilled water

Calibration:

Calibrate the pH meter using standard buffer solutions (pH 4.0 and 7.0), if necessary

Procedure for liquid manure

(EPA SW-846, Method 9040)

U.S. Environmental Protection Agency. 1986. Test methods for evaluating solid waste. USEPA report SW-846.

- Thoroughly mix liquid manure (manure should be at room temperature)
- Take 25 ml of liquid manure into a beaker
- Immerse pH electrode
- Record pH value when the meter has stabilized
- Repeat above steps for replicates

Procedure for semi-liquid manure

Wolf, N. 2003. Determination of manure pH. p. 48-49. *In*: Peters et al. (eds.) Recommended Methods of Manure Analysis. University of Wisconsin System. http://ecommerce.uwex.edu/pdfs/A3769.PDF (accessed on May 23, 2006)

- Thoroughly mix semi-liquid manure (manure should be at room temperature)
- Take 20 ml of semi-solid manure into a beaker
- Add 40 ml of distilled water
- Stir and mix it well with a glass rod
- Allow for 30 minutes to settle down solution
- Measure pH by immersing electrode into the supernatant solution
- Record pH value when the meter has stabilized
- Repeat above steps for replicates and report the result as pH (water 1:2)

Procedure for solid manure

Wolf, N. 2003. Determination of manure pH. p. 48-49. *In*: Peters et al. (eds.) Recommended Methods of Manure Analysis. University of Wisconsin System. http://cecommerce.uwex.edu/pdfs/A3769.PDF (accessed on May 23, 2006)

- Take 20 g of solid manure into a beaker
- Add 40 ml distilled water
- Stir and mix it well with a glass rod
- Allow for 30 minutes to settle down solution
- Measure pH by immersing electrode into the supernatant solution
- Record pH value when the meter has stabilized
- Repeat above steps for replicates and report the result as pH (water 1:2)

Total Solids or Moisture Content

Standard Method: 2540 B. Total Solids Dried at 103-105*C

Dish Preparation

**ALWAYS handle dishes with gloves on

1. Place clean evaporating dishes in oven at 103-105*C for 1 hour
2. Remove dishes from oven and cool to room temperature in a desiccator. This takes about 2-3 hours.

Testing

Liquids

**ALWAYS handle dishes with gloves on

1. Measure and record the weight of each measuring dish, using the enclosed balance
2. Place three 10-15 ml of samples (about 2/3 full) into separate evaporating dishes. Measure the samples with a broken 10 mL pipet.
3. Do not get any sample on the outside of the dish. If it happens, wipe it off quickly
4. Measure and record weight of each sample and dish, using the enclosed balance
5. Place sample into oven at 103-105*C for 24 hours
6. Remove dishes from oven and cool to room temperature in a desiccator which takes about 2-3 hours
7. Measure and record final weight of samples and dishes, using the enclosed balance

Solids

**ALWAYS handle dishes with gloves on

1. Measure and record the weight of each measuring dish, using the enclosed balance
2. Use about 1 gram of sample for each dish
3. Measure and record the weight of each sample and dish, using the enclosed balance
4. Place sample in 103-105°C oven for 24 hours
5. Remove samples from oven and cool to room temperature in a desiccator which takes about 2-3 hours
6. Measure and record the final weight of the sample and dish, using the enclosed balance
7. Repeat steps 4-6 until the weight is within 4% of the last drying cycle

Calculations

% total solids

$$1 - \frac{\text{(initial weight-final weight)}}{\text{initial weight}} \times 100$$

% Moisture

100 – TS

Ammonia , Rapidstill II

Standard Procedure
Standard Method: 4500-NH3 B. Preliminary Distillation Step & 4500-NH3 C. Titrimetric Method

Safety Precautions: When mixing acids, use the fume hood with the front pulled down. Wear a lab coat, safety glasses, and gloves. **Mix small amounts of acid into larger amounts of water not reversed!** Strong acids will burn holes in your clothing and will burn your skin.

Reagents Required

*Label all reagents with their name, date they were made, and your initials

Sodium Tetraborate (0.025M)

1. Measure 9.5 g $Na_2B_4O_7$*10 H_2O in a weigh boat
2. Dilute to 1 L with distilled water in a 1000 ml volumetric flask
3. Add a stir bar to the flask and mix on a stir plate until all the solid is dissolved, it may take 5 to 10 minutes

Borate buffer solution

1. Using a 500 mL volumetric flask, measure 500 mL of 0.025*M* Sodium Tetraborate and put in a 1000 mL volumetric flask.
2. Measure 88 mL 0.1 *N* NaOH by filling a 50 ml volumetric flask with 0.1 N NaOH, then measuring 38 mL with a 10mL pipet. Put into the 1000 mL volumetric flask along with the Sodium Tetraborate.
3. Dilute to 1 L with distilled water
4. Add a stir bar and mix well on a stir plate for approximately 5 minutes

Mixed indicator solution

*Prepare Monthly

1. Measure 20 mg methyl red indicator in a weigh boat and put it into a 100 mL volumetric flask
2. Dissolve in 100 mL 95% Ethyl Alcohol added to the flask.
3. Measure 100 mg methylene blue and put it into a 100 mL volumetric flask.
4. Dissolve in 100 mL 95% Ethyl Alcohol added to the flask.
5. Mix the two 100 mL flask together in a 250 volumetric flask, add a stir bar, and mix well on a stir plate for approximately 5 minutes

Indicating boric acid solution

*Prepare Monthly

1. Measure 20g H_3BO_3 in a weigh boat and add to a 1000 mL volumetric flask.
2. Add approximately 700 mL distilled water to the flask and dissolve the H_3BO_3 with a stir bar and a stir plate, it may take 10 to 15 minutes
3. Add 10 mL mixed indicator solution to the flask
4. Dilute to 1 L with distilled water, add a stir bar and mix well on a stir plate for approximately 5 minutes

Standard sulfuric acid titrant, 0.02N

1. Measure 2.8 mL concentrated Sulfuric Acid with a 10 mL pipet
2. Dilute to 1 L with distilled water in a 1000 mL volumetric flask to make 0.1*N* Sulfuric Acid. Add a stir bar and mix well on a stir plate for 5 to 10 minutes
3. Measure 200 mL 0.1*N* Sulfuric Acid with a 200 mL volumetric flask
4. Pour the 200 mL of 0.1 *N* Sulfuric Acid in a 1000 mL and dilute to 1 L with distilled water.
5. Add a stir bar and mix well on a stir plate for approximately 5 minutes

Sodium Hydroxide (6N)

1. Measure 240g NaOH in a large weigh boat
2. Dilute to 1 L with distilled water in a 1000 mL volumetric flask.
3. Add a stir bar to the flask and mix well on a stir plate until all the solid is dissolved this could take up to 30 minutes.

Distillation Preparation

1. Turn on cooling water by going under the sink and looking way in the back. In the top right corner there is a silver handle. Turn it 45° to the left, allowing water to flow through condenser
2. Depress *Boiler Water* switch, and fill to the top line on the flask (see #10. under distillation procedure)
3. Turn on the *Boiler Heater* by pressing the button
4. When water is at a steady boil, the unit is ready for operation
5. Make sure the NaOH inlet tube located on the left side of the Rapidstill is in a 100 mL graduated cylinder that is full of NaOH.

Manure dilution

20:1 water to manure ratio serial dilution

1. Add 25 mL distilled water to a 50 mL volumetric flask
2. Mix liquid manure for 1 minute at low speed with a drill mixer
3. With a carefully broken 10 mL pipet, fill the flask up to the line with manure sample to ensure there is exactly 25 mL of manure sample
4. Pour the contents of the 50 mL volumetric flask into a 500 mL volumetric flask.
5. Dilute the sample to 500 mL with distilled water

Sample Preparation

75 mL samples, 10:1 water to dilute-manure ratio

1. Mix liquid manure for 1 minute at low speed with drill mixer
2. Extract a 6.815 mL dilute-manure sample, place in a digestion tube
   *break a 10 mL pipet at the correct volume using the proper tools
3. Add 68.15 mL distilled water by filling a 50 mL volumetric flask, adding that to the digestion tube, and then adding the rest (18.15 mL) with a 10 mL pipet

4. Add 3.75 mL borate buffer solution with a 10 mL pipet

Sample Preparation of Known Sample for Calibration

150 mL samples with 100 mg/L NH_3

Manure and 100 mg/L NH_3 Sample

1. Extract a 13.7 mL of mixed sample, place in beaker
2. Add 15.0 mL 1000 mg/L NH_3 solution
3. Add 121.3 mL distilled H_2O
4. Add 7.5 mL borate buffer solution

Distilled H_2O and 100 mg/L NH_3 Sample

1. Place 15.0 mL 1000 mg/L NH_3 solution in a digestion tube using a 10 mL pipet
2. Add 135.0 mL distilled H_2O to the digestion tube by filling a 100 mL volumetric flask first then adding 35 mL with a 10 mL pipet
3. Add 7.5 mL borate buffer solution with a 10 mL pipet

Preparation of Blank Sample

Carry a blank sample through all steps of procedure to use in final calculations.

1. Measure 75 mL distilled H_20 using a 50 mL volumetric flask and a 10 mL pipet for the rest
2. Add 3.75mL borate buffer solution with a 10 mL pipet

Distillation Procedure

1. Open the protective casing, pull down on the bottom lever piece, and place the digestion tube containing the sample in the clamping device.
2. Place a 500 mL Erlenmeyer flask containing 50 mL indicating boric acid solution under the Distillate Outlet tube. Make sure the holes in the tube are completely immersed in liquid.
3. Make sure the boiler is full of water. If not, depress the *Boiler Water* Switch to refill the boiler.
4. Turn the *Boiler Heater* on.
5. Depress *NaOH Addition* button to add 5 mL 6N NaOH solution to the digestion tube according to the graduated cylinder the NaOH is in.

6. When the water reaches boiling begin distillation by setting the timer knob to the desired distilling time.
7. Distill for 20 minutes or until froth reaches the condenser arm
8. Collect distillate in the 500 mL Erlenmeyer flask.
9. Lower the flask so that the end of the outlet tube is free of contact with the liquid and continue distillation during the last minute or two to cleanse condenser and outlet tube.
10. When distillation has completed, the until will return to standby position, with the boiler heater still in operation. DON'T let the boiler stay on, switch the *Boiler Heater* button to the off position
11. Once the boiler is cool, depress *Boiler Water* switch to refill the boiler after each run. If doing additional distillations, turn the boiler heater back on, and the machine is ready when boiling resumes.
12. Run samples in duplicate, if numbers are not in agreement (up to 10%), then run a third sample.

Titration

1. Fill a 50 mL buret with 0.02 *N* H2SO4 and add a stirbar to the 500 mL flask containing the distillate.
2. Titrate, drop wise, the distillate in the flask.
3. Titrate ammonia in distillate with standard sulfuric acid titrant until indicator in distillate turns pale lavender

Calculation

1. Liquid samples: $\text{mg } NH_3\text{-N/L} = \frac{(A - B) \times 280}{\text{mL sample}} \times 20$

2. Sludge or sediment samples: $\text{mg } NH_3\text{-N/kg} = \frac{(A - B) \times 280}{\text{g dry wt sample}} \times 20$

Where:

A = volume of H_2SO_4 titrated for sample, mL
B = volume of H_2SO_4 titrated for blank, mL

Rapidstill II

Routine Maintenance

After Every Day

1. Install a clean, empty digestion tube.
2. Remove caustic, *NaOH* supply tubing from vessel containing *NaOH* and place in vessel of purified water.
3. Turn on cooling water and fill boiler. **Turn on boiler heater**.
4. Depress *NaOH Addition* until all of the caustic *NaOH* has been purged out of the system and into digestion tube.
5. Remove the digestion tube and dispose of the liquid properly.
6. Replace digestion tube and fill half full by depressing *NaOH Addition.*
7. When water is at a rolling boil, turn distillation timer to 10 minutes.
8. At end of distillation cycle, turn off the boiler heater and cooling water.
9. Remove digestion tube and dispose of liquid properly.
10. Clean exterior surfaces of machine using a soft cloth and a mild soap and water solution.

Weekly

1. Examine boiler for any build up of deposits. Accumulated deposits may be removed by a dilute solution of hydrochloric acid, or by using commercially available descaling solutions that are compatible with glass.
2. Examine all plumbing and steam lines, ensuring that the tubing is intact. Examine all tubing connections. Examine the connection stopper for deterioration or cracking.

Total Kjeldahl Nitrogen

Standard Procedure
Standard Method:

Safety Precautions:

1. Equipment should not be used until adequate training has been obtained, and the equipment manuals have been read.
2. Read the MSDS for sulfuric acid, sodium hydroxide, hydrochloric acid and boric acid. There are strong acids and bases (both heated) being used.
3. Wear long pants, lab coat, and close-toed shoes. Safety glasses and various types of gloves should also be worn.
4. This analysis should be conducted when there are other personnel in the area.

Reagents Required:

<u>Note:</u> Unless otherwise stated, prepare solutions in deionized water.
* Label all reagents with their name, date they were made, and your initials

Concentrated Sulfuric Acid (90-98%)

1. Store in the cabinet labeled *Corrosives* underneath the fume hood.
2. When using, place the bottle of acid in a spill tray.

Fishertab Kjeldahl tablets

1. Contains 15 mg Selenium in 1.5 gm K2SO4

Indicator Solution

1. Measure 225 mg of methyl red with a weigh boat using the enclosed balance
2. Measure 83 mg of methylene blue with a weight boat using the enclosed balance
3. Dissolve the methyl red and methylene blue in a 100 mL volumetric flask with 100 mL of 95% ethanol. This may take 10-20 minutes to dissolve.
4. Store the solution in an amber-colored bottle and label

4% Boric Acid

1. Measure 80 gm (500 gm) of powdered boric acid with a large weight boat
2. Slowly add the boric acid to about 1.5 L (10 L) of deionized water and allow the acid to dissolve by using a stir bar and a stir plate (it might take 30 minutes to 1 hour), (several hours for greater amounts)
3. Bring the volume up to **2 L** (12.5 L) with deionized water and continue stirring on the stir plate for 5 to 10 minutes

30% Sodium Hydroxide

1. Measure 750 gm (1800 gm) of dry NaOH using a large weigh boat
2. Slowly add the NaOH to 1.5 to 2 L (~5 L) water and allow the base to dissolved by using a stir bar and a stir plate
3. This is an exothermic reaction, container will get hot!!!

4. Bring the volume up to **2.5 L** (6 L) with deionized water and continue stirring on a stir plate for 5 to 10 minutes

Methyl Red Indicator solution

1. Measure 20 mg of methyl red using a weigh boat
2. Dissolve the methyl red in 60 mL absolute ethanol using a 100 mL volumetric flask. This may take 10-15 minutes.
3. Bring the volume of the solution up to 100 mL by adding 40 mL distilled water, and continue stirring for 5-10 minutes

0.1N Hydrochloric Acid: 1:120 dilution

1. Measure out 12.5 mL (125 mL) of concentrated HCl using a 10 mL pipet.
2. Put ~1 L (10 L) of deionized water in a container and add to it, slowly, the HCl
3. Add a stir bar to the solution and let it mix for 10-15 minutes on a stir plate
4. Bring the volume up to **1.5 L** (15 L) with deionized water and continue stirring

Standardization of Hydrochloric Acid:

1. THAM (Tris(hydroxymethyl)aminomethane) is a primary standard base that will be used to standardized the hydrochloric acid
2. Dry THAM in a desiccator (it should not be subjected to heat greater than 100°C
3. Measure about 0.25 gm or less (record exact weight) of THAM using a weigh boat.
4. Add the THAM to three 125 mL Erlenmeyer flasks and dissolve in about 30 mL distilled water by swirling the mixture
5. Add two drops of the Methyl Red Indicator (will be a yellow color)
6. Titrate the THAM solution to a red color with the HCl solution being standardized using the 25 mL buret.
7. Record the volume of acid required for each flask and calculate the normality of the HCl. Average the normality of the three flasks.

Normality of HCl = (gm THAM x 1000)/(121.1 x mL of HCl)

8. Indicate normality and the date standardized on the label of the *0.1N HCl*

Sample Preparation:

<u>Liquids</u>

1. Mix liquid manure for 1 minute at low speed with a drill mixer
2. Measure the liquid sample with a broken tipped pipet. If the sample is not able to be sucked up with a pipet, treat it as a solid sample.
3. At first we will try a range of sample volumes from 0 to 1.00 mL. Prepare duplicates or triplicates of each sample.
4. To improve accuracy using a 25 mL buret to titrate the ammonia, more than 15 mL of HCl should be used for the titration of each sample.

5. Use at least two blank tubes without sample in a run of 25 digestion tubes. The blanks should contain all reagents, receiving the same treatment as the samples. There will be an indicator color change in the blank. If not, something has gone wrong. Also, if new Boric acid or HCl is made during the day, blanks are needed for the new reagents. Blanks *must* be run everyday.
6. Samples can be weighed into digestion tubes one or more days before digesting if tubes are covered so they do not become contaminated.
7. 0.05-0.06 gm urea or 0.2 gm tryptophan can be used to check the system for complete digestion without loss of nitrogen.

Solids

1. Weight representative sample in a tarred weigh boat and record the weight.
2. Transfer the sample to a digestion tube making sure that everything get to the bottom of the tube. Prepared duplicates or triplicates of each sample.
3. To improve accuracy using a 25 mL buret to titrate the ammonia, more than 15 mL of HCl should be used for the titration of each sample.
4. For solid samples we will first test a range of sample weights from 0 to 1.00 gm
5. Use at least two blank tubes without sample in a run of 25 digestion tubes. The blanks should contain all reagents, receiving the same treatment as the samples. There will be an indicator color change in the blank. If not, something has gone wrong. Also, if new Boric acid or HCl is made during the day, blanks are needed for the new reagents. Blanks *must* be run everyday.
6. Samples can be weighed into digestion tubes one or more days before digesting if tubes are covered so they do not become contaminated.
7. 0.05-0.06 gm urea or 0.2 gm tryptophan can be used to check the system for complete digestion without loss of nitrogen.

Digestion Procedure:

1. Carefully insert the digestion tubes into the holes provided in the flask rack. The flask rack can be used for convenient handling and transportation of the digestion tubes.
2. Add 4 Fishertab Kjeldahl tablets to each digestion tube
3. Carefully add 20 mL of concentrated sulfuric acid using a 10 mL pipet to each tube prior to placing the tubes in the digestion block.
4. Turn the main power switch located on front of controller to ON position. *The digestion block must be totally contained in a chemical fume hood, and must have as much space between the back of it and the back of the hood as possible.* Set temperature to 410°C using temperature dial on control unit. Allow approximately one hour for unit to reach pre-set temperature (digestor is at pre-set temperature when lights located on front of the digestor are flashing).
5. After completing sample and reagent addition to the digestion tubes, carefully elevate the rack by grasping the handles provided and place in position on the digestor unit. As the rack is lifted, each tube will rest on its top rim. Carefully lower the rack so that each tube enters its respective hole and bottoms in the base of the unit.

6. Place end plates on the flask rack. These plates completely close the ends of the flask rack and allow the temperature of the upper portion of the tube to elevate proving for proper refluxing and condensation of the sulfuric acid. (A certain amount of foaming will occur at the beginning of the digestion. The refluxing of the acid washes any carbonized material back into the digestion solution. **If foaming is uncontrollable, reduce digestion temperature and/or sample size.**
7. Digest samples at 410 °C until the acid in the flask is clear, and fumes are contained within the digestion tube, and not thick in appearance. A time of two hours is minimal for complete digestion. The “clearness” of the acid (color and absence of particulate matter) and fume density are indicators for completeness of digestion.
8. After digestion is complete, remove flask rack containing tubes from digestor and place on heat resistant pad. **Wear heat-protective gloves!** Turn heat settings on the digestion block back to zero and turn off power if there is no more digestion runs for the day.
9. With the heat-protective gloves, carefully remove manifolds from the digestion tubs. **Caution:** The manifolds may leak condensed acid and the flask may emit fumes. Carry the manifolds to a sink. Clean manifolds and racks with water and running a lot of water down the drain to dilute the acid.
10. After the tubes containing the digest have cooled to room temperature, slowly add 75 mL of deionized water to each tube, swirling to mix. There may be some fume emissions from the tubes so **be careful**. Dilution must be made before a cake is formed from precipitated salts, but not before the digest is cool enough to contain the exothermic reaction.
11. *Contents in the tubes might turn orange or red-orange. This is common and will not affect results.* This distillation should be performed after water is added. If the tubes cannot be distilled, gently vortex the tubes, cover them with aluminum foil and place in the fume hood.

Setup of the Rapidstill Distillation Unit:

1. Add 70 mL of 4% Boric acid to each of the receiving flasks. Add five drops of Indicator solution (methyl red and methylene blue) to each receiving flask. Swirl to mix. (You can mix the boric acid and indicator solution together prior to putting it into the receiving flask).
2. Turn on cooling tap water by going under the sink and looking way in the back. In the top right corner there is a silver handle. Turn it 45° to the left, allowing water to flow through the condenser. The distillate should be cold as it comes out. The distillation coil should be cold at the bottom and somewhat warm at the top. *Check this flow rate periodically, as the water pressure can vary. If there is inadequate water flow to cool the distillation coil, ammonia will be lost with steam instead of being condensed as a liquid in the receiving flask.*
3. Depress *Boiler Water* switch, and fill to the line on the flask (back of the distillation unit)
4. Turn on the *Boiler Heater* by pressing the button. When water is at a steady boil, the unit is ready for operation

5. Make sure the NaOH inlet tube located on the left side of the Rapidstill is in a 500 mL graduate cylinder that is full of NaOH.

Distillation Procedure:

1. Open the safety screen, pull down on the bottom lever piece, and place the digestion tube containing the digestor sample in the clamping device. Close the safety screen.
2. Place the 500 mL Erlenmeyer receiving flask containing the 70 mL 4% Boric acid and 5 drop Indicator Solution under the Distillate Outlet tube on the front right part of the Rapidstill. Make sure the holes in the tube are completely immersed in liquid.
3. Make sure the boiler is full of water. If not, depress the *Boiler Water* switch to refill the boiler.
4. Turn the *Boiler Heater* on.
5. Depress the *NaOH Addition* button to add 85-90 mL of NaOH per 20 mL of acid used in the digestion. Measure this value according to the graduate cylinder the NaOH is contained in.
6. When the water is boiling nicely, being distillation by setting the timer knob to the desired distillation time.
7. Distill for 20 minutes or until froth reaches the condenser arm. The distillate is collected in the 500 mL Erlenmeyer flask.
8. Lower the flask so that the end of the outlet tube is free of contact with the liquid and continue distillation during the last minute or two to cleanse condenser and outlet tube.
9. When distillation is complete, the Rapidstill will return to standby position, with the boiler heater still in operation. DON'T let the boiler stay on, switch the *Boiler Heater* button to the off position.
10. Once the boiler is cool, depress *Boiler Water* switch to refill the boiler after each run. If doing additional distillations, turn the boiler heater back on, and the machine is ready when boiling resumes.
11. There may be a few mLs of sample left in the tube. Pour the remaining residue into waste container designated for selenium waste. When the container is full or the container has been in the lab for 90 days, the liquid needs to be disposed of through EH&S.

Titration:

1. Before titrating a sample, completely fill the buret with 0.1N HCl and drain to waste enough so the initial reading of the buret can be made. Record initial reading.
2. Place a small stir bar in the receiving flask and place on a stir plate beneath of the buret. Stir gently.
3. Add HCl from the buret and allow the color to change from emerald green to a gray to light purple.
4. Titrate to the graph to light purple endpoint. ***Note:*** *It is easy to overshoot the endpoint. When it takes longer for the green color to reappear, slow the addition of the acid down to one drop at a time. If too much acid is added (darker purple) the sample has been over titrated and is lost.*

5. Refill the buret for the next sample.

Calculations:

$$\%\ \text{Nitrogen in sample} = \frac{\text{Normality of acid x (mL HCl added – mL from blank) x 1.4}}{\text{Sample size}}$$

* Use an average of the replicates of each sample for the final value.

Routine Maintenance/Cleaning:

Digestion

* Clean with a detergent and water solution when the unit is cool.

1. Condensed sulfuric acid will accumulate in the digestion manifold. If acid drop on the digestion block, digestion tubes, support rack, or counter top in the hood, the acid should immediately be wiped up with a wet paper towel.
2. Wipe down outer surfaces of the digestion block. Wipe down hood bench if acid has spilled. Wipe out glass attachments at the end of the aspiration tubes. (Use wet paper towels.)
3. Wipe off metal tops of the racks, and the racks themselves using wet paper towels.

Calibration: The controller has been factory calibrated and should not require re-calibration. In the event re-calibration is required the following procedure should be followed.

1. Insert calibration resistor into the 2-pin sensor connector located on the rear of the control unit.
2. Place ON-OFF switch, located on the controller, to the ON position.
3. Adjust set-point indicator dial to a position where the indicator lights, located on front panel of digestor, are illuminated 50% of the time.
4. Loosen setscrew on set-point indicator dial and align calibration mark on dial with pointer label.
5. The digestor is now calibrated to give digestion temperature indicated on set-point dial.

Distillation

After Every Day

1. Wash digestion/distillation tubes in hot water (no detergent). Use a scrub brush to clean the outside and inside. Rinse 2 or 3 times with hot water. Rinse twice with distilled water. Place in drying oven or on a rack so they will dry.
2. Rinse receiving flasks three times with hot water, and twice with distilled water. Place in dry oven or on a rack so they will dry.
3. Install a clean, empty distillation tube.
4. Remove caustic, *NaOH* supply tubing from vessel containing *NaOH* and place in vessel of purified water.
5. Turn on cooling water and fill boiler. **Turn on boiler heater**.
6. Depress NaOH Addition until all of the caustic NaOH has been purged out of the system and into the digestion tube.
7. Remove the digestion tube and dispose of liquid properly.

8. Replace digestion tube and fill half full by depressing NaOH Addition.
9. When water is at a rolling boil, turn distillation timer to 10 minutes
10. At the end of the distillation cycle, turn off the boiler heater and cooling water. Remove the digestion tube and dispose of liquid properly.
11. Clean exterior surfaces of machine using a soft cloth and a mild soap and water solution.

Weekly

1. Examine boiler for any build up of deposits. Accumulated deposits may be removed by a dilute solution of hydrochloric acid, or by using commercially available descaling solutions that are compatible with glass.
2. Examine all plumbing and steam lines, ensuring that the tubing is intact. Examine all tubing connections. Examine the connection stopper for deterioration or cracking.

Appendix T: Maintenance Checklist

Southeastern Broiler Emissions Project Between Flock Requirements Checklist

House I.D.______________ Date ____________ Incoming Flock No. __________

☐ Clean screens and replace filters on the gas sample line intakes

☐ Check air flow rate in sample lines and solenoid valves

☐ Replace TEOM filters and exchange TEOM inlet heads and 2.5 micron cut cyclones

☐ Leak test the TEOMs after all other maintenance has been performed on them

☐ Instrument Calibration/Verification

____ INNOVA for NH_3

____ API for H_2S

____ VIG for NMH

____ Polytron I

☐ Check all solenoid valves (ON/OFF)

☐ Perform a system check on fan operational status and monitoring

☐ Check airflow rate at 20% of the exhaust fans (randomly selected)

☐ Replace any critical spare parts utilized during the previous flock

☐ Collect copies of calibration and event log sheets from previous flock and submit to Lara Moody for archiving.

☐ Collect litter samples and deliver to ISU for analysis

Checklists of needed items for between flock audits

Item	Quantity	In stock
Inclined Manometer (red liquid)	1	
Setra 264 sensor (New)	1	
Humidity sensor (New + calibrator)	2	
24 VDC power supply	1	
Barometric sensor (calibrated)	1	
4-20 mA HOBO cable	2	
4-Channel HOBO logger	1	
Thermometer (-8 to 50 oC) (NIST) (LEAP lab?)	1	
Cooler (1-2 Gal)	2	
Pump (10 LPM)	1	
Tubing 1/8” ID	10 feet	
TEE (1/4 “ OD)	1	
Valve (ball)	1	
Box with adjustable open (cardboard) -Setra 264 calibration	1	
Solt (Li Cl and Na Cl)	500 gm	
Distilled water	1	
Clean syringe (0-10mL)	2	
Wide mouth bottle (changeable cover)?	2B + 4 C	
Ruler (for TEOM)	1	
Fitting box (Screw drivers, Hex drivers)	1	
Electrical BOX	1	
Coverall and sprinkler (disinfect)	1	
30 ft power extension cord	4	
cFP + crossover cable	1	
Dilutor+ manual	1	
H2S gas + regulator	1	
Manuals and checklist (TEOM, INNOVA)		
Power tool + drill bits	1	

☐ **Thermocouple Check (Unit: °C)**

Time	**Location**	**Temp 1/Standard**	**Temp 2/Standard**	**Temp 3/Standard**

☐ **Check air flow rate in sample lines and solenoid valve**

Time	Temp., °C	Location	Flow rate, LPM	Valve
		SW1		
		SW3		
		Tunnel		
		Ambient		

☐ **Gal-gas injection from sampling port**

Time	Temp., °C	Location	Flow rate, LPM	NH_3 Concentration, ppm
		SW1		
		SW3		
		Tunnel		
		Ambient		

☐ **Leak test the TEOMs**

Time	**Temp., °C**	**Location**	**TEOM SN**	**Main Flow rate, LPM**	**Aux Flow rate, LPM**

☐ **API 101 E check**

Time	Items	Unit =	Notes
	Ambient pressure, (mm Hg)		
: :	Sample airflow (L/min)		
: :	Zero air applied	---	Cylinder P: ___ psi
: :	H_2S Reading		
: :	H_2S (______ ppb) applied	---	Cylinder P: ___ psi
: :	H_2S Reading		
: :	New Calibration	Yes/No	
: :	Zero air applied		
: :	H_2S applied (______ ppb)		
: :	Finish calibration	Yes/No	
: :	Time switch off	---	
: :	Connect analyzer back to sampling system.		
Note:			

☐ **Polytro I Calibration**

Time	Items	Unit =	Notes
	Ambient pressure, (mm Hg)		
: :	Sample airflow (L/min)		
: :	Zero air applied	---	Cylinder P: ___ psi
: :	H_2S Reading		Calibration
: :	H_2S (______ ppb) applied	---	Cylinder P: ___ psi
: :	H_2S Reading		Calibration
: :	New Calibration	Yes/No	Calibration
: :	Finish calibration	Yes/No	
: :	Time switch off	---	
: :	Connect analyzer back to sampling system.		
Note:			

Innova check Time	Items	Unit =	Notes
	Ambient pressure, (mm Hg)		
: :	Sample airflow (L/min)		
: :	Zero air applied	---	Cylinder P: ___ psi
: :	NH_3 Reading		
: :	CO_2 Reading		
	N_2O Reading		
	CH_4 Reading		
	Propane Reading		
: :	CO_2 (______ ppm) applied (With Nafion Tubing)	---	Cylinder P: ___ psi
: :	CO_2 Reading		
: :	NH_3 (______ ppm) applied	---	Cylinder P: ___ psi
: :	NH_3 Reading		
: :	CH_4 (______ ppm) applied	---	Cylinder P: ___ psi
	CH_4 Reading		
: :	Propane (______ ppm) applied	---	Cylinder P: ___ psi
	Propane Reading		
: :	N_2O (______ ppm) applied	---	Cylinder P: ___ psi
	N_2O Reading		
: :	New Calibration	Yes/No	
: :	Zero air applied		
: :	Zero humidity air applied		
: :	NH_3 applied		
: :	CO_2 applied (With Nafion Tubing)		
: :	Propane applied		
: :	CH_4 applied		
: :	N_2O applied		
: :	Download to Bank	Yes/No	
: :	Time switch off	---	
: :	Connect analyzer back to sampling system.		
Note:			

☐ **VIG 200 check**

Time	Items	Unit =	Notes
	Ambient pressure, (mm Hg)		
: :	Sample airflow (L/min)		
: :	Zero air applied	---	Cylinder P: ___ psi
: :	Total Reading		
: :	CH$_4$ Reading		
: :	Propane Reading		
: :	CH$_4$ (______ ppm) applied	---	Cylinder P: ___ psi
	CH$_4$ Reading		
: :	Propane (______ ppm) applied	---	Cylinder P: ___ psi
	Propane Reading		
: :	New Calibration	$^{\text{Yes}}/_{\text{No}}$	
: :	Zero air applied		
	Total adjustment: CH$_4$ adjustment: Propane adjustment:		
	Total Reading: CH$_4$ Reading: Propane Reading:		
: :	CH$_4$ applied		
	Total adjustment: CH$_4$ adjustment: Propane adjustment:		
	Total Reading: CH$_4$ Reading: Propane Reading:		
: :	Propane applied		
	Total adjustment: CH$_4$ adjustment: Propane adjustment:		
	Total Reading: CH$_4$ Reading: Propane Reading:		
: :	Finish calibration	$^{\text{Yes}}/_{\text{No}}$	
: :	Time switch off	---	
: :	Connect analyzer back to sampling system.		
Note:			

☐ **Check all solenoid valves (ON/OFF)**

SV#	NO1	NC1	NO2	NC2	NO3	NC3	NO4	NC4

☐ **Fan current switch check**

Fan #	SW1	SW2	SW3	SW4	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10

☐ **Check airflow rate at 20% of the exhaust fans (randomly selected)**

Fan #	Flow rate, cfm (previous calibration)				Flow rate, cfm				Diff, %
	0.04”	0.08”	0.12”	0.16”	0.04”	0.08”	0.12”	0.16”	

☐ **Replace any critical spare parts utilized during the previous flock**

Part	**Description**	**Note**

☐ **Collect copies of calibration and event log sheets from previous flock and submit to Lara Moody for archiving.**

☐ **Collect litter samples and deliver to ISU for analysis**

Appendix U: Monitoring Equipment Specifics

1. INNOVA 1412 Photoacoustic Field Gas-Monitor

Product Data

1412 Photoacoustic Field Gas-Monitor

USES:

- Indoor Air Quality measurements
- Ventilation measurements using tracer-gas
- Occupational Health and Safety measurements – of possible production or accumulation of toxic/carcinogenic substances in working areas
- Monitoring of anaesthetic agents in hospitals
- Emission monitoring of greenhouse gases from agricultural production
- Emission monitoring of exhaust from chemical processes

FEATURES:

- Selectively measures a wide range of gases/vapours
- Linear response over a wide dynamic range
- High stability (low drift) makes calibration only necessary 1-2 times a year
- Extremely reliable due to self-testing procedures
- User-friendly procedures for calibrating the monitor, presenting and analysing measurement data via the PC user-interface
- Accurate – compensates for temperature and pressure fluctuations, water-vapour interference and interference from other known gases
- Extremely low-volume flushing possible
- Operates immediately – no warm-up time necessary
- Presents measurement data via connected PC both in tabular and graphic formats – up to 5 gas concentration and water vapour graphs displayed, simultaneously

Introduction

The 1412 Photoacoustic Field Gas-Monitor is a highly accurate, reliable and stable quantitative gas monitoring system. It uses a measurement system based on the photoacoustic infra-red detection method, and is capable of measuring almost any gas that absorbs infra-red light.

Gas selectivity is achieved through the use of optical filters. By installing up to 5 of these filters in the 1412, it can measure the concentration of up to 5 component gases and water vapour in any air sample. Although the detection limit is gas-dependent, it is typically in the ppb region. The accuracy of these measurements is ensured by the 1412's ability to compensate for temperature and pressure fluctuations, water-vapour interference and interference from other gases known to be present. Reliability of measurement results can be ensured by regular self-tests, which the 1412 performs. By the nature of this measurement system, it requires no consumables and very little regular maintenance, for example for most applications recalibration is only necessary 1-2 times a year.

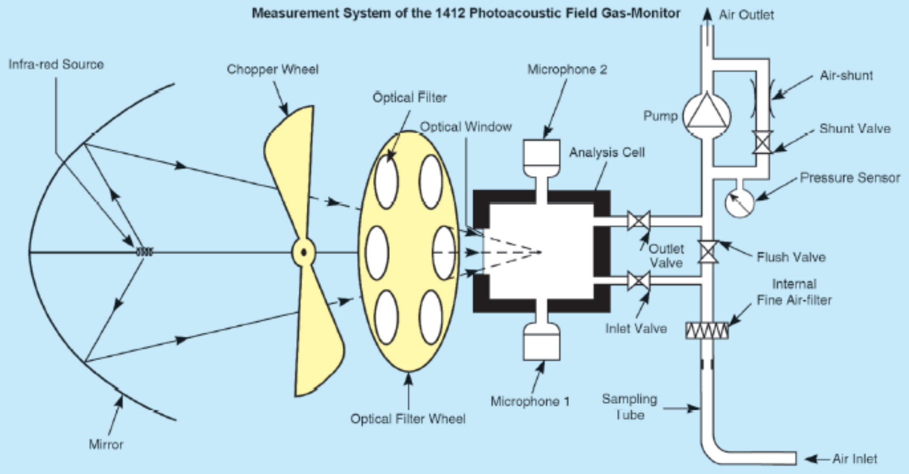
The monitoring system is easily operated through either of the two user interfaces: the front panel with its push-buttons and display providing short explanatory texts, or the PC Software, with its graphical interface. Both interfaces enable the monitor to be set-up, a measurement sequence started and the resulting concentration values of the specified gases viewed while monitoring.

The monitor is equipped with 2 standard interfaces: IEEE-488 and RS-232. These enable the monitor to be integrated into automated process systems. The 1412 has a built-in pump system that allows samples to be drawn from up to 50 m away.

Selectivity

The gas selectivity of the 1412 is determined by the optical filters installed in its filter wheel.

Because water is nearly always present in ambient air and absorbs infra-red light at most wavelengths, it contributes to the total acoustic signal in the analysis cell. Therefore, the monitor is permanently



Measurement System of the 1412 Photoacoustic Field Gas-Monitor

Measurement Cycle

1. The pump draws air from the sampling point through the air-filter to flush out the "old" air in the measurement system and replace it with a "new" air sample. The pressure sensor is used to check that the pump sequence is elapsed successfully and to measure the actual air-pressure.
2. The "new" air sample is hermetically sealed in the analysis cell by closing the inlet and outlet valves.
3. Light from an infra-red light source is reflected off a mirror, passed through a mechanical chopper, which pulsates it, and then through one of the optical filters in the filter wheel.
4. The gas being monitored, causing the temperature of the gas to increase selectively absorbs the light transmitted by the optical filter. Because the light pulsating, the gas temperature increases and decreases, causing an equivalent increase and decrease in the pressure of the gas (an acoustic signal) in the closed cell.
5. Two microphones mounted in the cell wall measure this acoustic signal, which is directly proportional to the concentration of the monitored gas present in the cell.
6. The filter wheel turns so that light is transmitted through the next optical filter, and the new signal is measured. The number of times this is repeated is dependent upon the number of gases being measured.
7. The response time is down to approx. 13 sec. for one gas or water vapour, or approx. 40 sec. if 5 gases and water vapour are measured.

fitted with a special filter, which measures water vapour and enables the 1412 to compensate for watervapour's interference. By selecting different filters, this technique can also be used to cross-compensate for known interferent gases.

Calibration

After the relevant optical filters are installed, the monitor must be calibrated. This is achieved through easy-to-use menudriven instructions. With its high stability, calibration of the 1412, is seldom necessary more than once a year.

Calibration is performed using either the PC Software or directly from the front panel.

Operation

The 1412 monitoring system is easy to operate using either the PC Software or the frontpanel push-keys (which can be locked and accessed at 3 levels using passwords). The monitor can be operated as both an on-line and off-line instrument. Using these user-interfaces with their logical division of information, everything that needs to be defined is achieved prior to starting the monitoring task.

Setting-up the Monitor

The Set-up option enables all the parameters necessary to complete the monitoring task to be defined.

Within this option, the Sample Integration Times (S.I.T.) is set - enabling measurement results to be weighted - sensitivity against speed.

Starting Measurements

Once the set-up parameters have been defined, measurements can be started either immediately or later using a delayed start time. Once started, the monitoring task then continues until it is stopped either manually or using a defined stop time.

Alarms

When measuring, two Alarm trigger levels, which provide high alarm limit 1 and 2 for each measured gas, can be defined. These can also be linked to audible alarms.

Measurement Results

On-line Measurements

Using one or more of the monitor's standard interfaces, measurement results are transferred directly to a PC or control console. Here they can be displayed on screen as real-time values in tables and graphs (see Fig. 1) or integrated into the process system.

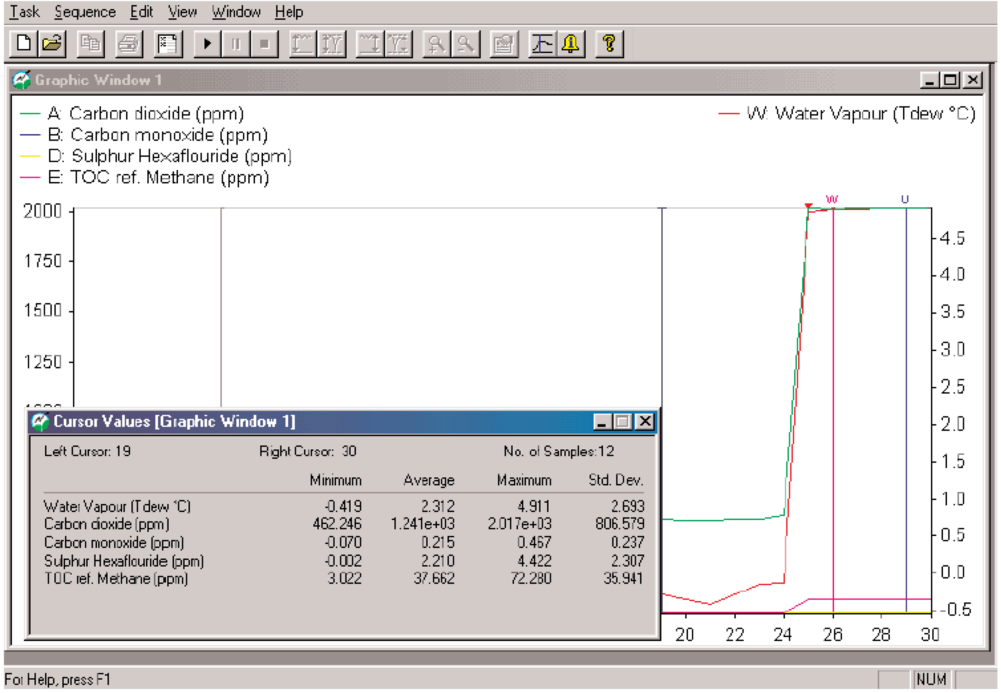
In the PC Software, the graphs can be set up to display only the desired gases, defined concentration ranges and results from statistical analysis.

Also, when using the PC Software, all measurement data is stored in user-defined databases, in a MS-Access format.

Off-line Measurements

Gas-measurement result data is displayed on the 1412's screen (Display Memory) as soon as it is available, and is constantly updated. During a task, the 1412 performs running statistical analysis of the measured gas concentrations, calculating a variety of values for each monitored gas.

The data in Display Memory can be copied to the Background Memory, which is a non-volatile storage area. Data stored in Background Memory can be recalled to Display Memory. From this memory, data can, if necessary, be uploaded to the PC Software and printed out in a list form on any standard text printer via the 1412's IEEE and RS-232 interfaces.



Left Cursor: 19 Right Cursor: 30 No. of Samples: 12

	Minimum	Average	Maximum	Std. Dev.
Water Vapour (Tdew °C)	-0.419	2.312	4.911	2.693
Carbon dioxide (ppm)	462.246	1.241e+03	2.017e+03	806.579
Carbon monoxide (ppm)	-0.070	0.215	0.467	0.237
Sulphur Hexaflouride (ppm)	-0.002	2.210	4.422	2.307
TOC ref. Methane (ppm)	3.022	37.662	72.280	35.941

Fig.1 Displaying detailed measurement data using the cursors in the graphic or table windows

Reliability

Executive selftest check: software, data integrity, and the 1412's components, to ensure that they function properly. If a fault is found, it is reported in the measurement results, so that the integrity of the results can be ensured.

If the power-supply fails, the 1412 will automatically start-up again when power is restored. Measurement data stored in the monitor's memory is not affected.

Maintenance

The only maintenance tasks necessary are calibration and changing the air-filter. Both tasks are easily performed, and the frequency for changing the air-filter depends on the individual applications.

Remote Control Options

Innova AirTech Instruments offers two additional application software programs, the 7300 Application Software and the 7620 Application Software.

Using 7300, a computer can remotely control a 1412 together with one 1309 Multipoint Sampler for sequentially monitoring air-samples from up to 12 locations.

Using the 7620, a computer can control a 1412 together with up to two 1303 Multipoint Sampler and Doser units. This enables up to 12 locations to be dosed with a tracer-gas and air-samples to be drawn from each location for analysis by the 1412. The software uses the resultant measurements to calculate the air-change or ventilation efficiency of each location.

Ordering Information

1412 Photoacoustic Field Gas-Monitor

Optical filters necessary for the user's monitoring task can be ordered together with the 1412, and installed by *INNOVA*. The 1412 is then delivered zero-point and humidity interference calibrated.

Includes following accessories

AT 2177	PTFE tubing
Mains cable	
WL 0945	RS-232 Interface cable (9pin–25pin) null-modem included

PC Software for Photoacoustic Field Gas-Monitor
Instruction Manual (CD Rom)

Optional Accessories

The 1412 can be span-calibrated for certain gases (option UA 1098) — contact your local *INNOVA* representative for details of the gases for which this can be done.

QA 0164	Tweezers

27 optical filters:
UA 0968 – UA 0989 and

UA 0936	Optical Filters
UA 6008	Optical Filter
UA 6009	Optical Filter
UA 6010	Optical Filter
UA 6016	Optical Filter
UA 1098	Span Calibration
UD 5037	Nafion (copolymer of TFE & fluorosuphonyl monomer) tubing

AO 0265	IEEE–IEEE Interface cable
AO 0264	IEEE–IEC 625 Interface cable
WL 0946	RS-232 Interface cable (25pin–25pin) null-modem included
JP 0600	6-pin DIN plug (male) with locking collar for alarm relay
AF 0614	PTFE tubing
UA 1357A	Genie Membrane separator
1303	Multipoint Sampler and Doser
1309	Multipoint Sampler
7300	Application Software
7620	Application Software
BA 6011	Instruction Manual (Printed)

Innova AirTech Instruments A/S reserves the right to change specifications and accessories without notice

Specifications 1412

MEASUREMENT TECHNIQUE:
Photoacoustic infra-red spectroscopy.

Your local *INNOVA* representative will assist in the selection of suitable optical filters. Details are provided in the Gas Detection Limits chart.

RESPONSE TIME:
Is dependent on the Sample Integration Time (S.I.T.) and the flushing time defined. The fastest response time for one gas is 13s and for 5 gases and water vapour 40s. Please see the examples below:

MEASUREMENT SPECIFICATIONS:•

Monitor Set-up	Response Times
S.I.T.: "Normal" (5s) Flushing: Auto, (Tube 1m)	One gas: ~25s 5 gases + water: ~75s
S.I.T.: "Fast" (1s) Flushing: Tube "OFF" Chamber 4s	One gas: ~15s 5 gases + water: ~45s

Detection Limit: Gas-dependent, but typically in the ppb region. Using the Gas Detection Limits chart, the detection limit for a selected sample integration time (S.I.T.) can be calculated.
Dynamic Range: Typically 4 orders of magnitude (i.e. 10.000 times the detection limit at 5 S.I.T.). Using two span concentrations it can be expanded to 5 orders of magnitude.
Zero Drift: Typically ± Detection limit♣ per 3 months•.
Influence of temperature♦: ±10% of detection limit♣/°C.
Influence of pressure♥: ±0.5% of detection limit♣/mbar.
Repeatability: 1% of measured value•
Range Drift: ± 2.5% of measured value per 3 months•.
Influence of temperature♦: ± 0.3% of measured value/°C.
Influence of pressure♥: – 0.01% of measured value/mbar.
Reference conditions:
- Measured at 20°C, 1013 mbar, and relative humidity (RH): 60%. (A concentration of 100x detection limit♣ was used in determining these specifications.)

♦ Measured at 1013 mbar, and RH: 60%.
♥ Measured at 20°C and RH: 60%.
♣ Detection limit is @5s S.I.T.

Interference:
The 1412 automatically compensates for temperature and pressure fluctuations in its analysis cell, and can compensate for water vapour in the air sample. If an optical filter is installed to measure a known interferent the 1412 can cross-compensate for the interferent.
Acoustic Sensitivity: not influenced by external sound.
Vibration Sensitivity: strong vibrations at 20Hz can affect the detection limit.

INTERNAL DATA STORAGE CAPACITY:
Dependent on the number of gases being measured. Sufficient for a 12-day monitoring task, monitoring 5 gases and water vapour every 10min.

GENERAL:
Pumping Rate: 30cm³/s (flushing sampling tube) and 5cm³/s (flushing measurement chamber).
Power Requirement: 100 - 240VAC, 50 – 60Hz.
Complies with IEC536 Class 1 Safety Standards.
Power Consumption: ~120VA.

Air Volume per sample:

Flushing Settings	Volume of Air
Auto: Tube Length: 1m	140cm³/sample
Fixed Time: Chamber 2s, Tube 3s	100cm³/sample
Fixed Time: Chamber 2s, Tube "OFF"	10cm³/sample

Alarm Relay Socket: for connection to one or two alarm relays (visual/audio). Alarm levels for each gas are user-defined. Max. 25VDC, max. 100mA.
Back-up Battery: 3V lithium battery, life-time 5 years. This protects data stored in memory, and powers the internal clock.

Dimensions:
Height: 175 mm (6.9 in).
Width: 395 mm (15.6 in).
Depth: 300 mm (11.8 in).
Weight: 9 kg (19.8lbs).

COMMUNICATION:
The monitor has 2 interfaces: IEEE 488 and RS-232. These are used for data exchange and remote control of the 1412. The PC Software communicates using the RS-232 interface.

PC SOFTWARE REQUIREMENTS:
Hardware:
A Pentium (166MHz) processor or better.
Min. 64MB of RAM (depending on Op Sys.).
Min. 40MB of space available on the hard disk.
One RS–232 port.
Software:
Windows 98, 2000 (min. SP1),
NT 4.0 (min. SP4).

WARNING!
The 1412 must not be placed in areas with flammable gases/vapours in explosive concentrations, or be used to monitor explosive concentrations of these. Also, monitoring of certain aggressive gases, or a very high concentration of water vapour, could damage the 1412. Ask your local INNOVA representative for further information.

COMPLIANCE WITH STANDARDS:

CE	CE-mark indicates compliance with: EMC Directive and Low Voltage Directive. UL-mark indicates compliance with: UL Standards.
Safety	EN/IEC 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use. UL 3101–1: Safety requirements for electrical equipment for laboratory use. CAN/CSA–C22.2 No. 1010.1–92: Safety requirements for equipment for measurement, control and laboratory use.
EMC	EN 50270:1999. Emission and immunity requirements for electrical apparatus for the detection and measurement of combustible gases, toxic gases, or oxygen. Emission for type 1 and immunity for type 2. EN 50081–1:1992. Generic emission standard. Part 1: Residential, commercial and light industry. EN 61000/–4-2: Immunity requirements for electrostatic discharge. EN 61000/–4-3: Immunity requirements for radiated electromagnetic field. ENV 50204/–4-4,4-5,4-6,4-8,4-11: Immunity requirements for radiated electromagnetic field. FCC Class B limits.
Temperature	IEC68–2-1 & IEC68–2-2: Environmental Testing. Cold and Dry Heat. Operating Temperature: + 5°C to + 40°C (+41°F to +104°F). Storage Temperature: –25°C to +55°C (–13°F to +131°F).
Humidity	IEC 68–2-3: 90% RH (non-condensing at 30°C).

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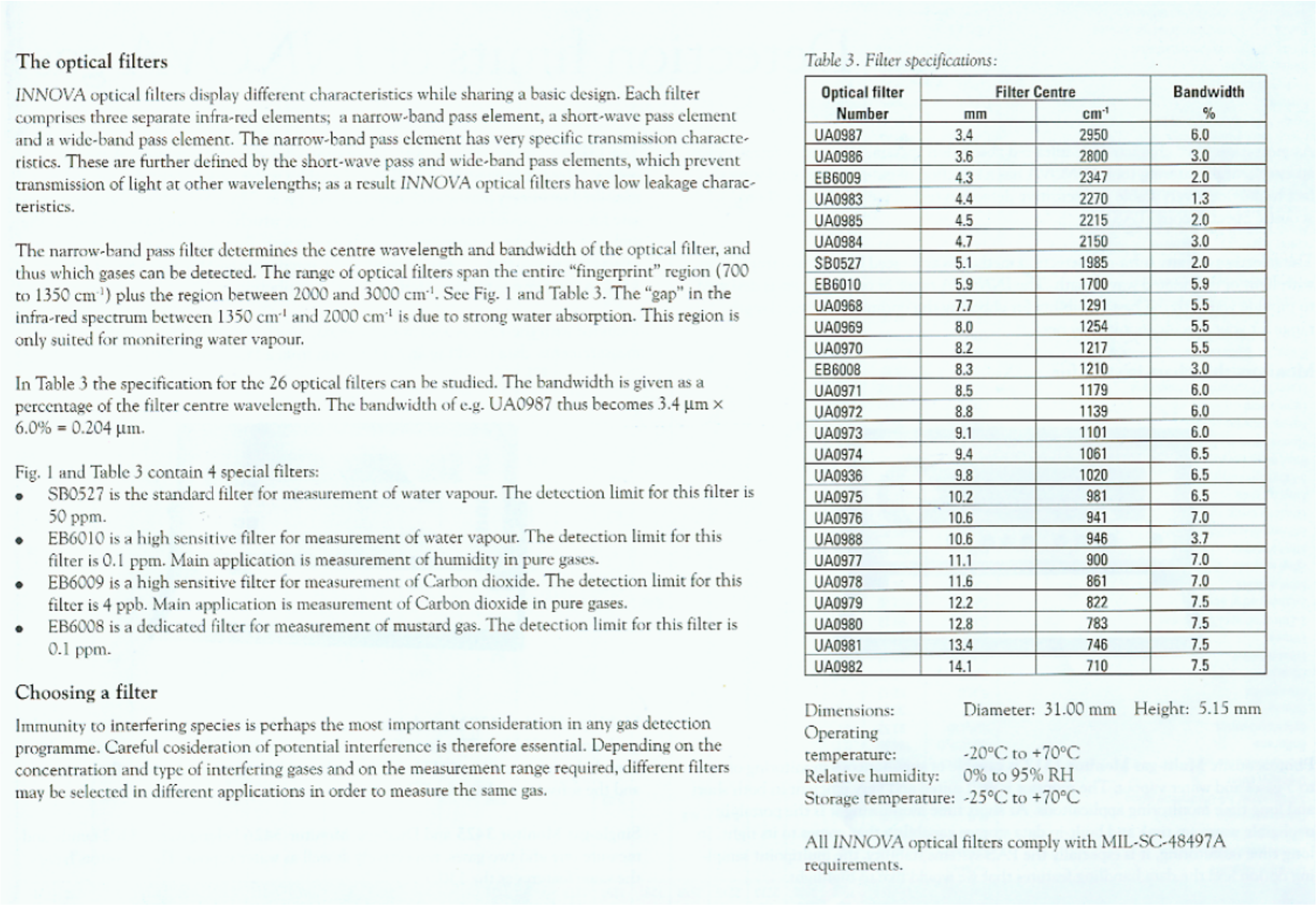
please call +45 44 20 01 00, or visit our homepage on the Internet at www.innova.dk.

2. Optical Filters for INNOVA 1412



The optical filters

INNOVA optical filters display different characteristics while sharing a basic design. Each filter comprises three separate infra-red elements; a narrow-band pass element, a short-wave pass element and a wide-band pass element. The narrow-band pass element has very specific transmission characteristics. These are further defined by the short-wave pass and wide-band pass elements, which prevent transmission of light at other wavelengths; as a result *INNOVA* optical filters have low leakage characteristics.

The narrow-band pass filter determines the centre wavelength and bandwidth of the optical filter, and thus which gases can be detected. The range of optical filters span the entire "fingerprint" region (700 to 1350 cm^{-1}) plus the region between 2000 and 3000 cm^{-1}. See Fig. 1 and Table 3. The "gap" in the infra-red spectrum between 1350 cm^{-1} and 2000 cm^{-1} is due to strong water absorption. This region is only suited for monitering water vapour.

In Table 3 the specification for the 26 optical filters can be studied. The bandwidth is given as a percentage of the filter centre wavelength. The bandwidth of e.g. UA0987 thus becomes 3.4 µm × 6.0% = 0.204 µm.

Fig. 1 and Table 3 contain 4 special filters:

- SB0527 is the standard filter for measurement of water vapour. The detection limit for this filter is 50 ppm.
- EB6010 is a high sensitive filter for measurement of water vapour. The detection limit for this filter is 0.1 ppm. Main application is measurement of humidity in pure gases.
- EB6009 is a high sensitive filter for measurement of Carbon dioxide. The detection limit for this filter is 4 ppb. Main application is measurement of Carbon dioxide in pure gases.
- EB6008 is a dedicated filter for measurement of mustard gas. The detection limit for this filter is 0.1 ppm.

Choosing a filter

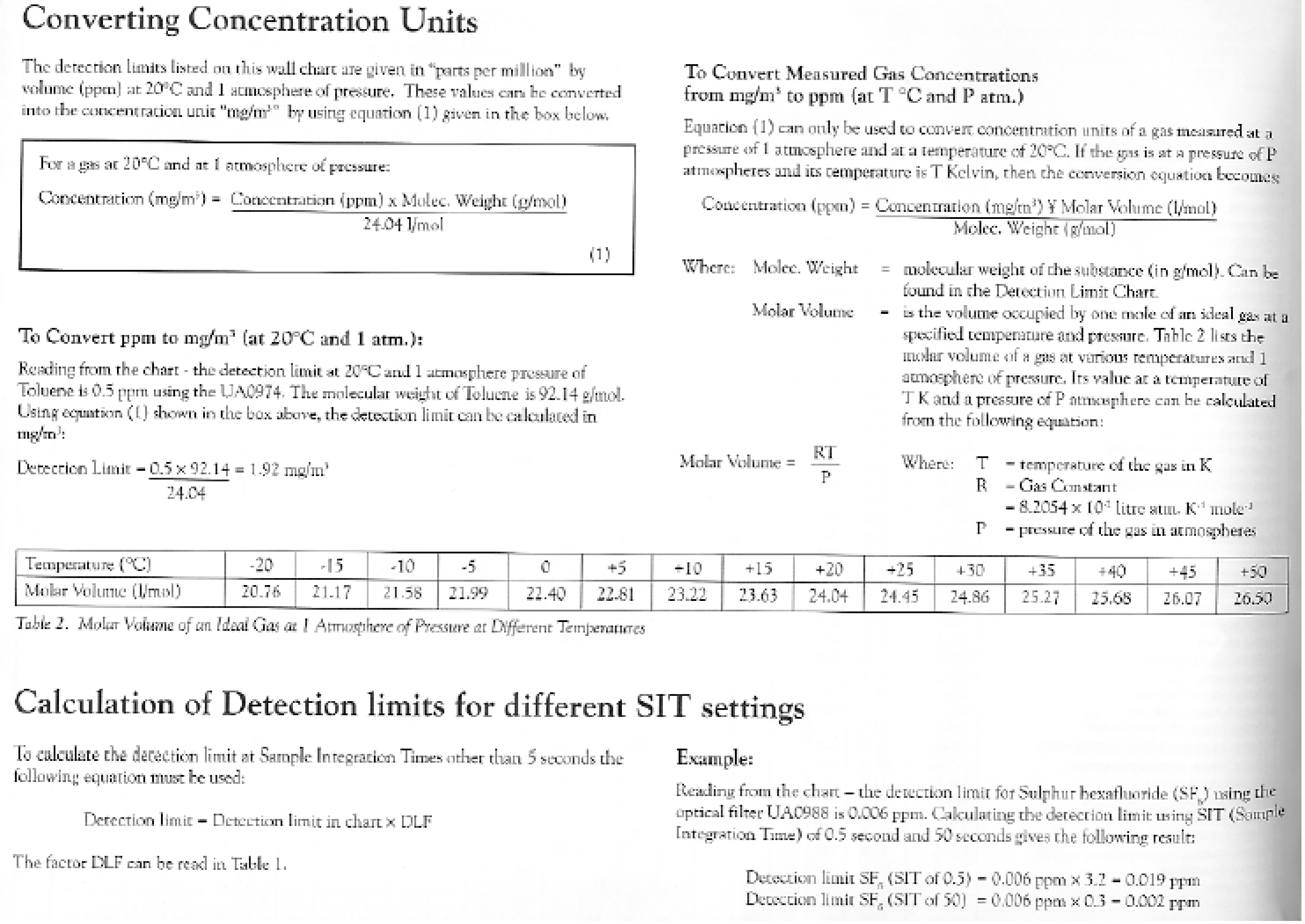
Immunity to interfering species is perhaps the most important consideration in any gas detection programme. Careful cosideration of potential interference is therefore essential. Depending on the concentration and type of interfering gases and on the measurement range required, different filters may be selected in different applications in order to measure the same gas.

Table 3. Filter specifications:

Optical filter Number	Filter Centre		Bandwidth
	mm	cm^{-1}	%
UA0987	3.4	2950	6.0
UA0986	3.6	2800	3.0
EB6009	4.3	2347	2.0
UA0983	4.4	2270	1.3
UA0985	4.5	2215	2.0
UA0984	4.7	2150	3.0
SB0527	5.1	1985	2.0
EB6010	5.9	1700	5.9
UA0968	7.7	1291	5.5
UA0969	8.0	1254	5.5
UA0970	8.2	1217	5.5
EB6008	8.3	1210	3.0
UA0971	8.5	1179	6.0
UA0972	8.8	1139	6.0
UA0973	9.1	1101	6.0
UA0974	9.4	1061	6.5
UA0936	9.8	1020	6.5
UA0975	10.2	981	6.5
UA0976	10.6	941	7.0
UA0988	10.6	946	3.7
UA0977	11.1	900	7.0
UA0978	11.6	861	7.0
UA0979	12.2	822	7.5
UA0980	12.8	783	7.5
UA0981	13.4	746	7.5
UA0982	14.1	710	7.5

Dimensions:	Diameter: 31.00 mm Height: 5.15 mm
Operating temperature:	-20°C to +70°C
Relative humidity:	0% to 95% RH
Storage temperature:	-25°C to +70°C

All *INNOVA* optical filters comply with MIL-SC-48497A requirements.



Converting Concentration Units

The detection limits listed on this wall chart are given in "parts per million" by volume (ppm) at 20°C and 1 atmosphere of pressure. These values can be converted into the concentration unit "mg/m³" by using equation (1) given in the box below.

For a gas at 20°C and at 1 atmosphere of pressure:

$$\text{Concentration (mg/m}^3\text{)} = \frac{\text{Concentration (ppm)} \times \text{Molec. Weight (g/mol)}}{24.04\ \text{l/mol}} \qquad (1)$$

To Convert ppm to mg/m³ (at 20°C and 1 atm.):

Reading from the chart - the detection limit at 20°C and 1 atmosphere pressure of Toluene is 0.5 ppm using the UA0974. The molecular weight of Toluene is 92.14 g/mol. Using equation (1) shown in the box above, the detection limit can be calculated in mg/m³:

$$\text{Detection Limit} = \frac{0.5 \times 92.14}{24.04} = 1.92\ \text{mg/m}^3$$

To Convert Measured Gas Concentrations from mg/m³ to ppm (at T °C and P atm.)

Equation (1) can only be used to convert concentration units of a gas measured at a pressure of 1 atmosphere and at a temperature of 20°C. If the gas is at a pressure of P atmospheres and its temperature is T Kelvin, then the conversion equation becomes:

$$\text{Concentration (ppm)} = \frac{\text{Concentration (mg/m}^3\text{) ¥ Molar Volume (l/mol)}}{\text{Molec. Weight (g/mol)}}$$

Where: Molec. Weight = molecular weight of the substance (in g/mol). Can be found in the Detection Limit Chart.

Molar Volume = is the volume occupied by one mole of an ideal gas at a specified temperature and pressure. Table 2 lists the molar volume of a gas at various temperatures and 1 atmosphere of pressure. Its value at a temperature of T K and a pressure of P atmosphere can be calculated from the following equation:

$$\text{Molar Volume} = \frac{RT}{P}$$

Where:
T = temperature of the gas in K
R = Gas Constant
= 8.2054×10^{-2} litre atm. K^{-1} $mole^{-1}$
P = pressure of the gas in atmospheres

Temperature (°C)	-20	-15	-10	-5	0	+5	+10	+15	+20	+25	+30	+35	+40	+45	+50
Molar Volume (l/mol)	20.76	21.17	21.58	21.99	22.40	22.81	23.22	23.63	24.04	24.45	24.86	25.27	25.68	26.07	26.50

Table 2. Molar Volume of an Ideal Gas at 1 Atmosphere of Pressure at Different Temperatures

Calculation of Detection limits for different SIT settings

To calculate the detection limit at Sample Integration Times other than 5 seconds the following equation must be used:

Detection limit = Detection limit in chart × DLF

The factor DLF can be read in Table 1.

Example:

Reading from the chart – the detection limit for Sulphur hexafluoride (SF_6) using the optical filter UA0988 is 0.006 ppm. Calculating the detection limit using SIT (Sample Integration Time) of 0.5 second and 50 seconds gives the following result:

Detection limit SF_6 (SIT of 0.5) = 0.006 ppm × 3.2 = 0.019 ppm
Detection limit SF_6 (SIT of 50) = 0.006 ppm × 0.3 = 0.002 ppm

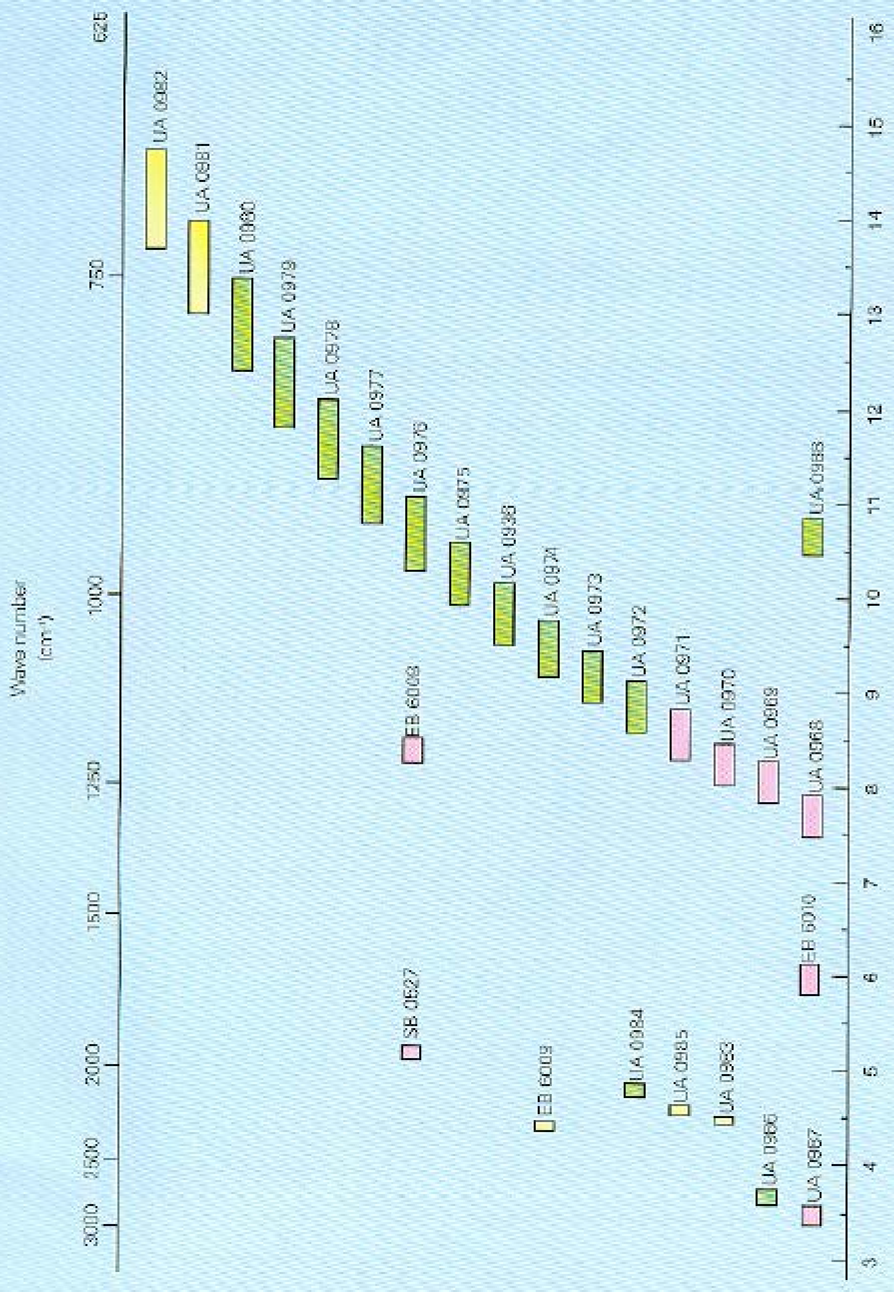
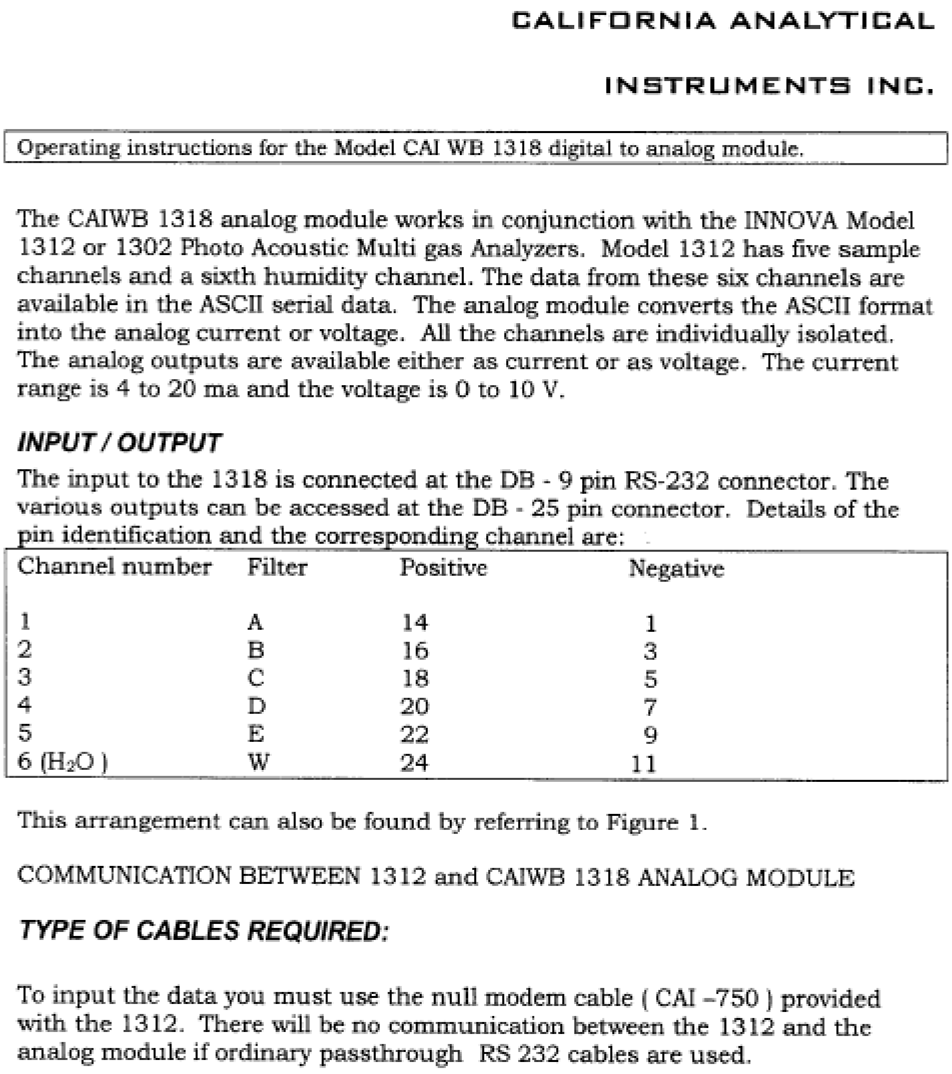


Fig. 1 Centre Wavelengths and Half-power Bandwidths of the INNOVA Optical Filters

3. California Analytical Digital to Analog Module for INNOVA



CALIFORNIA ANALYTICAL

INSTRUMENTS INC.

Operating instructions for the Model CAI WB 1318 digital to analog module.

The CAIWB 1318 analog module works in conjunction with the INNOVA Model 1312 or 1302 Photo Acoustic Multi gas Analyzers. Model 1312 has five sample channels and a sixth humidity channel. The data from these six channels are available in the ASCII serial data. The analog module converts the ASCII format into the analog current or voltage. All the channels are individually isolated. The analog outputs are available either as current or as voltage. The current range is 4 to 20 ma and the voltage is 0 to 10 V.

INPUT / OUTPUT

The input to the 1318 is connected at the DB - 9 pin RS-232 connector. The various outputs can be accessed at the DB - 25 pin connector. Details of the pin identification and the corresponding channel are:

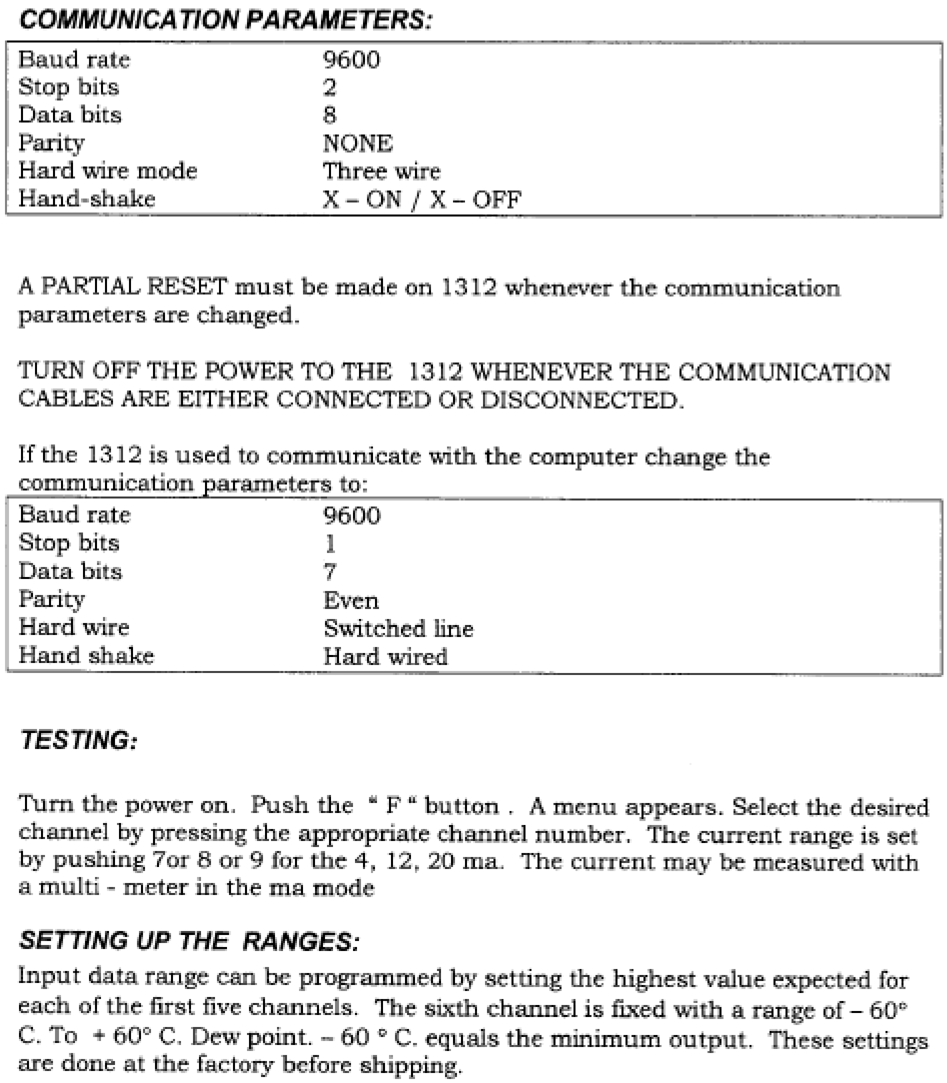
Channel number	Filter	Positive	Negative
1	A	14	1
2	B	16	3
3	C	18	5
4	D	20	7
5	E	22	9
6 (H_2O)	W	24	11

This arrangement can also be found by referring to Figure 1.

COMMUNICATION BETWEEN 1312 and CAIWB 1318 ANALOG MODULE

TYPE OF CABLES REQUIRED:

To input the data you must use the null modem cable (CAI –750) provided with the 1312. There will be no communication between the 1312 and the analog module if ordinary passthrough RS 232 cables are used.



COMMUNICATION PARAMETERS:

Baud rate	9600
Stop bits	2
Data bits	8
Parity	NONE
Hard wire mode	Three wire
Hand-shake	X – ON / X – OFF

A PARTIAL RESET must be made on 1312 whenever the communication parameters are changed.

TURN OFF THE POWER TO THE 1312 WHENEVER THE COMMUNICATION CABLES ARE EITHER CONNECTED OR DISCONNECTED.

If the 1312 is used to communicate with the computer change the communication parameters to:

Baud rate	9600
Stop bits	1
Data bits	7
Parity	Even
Hard wire	Switched line
Hand shake	Hard wired

TESTING:

Turn the power on. Push the " F " button . A menu appears. Select the desired channel by pressing the appropriate channel number. The current range is set by pushing 7or 8 or 9 for the 4, 12, 20 ma. The current may be measured with a multi - meter in the ma mode

SETTING UP THE RANGES:

Input data range can be programmed by setting the highest value expected for each of the first five channels. The sixth channel is fixed with a range of – 60° C. To + 60° C. Dew point. – 60 ° C. equals the minimum output. These settings are done at the factory before shipping.

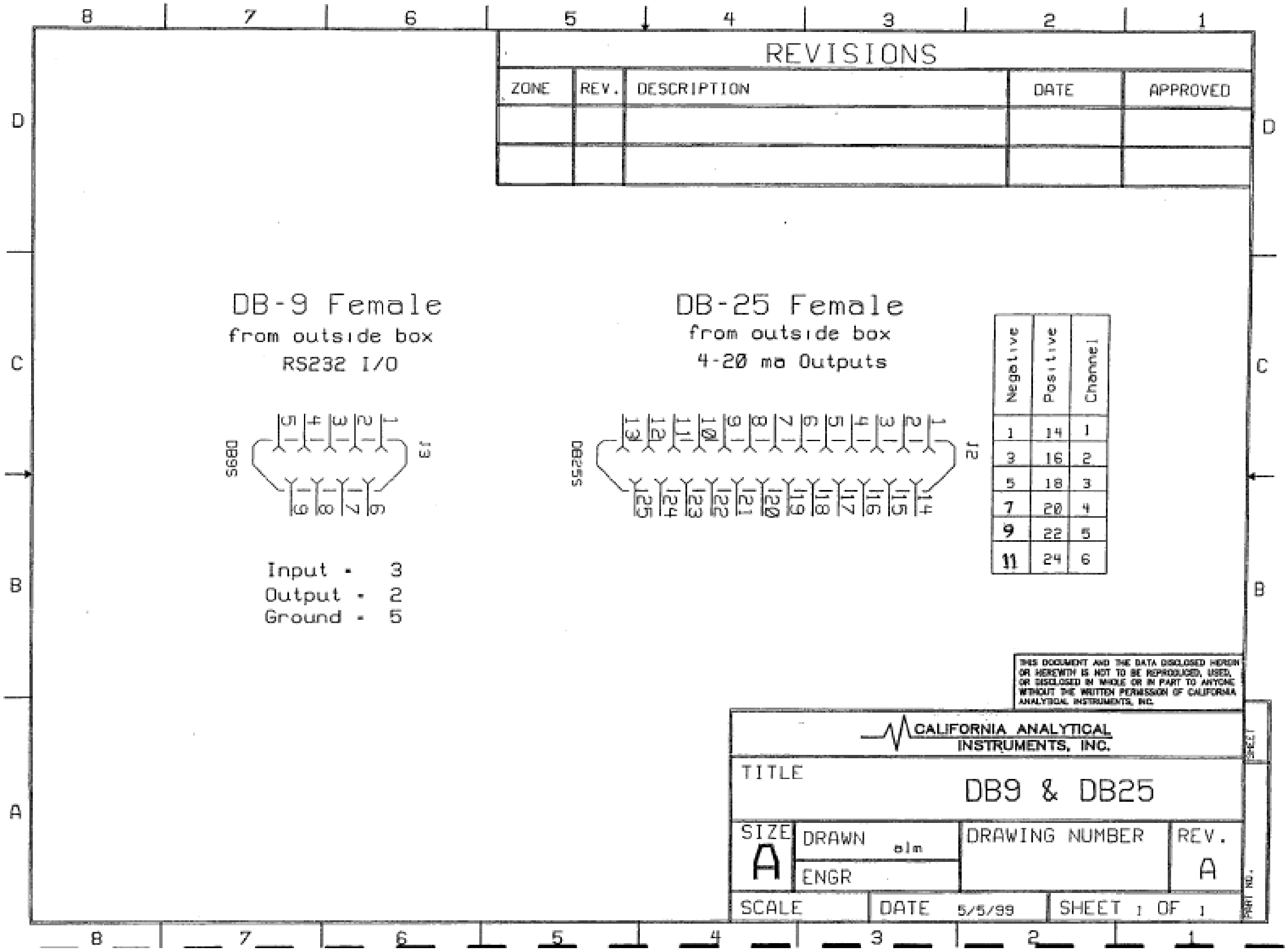
CHANGING THE RANGES:

Turn the power off. Hold the " F " button down for 5 seconds while turning the power back on. When released a secret menu appears displaying the current settings for all the five or requested programmable channels. To change the range, follow the menu on the screen. For example to change the previously set value on channel 1 press 1 on the keypad. Enter the new range by sequentially pressing digits followed by B for plus (+) and A for minus (-) to enter the exponent. If the entry is correct accept it by pressing " F ". If not press C and start over. Press C after making the desired changes for the channels 1 to 5. By way of illustration 100E-03 is 0.100, this corresponds to 20 ma at 0.1 ppm., 12 ma at 50 E-03 or 0.05 ppm and about 4 ma for 1E –02 or smaller.

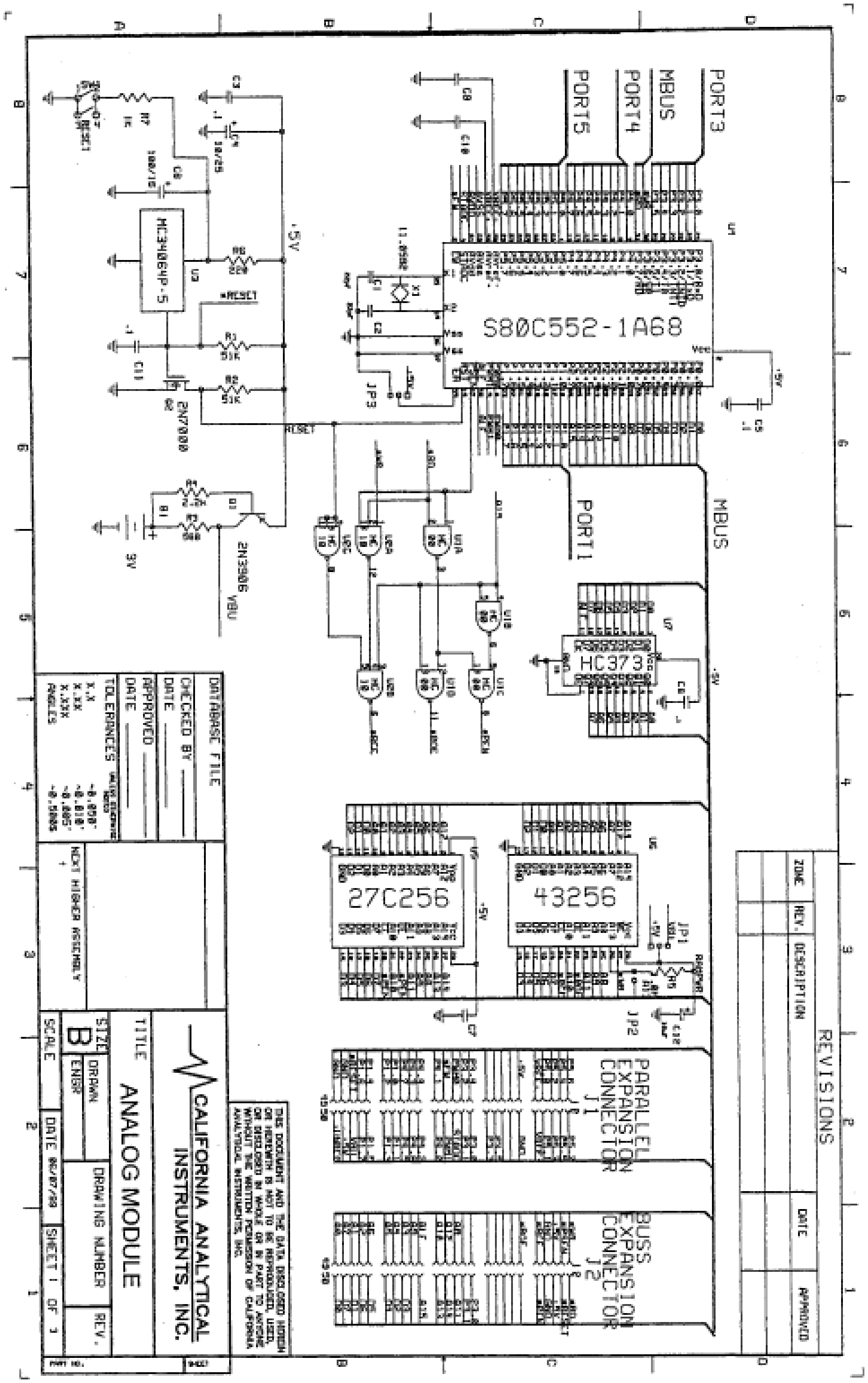
Pressing any key during the operation, the monitoring will cease and a maintenance menu will appear. The operator can select any or all the five channels and set the output to 4,12 or 20 ma. Exiting the maintenance menu will return the analog module to normal operating mode.

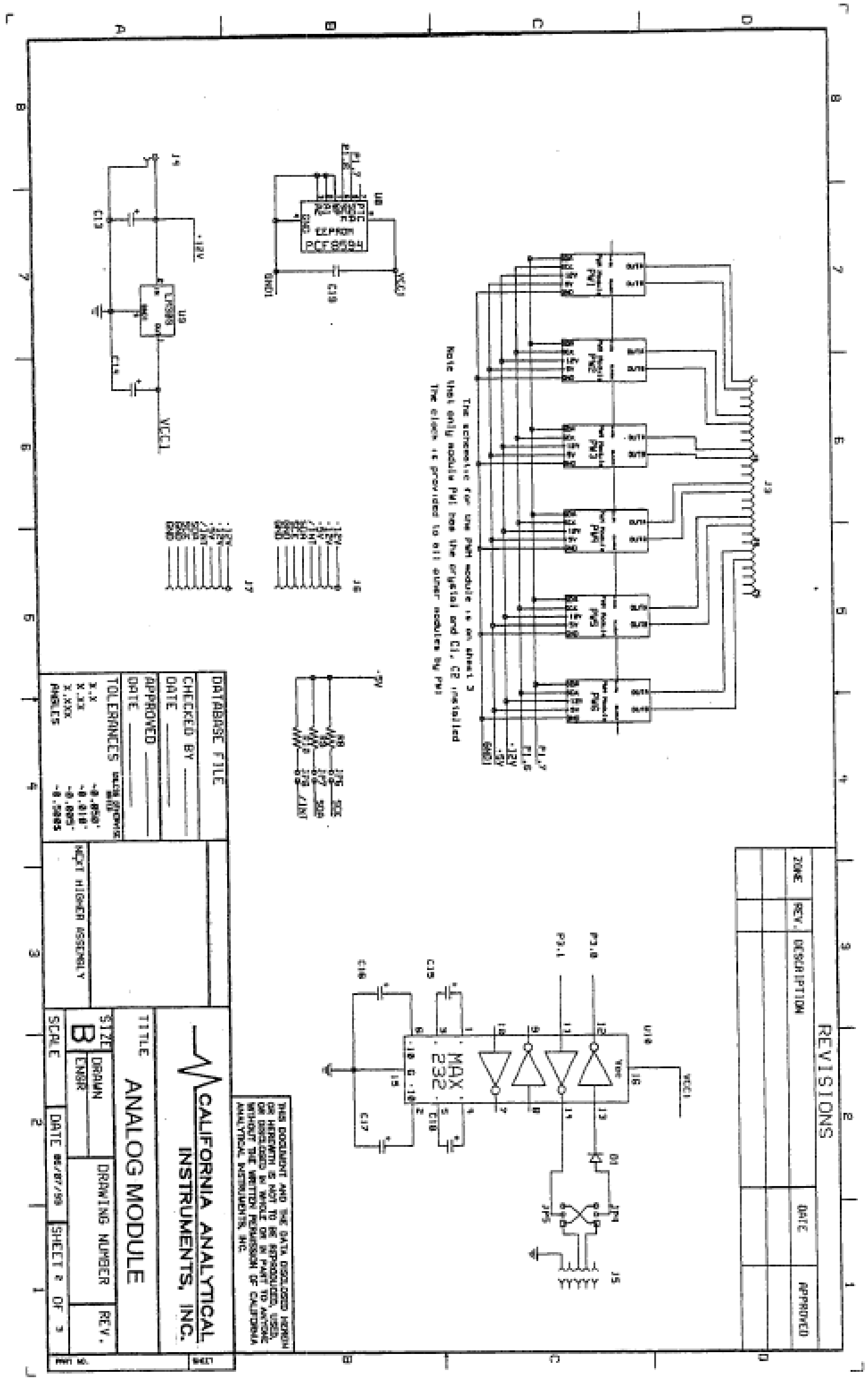
OUTPUTS:

All the outputs are expressed in ma.as set from 4 to 20 ma. If the readout from 1312 is zero or a negative number then the output current will appear as zero. If the humidity is set in degrees dew point Celsius, below zero the output current will appear as zero ma.. However, if the ppm units for moisture are selected then the current output will be ma at temperatures below zero degrees.



Negative	Positive	Channel
1	14	1
3	16	2
5	18	3
7	20	4
9	22	5
11	24	6


S80C552-1A68
PORT3
MBUS
PORT4
PORT5
PORT1
MBUS
MC34064P-5
2N7000
2N3906
9V
RESET
11.0592
JP3
HC373
27C256
43256
JP1
JP2
PARALLEL EXPANSION CONNECTOR J1
BUSS EXPANSION CONNECTOR J2
REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
DATABASE FILE
CHECKED BY
DATE
APPROVED
DATE
TOLERANCES
NEXT HIGHER ASSEMBLY
CALIFORNIA ANALYTICAL INSTRUMENTS, INC.
TITLE
ANALOG MODULE
SIZE
B
DRAWN
ENGR
DRAWING NUMBER
REV.
SCALE
DATE
SHEET 1 OF 3


REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
MAX 232
U10
VCC1
J5
JP4
JP5
D1
P3.0
P3.1
C15
C16
C17
C18
J3
PW1
PW2
PW3
PW4
PW5
PW6
The schematic for the PWM module is on sheet 3
Note that only module PW1 has the crystal and C1, C2 installed
The clock is provided to all other modules by PW1
GND1
-12V
-5V
J6
J7
U8
EEPROM
PCF8594
C19
VCC1
J4
C13
-12V
U9
C14
VCC1
DATABASE FILE
CHECKED BY
DATE
APPROVED
DATE
TOLERANCES
X.X
X.XX
X.XXX
ANGLES
NEXT HIGHER ASSEMBLY
CALIFORNIA ANALYTICAL INSTRUMENTS, INC.
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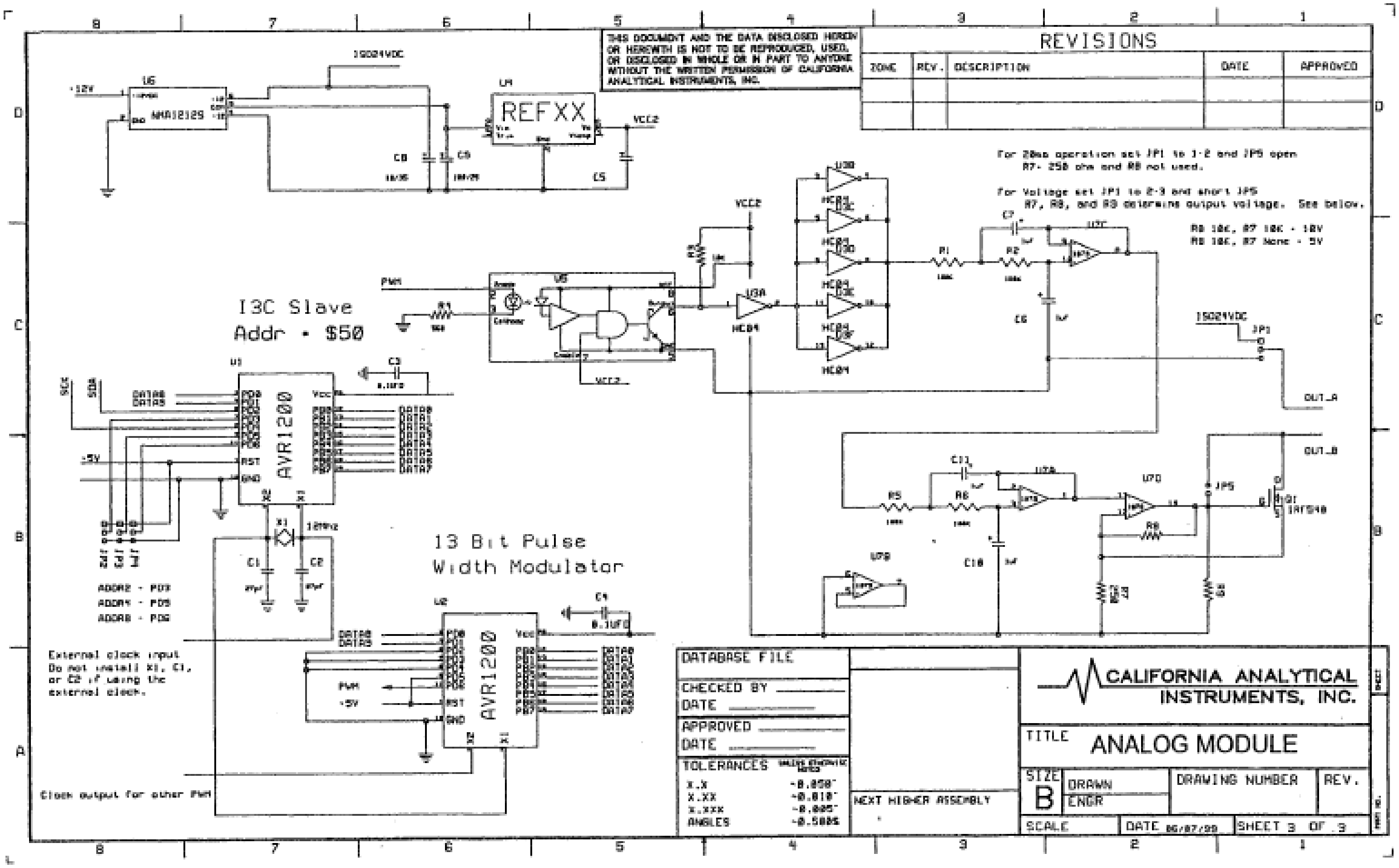
TITLE
ANALOG MODULE
SIZE
B
DRAWN
ENGR
DRAWING NUMBER
REV.
SCALE
DATE 05/07/99
SHEET 2 OF 3
PART NO.
SHEET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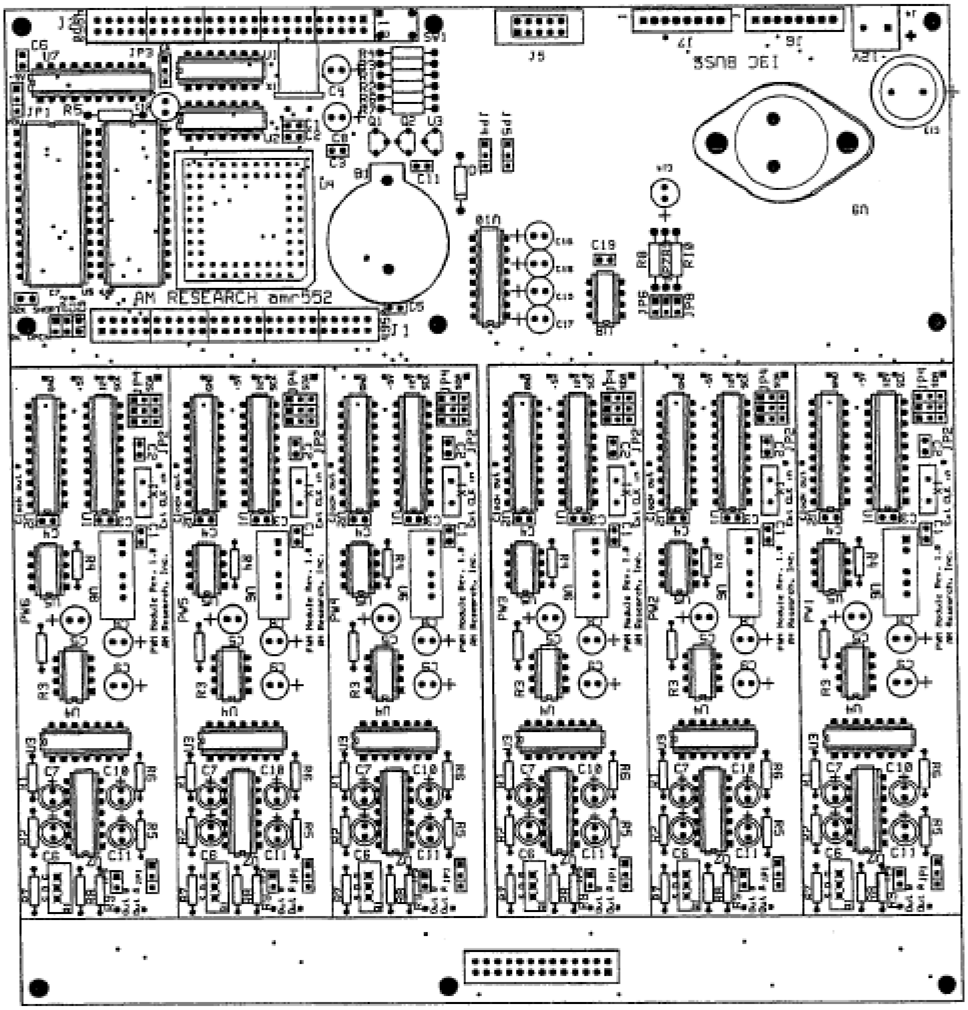
REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
+12V
U6
NMA1212S
15O24VDC
U4
REFXX
VCC2
C8
C9
C5
For 20ma operation set JP1 to 1-2 and JP5 open
R7- 250 ohm and R8 not used.
For Voltage set JP1 to 2-3 and short JP5
R7, R8, and R9 determine output voltage. See below.
R8 10K, R7 10K - 10V
R8 10K, R7 None - 5V
PWM
R4
U5
R3
U3A
HC04
U3B
U3C
U3D
U3E
U3F
R1
R2
C7
U7C
C6
15O24VDC
JP1
OUT_A
OUT_B
I3C Slave
Addr - $50
U1
AVR1200
SCK
SDA
DATA0
DATA5
C3
0.1UF
+5V
RST
GND
X1
X2
12MHz
C1
C2
ADDR2 - PD3
ADDR4 - PD5
ADDR8 - PD6
13 Bit Pulse
Width Modulator
U2
C4
0.1UFD
PWM
+5V
C11
U7A
R5
R6
C10
U7B
U7D
R8
R7
R9
JP5
Q1
IRF540
External clock input
Do not install X1, C1,
or C2 if using the
external clock.
Clock output for other PWM
DATABASE FILE
CHECKED BY
DATE
APPROVED
DATE
TOLERANCES
X.X -0.050"
X.XX -0.010"
X.XXX -0.005"
ANGLES -0.5085
NEXT HIGHER ASSEMBLY
CALIFORNIA ANALYTICAL INSTRUMENTS, INC.
TITLE
ANALOG MODULE
SIZE
B
DRAWN
ENGR
DRAWING NUMBER
REV.
SCALE
DATE 06/07/99
SHEET 3 OF 3


AM RESEARCH amr552
J5
J7
J6
SW1
B1
U4
U9
U10
U11
C19
C4
C8
C9
C11
R5
R8
R10
JP1
JP3
JP5
JP6
JP8
PW1
PW2
PW3
PW4
PW5
PW6
J1

4. Volgen America Switching Power Supply

Volgen America-SPN100 Series

100 WATT, Universal Input
Fully Enclosed Switching Power Supply

FEATURES

- **POWER FACTOR CORRECTED**
- **UNIVERSAL INPUT (AC85-264V)**
- **BUILT-IN OVERVOLTAGE PROTECTION**
- **OVERCURRENT PROTECTION**
- **LIGHTWEIGHT CONSTRUCTION**
- **METAL CHASSIS WITH COVER**
- **COMPACT LOW-PROFILE PACKAGE**
- **3 YEAR WARRANTY**

SAFETIES/EMI

CE UL cUL

FCC-B
EN 55022-B
VCCI-II

ELECTRICAL SPECIFICATIONS

All specifications are typical at nominal input, full load.

INPUT SPECIFICATIONS

Input Voltage	AC 85V-264V DC 110V-340V
Input Frequency	47-63 Hz
Input Current	0.66~1.3A Typ
Inrush Current (100/230VAC cold start)	15~25A
Power Factor	0.99

OUTPUT SPECIFICATIONS

Output Voltage	See Chart
Output Adjustment	+/-10%
Efficiency	79~87%
Over-Voltage Protection	115 - 150% Manual Reset
Over-Current Protections	Automatic Recovery (105% min)
Ripple and Noise	100 mVp-p max.
Hold-Up Time	50 mS
Line/Load Regulation	See Chart
Rise Time	800-1600 mS
Leakage Current (100/230VAC)	0.75 mA

GENERAL SPECIFICATIONS

MTBF	>140,000 Hours
Isolation Voltage	
Primary to Secondary	3000 VAC
Primary to Case	1500 VAC
Secondary to Case	500 VAC
Isolation Resistance	100-Mohms min.

ENVIRONMENTAL SPECIFICATIONS

Operating Temperatures	0°-60°C Derates linearly 2.5%/°C after 50°C
Cooling	Convection
Temperature Coefficient	0.02%/°C
Humidity	20 - 85% Rh (Non-condensing)
Storage Temperature	-20°~85°C
Shock Vibration	Shock: 20G (3 directions each 3 times) Vibration: 10~55Hz

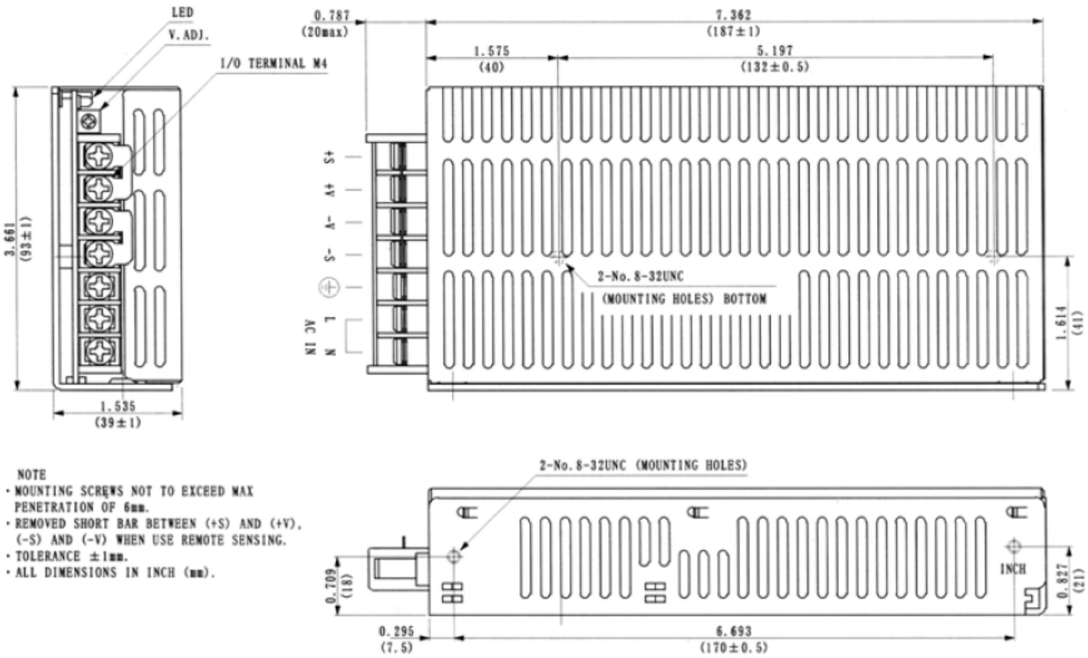
PHYSICAL SPECIFICATIONS

Metal Enclosed, Terminal Block

MODEL	OUTPUT VOLTAGE	CURRENT 85~264 VAC	OUTPUT CURRENT		LINE REGULATION (85~132VAC) (170~264VAC)	LOAD REGULATION (mVmax) (0-100% Load)
			100VAC	230VAC		
SPN100-05S	5V	20.0 A	79%	81%	10	20
SPN100-12S	12V	8.6 A	83%	85%	10	20
SPN100-15S	15V	7.0 A	83%	86%	10	20
SPN100-24S	24V	4.4 A	83%	86%	20	40
SPN100-48S	48 V	2.2 A	84%	87%	20	40

NOTE:

All specifications typical and nominal/full load and 25°C unless otherwise noted.
Avoid sustained operation in overload or dead short conditions.
Specifications subject to changes without notice.



NOTE
- MOUNTING SCREWS NOT TO EXCEED MAX PENETRATION OF 6mm.
- REMOVED SHORT BAR BETWEEN (+S) AND (+V), (-S) AND (-V) WHEN USE REMOTE SENSING.
- TOLERANCE ±1mm.
- ALL DIMENSIONS IN INCH (mm).

***No. 6-32 mounting holes standard**
***Dimensions in mm**
***Terminal block or "pin"**
type connector available

5. Thomas Diaphragm Pump, Model 107CAB18

DIAPHRAGM

Pumps and Compressors

107 Series

MODELS:

Standard models available.

107CAB18, 107CCD18, 107CEF18, 107CGH18
107CDC20

Other models based on availability and minimum purchase.

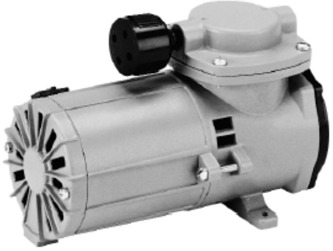
FEATURES (AC& DC):

- Oil-less operation
- Permanently lubricated bearings
- Closed housing and motor vents (107CDC/C only)
- Stainless valves
- Die cast aluminum head, valve plate and diaphragm hold down plate with dichromate conversion treatment
- Balanced for smooth, low vibration operation
- Long-life diaphragm
- Field service capability
- UL® recognized motor and thermal protector (115 Volt, AC only)
- Inlet filter
- CE approval on all standard 220-240/50hz models (Consult factory for non-standard models.)

Consult factory for custom applications

107CAB, CCD

107CEF, CGH



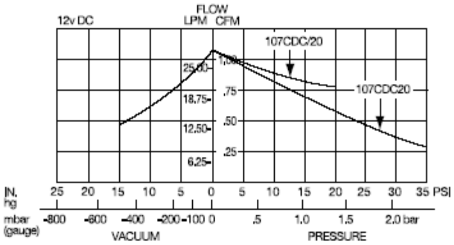
107CDC

ISO 9001 CERTIFIED

THOMAS®
PUMPS & COMPRESSORS

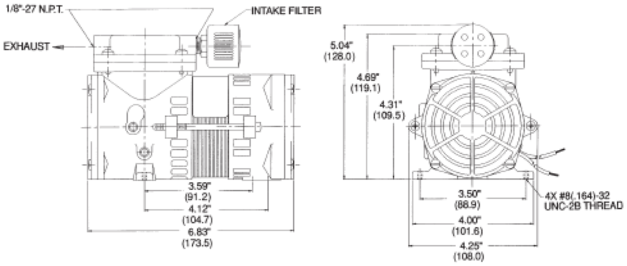
107 SERIES (DC) PERFORMANCE DATA:

		STANDARD			
MODEL NUMBER:		107CDC20		107CDC/C20	
HEAD CONFIGURATION:		Pressure/Vacuum		Pressure/Vacuum	
STROKE:		.200 Inches		.200 Inches	
PRESSURE:		Flow @ 12v		Flow @ 12v	
CFM @ PSI	LPM @ bar				
PSI	bar	CFM	LPM	CFM	LPM
0	0	1.40	39.6	1.40	39.6
5	.5	1.34	35.1	1.34	35.1
10	1.0	1.12	27.1	1.12	27.1
15	1.5	.94	20.2	.94	20.1
20	2.0	.77	14.5	.77	
25	3.0	.61	6.2		
30		.49			
35		.39			
MAX. CONTINUOUS PRESSURE:		35 PSI	2.4 bar	20 PSI	1.4 bar
MAX. INTERMITTENT PRESSURE:		35 PSI	2.4 bar	20 PSI	1.4 bar
VACUUM:		Flow @ 12v		Flow @ 12v	
CFM @ IN. hg	LPM @ mbar (gauge)				
IN. hg	mbar (gauge)	CFM	LPM	CFM	LPM
0	0	1.40	39.6	1.40	39.6
5	-100	1.09	34.4	1.09	34.4
10	-200	.80	29.3	.80	29.3
15	-400	.48	19.3	.48	19.3
20	-600		8.6		8.6
25					
MAX. VACUUM:		22.9" hg	-775 mbar	22.9" hg	-775 mbar
MAX. AMBIENT TEMPERATURE:		104°F	40°C	104°F	40°C
MIN. AMBIENT TEMPERATURE:		50°F	10°C	50°F	10°C
MAX. RESTART PRESSURE:		15 PSI	1.0 bar	15 PSI	1.0 bar
MAX. RESTART VACUUM:		22.9" hg	-775 mbar	22.9" hg	-775 mbar
MOTOR VOLTAGE/FREQUENCY:		12v DC		12v DC	
HORSEPOWER:		1/10		1/10	
MOTOR TYPE:		Permanent Magnet		Permanent Magnet	
CURRENT AT RATED LOAD (AMPS):		8.5		8.5	
POWER AT RATED LOAD (WATTS):					
STARTING CURRENT (LOCKED ROTOR AMPS):		40.0		40.0	
INSULATION CLASS:		A		A	
MIN. FULL LOAD SPEED (RPM):		2970		2970	
THERMAL PROTECTOR:		No		No	
CAPACITOR VALUE:					
NET WEIGHT:		4.5 lbs.	2.0 Kg	4.7 lbs.	2.1 Kg

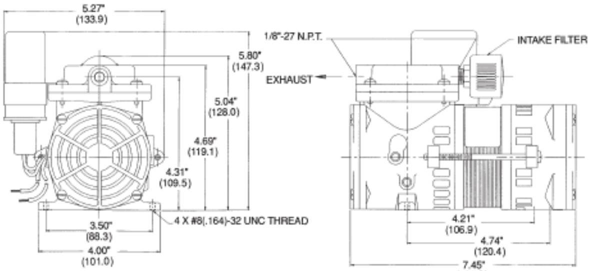


DIMENSIONS:

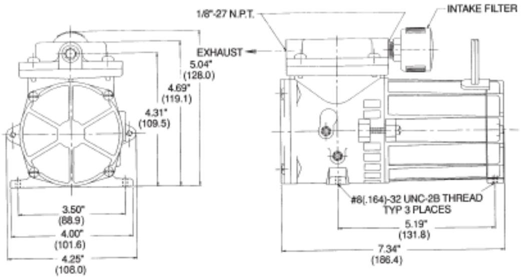
Millimeters are in ( )



107CAB, CCD



107CEF, CGH



107CDC & 107CDC/C

NOTE: 107CDC/C has closed motor vents

Note: Models pictured are representative of the series and do not represent a specific model number. Consult factory for detailed physical description.

Printed in U.S.A. Form No. 850-2274 9/01

THOMAS
PUMPS & COMPRESSORS
1419 Illinois Avenue, P.O. Box 29
Sheboygan, WI 53082-0029 USA
(920) 457-4891 Fax (920) 451-4276
Internet: http://www.thomaspumps.com

6. Setra Differential Pressure Transducer

Model 264

Very Low Differential Pressure Transducer

Unidirectional Ranges: 0 - 0.1 to 0 - 100 in. W.C.
Bidirectional Ranges: 0 - ±0.5 to 0 - ±50 in. W.C.
Air or Non-Conducting Gas

Setra Systems 264 pressure transducers sense differential or gauge (static) pressure and convert this pressure difference to a proportional electrical output for either unidirectional or bidirectional pressure ranges. The 264 Series is offered with a high level analog 0 to 5 VDC or 4 to 20 mA output.

Used in Building Energy Management Systems, these transducers are capable of measuring pressures and flows with the accuracy necessary for proper building pressurization and air flow control.

The 264 Series transducers are available for air pressure ranges as low as 0.1 in. W.C. full scale to 100 in. W.C. full scale. Static standard accuracy is ±1.0% full scale in normal ambient temperature environments, but higher accuracies are available. The units are temperature compensated to 0.033% FS/°F thermal error over the temperature range of 0°F to +150°F.

The Model 264 utilizes an improved all stainless steel micro-tig welded sensor. The tensioned stainless steel diaphragm and insulated stainless steel electrode, positioned close to the diaphragm, form a variable capacitor. Positive pressure moves the diaphragm toward the electrode, increasing the capacitance. A decrease in pressure moves the diaphragm away from the electrode, decreasing the capacitance. The change in capacitance is detected and converted to a linear DC electrical signal by Setra's unique electronic circuit.

The tensioned sensor allows up to 10 PSI overpressure (in either direction) with no damage to the unit. In addition, the parts that make up the sensor have thermally matched coefficients, which promote improved temperature performance and excellent long term stability.

NOTE: Setra quality standards are based on ANSI-Z540-1.
The calibration of this product is NIST traceable.

U.S. Patent nos. 4093915; 4358814; 4434203; 6019002; 6014800.
Other Patents Pending.

159 Swanson Rd., Boxborough, MA 01719/Telephone: 978-263-1400/Fax: 978-264-0292

Applications

- Heating, Ventilating and Air Conditioning (HVAC)
- Energy Management Systems
- Variable Air Volume and Fan Control (VAV)
- Environmental Pollution Control
- Lab and Fume Hood Control
- Oven Pressurization and Furnace Draft Controls

Features

- Up to 10 PSI Overpressure on All Ranges
- Installation Time Minimized with Snap Track Mounting and Easy- To-Access Pressure Ports and Electrical Connections
- 0 to 5 VDC or 2-wire 4 to 20 mA Analog Outputs Are Compatible with Energy Management Systems
- Reverse Wiring Protection
- Internal Regulation Permits Use with Unregulated DC Power Supplies
- Meets CE Conformance Standards

When it comes to a product to rely on - choose the Model 264. When it comes to a company to trust - choose Setra.

ISO 9001 Certified

Visit Setra Online:
http://www.setra.com

setra

800-257-3872

Model 264 Specifications

Performance Data

	Standard	Optional	
Accuracy* RSS(at constant temp)	±1.0% FS	±0.4% FS	±0.25% FS
Non-Linearity, BFSL	±0.96% FS	±0.38% FS	±0.22% FS
Hysteresis	0.10% FS	0.10% FS	0.10% FS
Non-Repeatability	0.05% FS	0.05% FS	0.05%FS

Thermal Effects**	
Compensated Range °F(°C)	0 to +150 (-18 to +65)
Zero/Span Shift %FS/°F(°C)	0.033 (0.06)
Maximum Line Pressure	10 psi
Overpressure	Up to 10 psi in Positive or Negative Direction.
Long Term Stability	0.5% FS/1 YR

Position Effect	Range	Zero Offset (%FS/G)
(Unit is factory calibrated at 0g effect in the vertical position.)	To 0.5 in. WC	0.60
	To 1.0 in.WC	0.50
	To 2.5 in.WC	0.22
	To 5 in. WC	0.14

* RSS of Non-Linearity,Hysteresis,and Non-Repeatability.

**Units calibrated at nominal 70°F. Maximum thermal error computed from this datum.

Environmental Data

Temperature	
Operating* °F (°C)	0 to +175 (-18 to +79)
Storage °F (°C)	-65 to +250 (-54 to +121)

*Operating temperature limits of the electronics only. Pressure media temperatures may be considerably higher.

Physical Description

Case	Fire-Retardant Glass Filled Polyester
Mounting	Four screw holes on removable zinc plated steel base (designed for 2.75" snap track)
Electrical Connection	Screw Terminal Strip
Pressure Fittings	3/16" O.D. barbed brass pressure fitting for 1/4" push-on tubing
Zero and Span Adjustments	Accessible on top of case
Weight (approx.)	10 ounces

Pressure Media

Typically air or similar non-conducting gases.

Specifications subject to change without notice.

Electrical Data (Voltage)

Circuit	3-Wire (Com, Exc, Out)
Excitation	9 to 30 VDC
Output*	0 to 5 VDC**
Bidirectional output at zero pressure:	2.5 VDC**
Output Impedance	100 ohms

*Calibrated into a 50K ohm load, operable into a 5000 ohm load or greater.

**Zero output factory set to within ±50mV (±25 mV for optional accuracies).

**Span (Full Scale) output factory set to within ±50mV. (±25 mV for optional accuracies).

Electrical Data (Current)

Circuit	2-Wire
Output*	4 to 20mA**
Bidirectional output at zero pressure:	12mA**
External Load	0 to 800 ohms

Minimum supply voltage (VDC) = 9+ 0.02 x (Resistance of receiver plus line).

Maximum supply voltage (VDC) = 30+ 0.004 x (Resistance of receiver plus line).

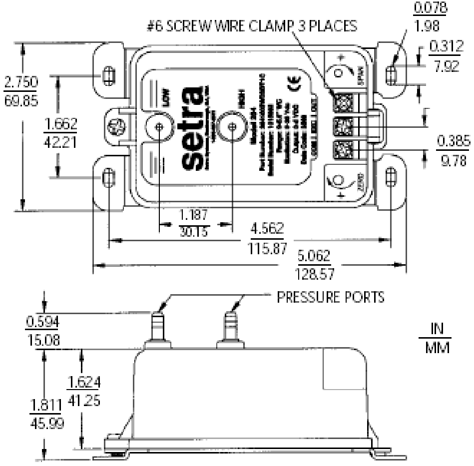
*Calibrated at factory with a 24 VDC loop supply voltage and a 250 ohm load.

**Zero output factory set to within ±0.16mA (±0.08 mA for optional accuracies).

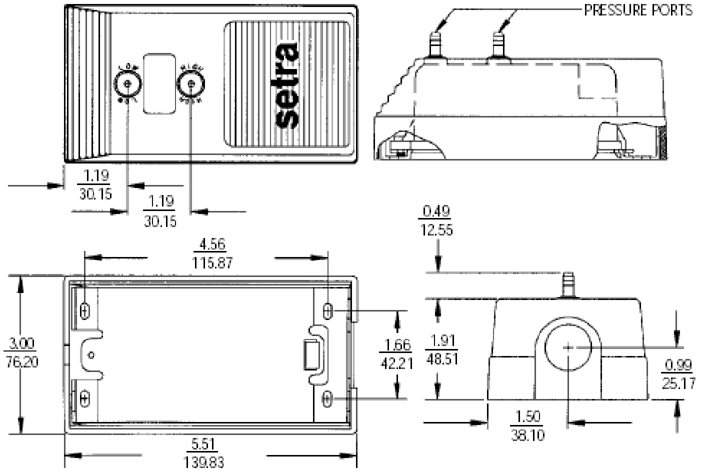
**Span (Full Scale) output factory set to within ±0.16mA (±0.08 mA for optional accuracies).

Outline Drawings

Code T1 Electrical Termination Dimensions



Optional 1/2" Conduit Electrical Enclosure Dimensions



SSP264 Rev.D 04/19/01

ORDERING INFORMATION

Code all blocks in table.

Example: Part No. 26412R5WD11T1C for a 264 Transducer 0 to 2.5 in. WC Range, 4 to 20 mA Output, Terminal Strip Electrical Connection, and ±1% Accuracy.

2 6 4 1 – ☐☐☐☐☐ – ☐☐ – ☐☐ – ☐

Model

2641 = 264

Ranges

Differential

0R1WD = 0 to 0.1 in. WC
R25WD = 0 to 0.25 in. WC
0R5WD = 0 to 0.5 in. WC
001WD = 0 to 1 in. WC
2R5WD = 0 to 2.5 in. WC
003WD = 0 to 3 in. WC
005WD = 0 to 5 in. WC
010WD = 0 to 10 in. WC
015WD = 0 to 15 in. WC
025WD = 0 to 25 in. WC
050WD = 0 to 50 in. WC
100WD = 0 to 100 in. WC

Bidirectional

R05WB = ±0.05 in. WC
0R1WB = ±0.1 in. WC
R25WB = ±0.25 in. WC
0R5WB = ±0.5 in. WC
001WB = ±1 in. WC
1R5WB = ±1.5 in. WC
2R5WB = ±2.5 in. WC
005WB = ±5 in. WC
7R5WB = ±7.5 in. WC
010WB = ±10 in. WC
025WB = ±25 in. WC
050WB = ±50 in. WC

Output

11 = 4-20 mA
2D = 0 to 5 VDC

Elec. Termination

Standard
T1 = Terminal Strip
Optional
A1 = 1/2" Conduit Enclosure

Accuracy

Standard
C = ±1% FS
Optional (w/Cal. Cert.)
E = ±0.4% FS
F = ±0.25% FS
G = ±1% FS

Please contact factory for versions not shown.

While we provide application assistance on all Setra products, both personally and through our literature, it is the customer's responsibility to determine the suitability of the product in the application.

159 Swanson Road, Boxborough, MA 01719/Tel: 978-263-1400;
Toll Free: 800-257-3872; Fax: 978-264-0292; email: sales@setra.com

7. Vaisala Humidity and Temperature Sensor

VAISALA

P.O. Box 26, FIN-00421 Helsinki, FINLAND
Tel: +358 9 894 91
Fax: +358 9 8949 2485
Email: industrialsales@vaisala.com
www.vaisala.com

HMW61/71 Humidity and Temperature Transmitter for Industrial/HVAC Applications

Vaisala HUMICAP® Humidity and Temperature Transmitters HMW61/71 are protected against dust and sprayed water.

The wall mount Vaisala HUMICAP® Humidity and Temperature Transmitters HMW61 and HMW71 are designed for monitoring relative humidity and temperature in demanding environments.

Withstands dust and sprayed water

The transmitters are protected against dust and sprayed water, meeting the IP65 (NEMA 4) requirements. All the materials used have been chosen for excellent corrosion resistance. In addition, the transmitters incorporate Vaisala HUMICAP® Sensor, which is insensitive to dust and most chemicals.

All of these features make the HMW61/71 transmitters especially suitable for humid and wet environments, e.g. greenhouses, live stock farms, indoor swimming pools and other wash down areas.

Measures both humidity and temperature

The HMW61/71 transmitters are available as relative humidity only (U), and as relative humidity and temperature (Y).

Fast, on-site calibration

The accuracy of the transmitters is simple to check using either the Vaisala HUMICAP® Hand-Held Humidity and Temperature Meter HM70 or the Vaisala HUMICAP® Humidity Indicator HMI41. The calibration can be done in seconds with a single potentiometer without disturbing operation, resulting in savings in both maintenance time and costs.

Customized calibration and maintenance contracts for HMW61/71 are available on request.

Features/Benefits

- Full 0...100 %RH measurement
- Accuracy up to ±2 %RH
- True two-wire transmitter with a 4...20 mA loop powered output (HMW61)
- Three-wire transmitter with a selectable signal output of 0...1 V, 0...5 V or 0...10 V (HMW71)
- Optional temperature measurement
- Electronic, on-site, one-point calibration
- Vaisala HUMICAP® Sensor for excellent accuracy and long-term stability, negligible hysteresis and resistance to dust and most chemicals.
- Temperature compensated
- IP65 (NEMA 4) housing
- NIST traceable (certificate included)

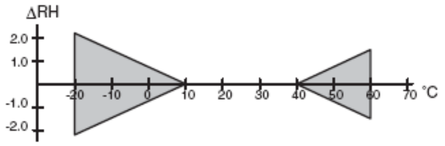
Vaisala HUMICAP® Humidity and Temperature Transmitters HMW61/71 are especially suitable for humid and wet environments.

Technical Data

Relative humidity

Measurement range	0 to 100 %RH
Accuracy at +20 °C (+68 °F)	±2 %RH (0 to 90 %RH) ±3 %RH (90 to 100 %RH)

Temperature dependence

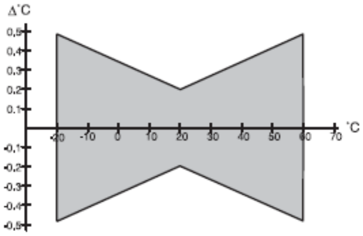


Response time (90%) at +20 °C (+68 °F) in still air	15 seconds (with membrane filter)
Humidity sensor	HUMICAP® 180

Temperature (Y model only)

Measurement range	-20...+60 °C (-4...+140 °F) Optional temperature scales available on request.

Accuracy



Linearity	better than 0.1 °C (0.18 °F)
Temperature sensor	Pt 1000 IEC 751 class B

General HMW61U/Y

Supply voltage	10...35 VDC (RL = 0 ohms) 20...35 VDC (RL = 500 ohms)
Output signal	4...20mA

Output signal corresponds to 0...100 %RH and -20...+80 °C (-4...+176 °F)

General HMW71U/Y

Supply voltage range depends on the selected output signal. When an AC supply is used, an isolated source is recommended.

	DC	AC
0...1 V	10...35 V	9...24 V
0...5 V	14...35 V	12...24 V
0...10 V	19...35 V	16...24 V

Output signal corresponds to 0...100 %RH and -20...+80 °C (-4...+176 °F)

Factory setting 0...1 V. Other outputs selectable by jumper connections. An output change causes an error, which is less than 0.5 %RH without recalibration.

Power consumption @ 24 VAC	
HMW71U	10 mA typical
HMW71Y	12 mA typical

General

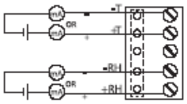
Operating temperature range	-20 °C...+60 °C (-4...+140 °F)
Storage temperature range	-40 °C...+80 °C (-40...+176 °F)
Material:	
Housing	ABS/PC plastic
Probe	ABS/PC plastic
Mounting plate	ABS plastic
Housing classification	IP65 (NEMA 4)
Sensor protection	
Membrane filter	part no. DRW010525
Probe cap	part no. HM47329
Connections	Screw terminals 0.5...1.5 mm²

For field check
HM70 hand-held humidity and temperature meter or HMI41 humidity indicator

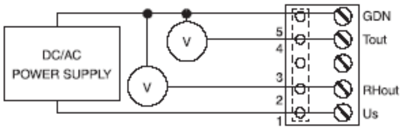
Complies with EMC standard EN61326-1:1997 + Am1:1998 + Am2:2001; Industrial Environment.

Wiring

HMW61 wiring diagram

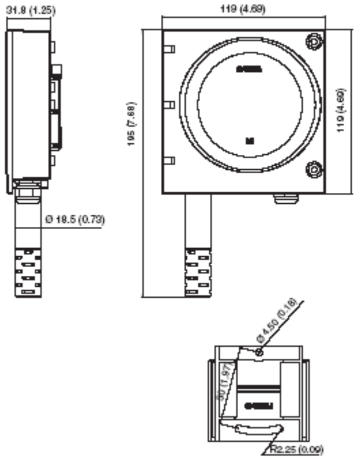


HMW71 wiring diagram



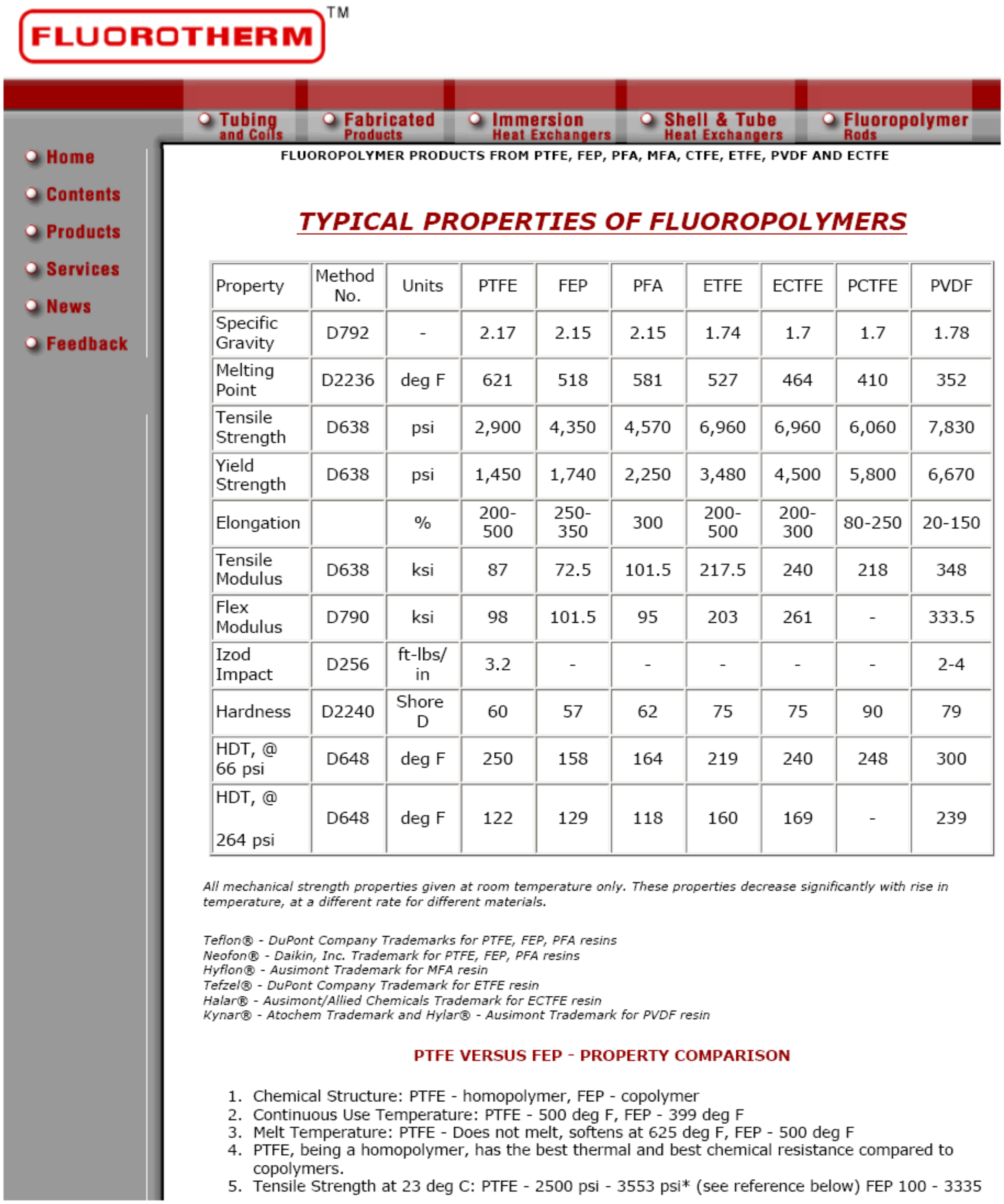
Dimensions

Dimension in mm (inches).



HUMICAP® is a registered trademark of Vaisala.
Specifications subject to change without prior notice.

8. Fluorotherm FEP Tubing



FLUOROPOLYMER PRODUCTS FROM PTFE, FEP, PFA, MFA, CTFE, ETFE, PVDF AND ECTFE

TYPICAL PROPERTIES OF FLUOROPOLYMERS

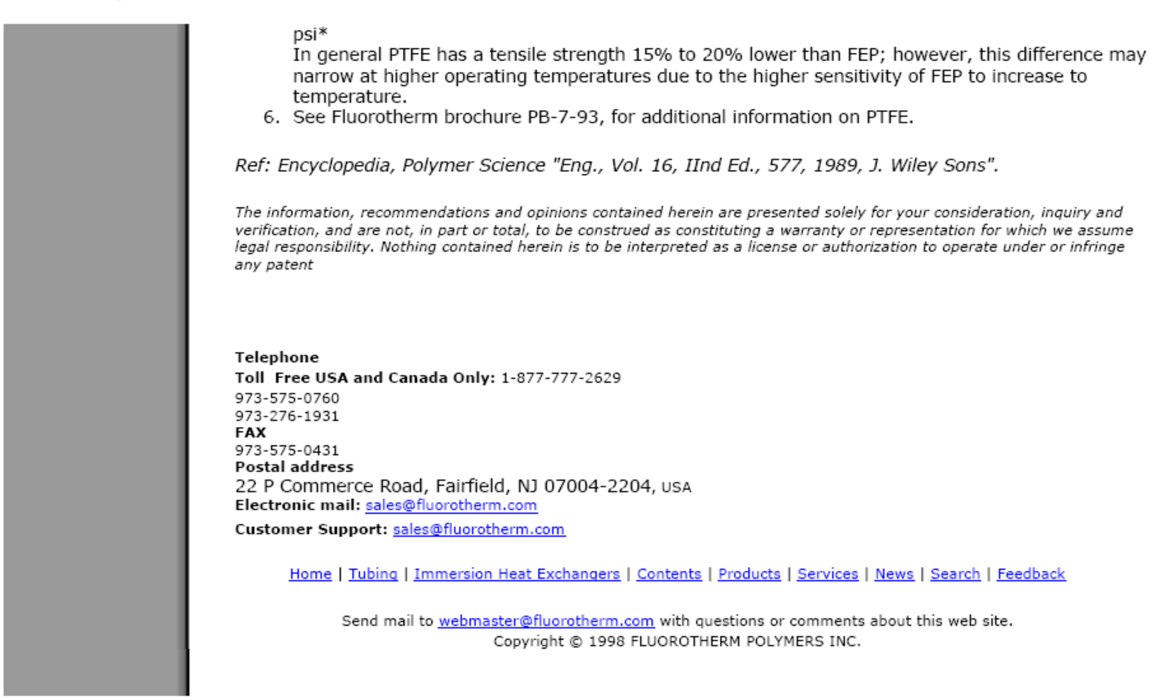
Property	Method No.	Units	PTFE	FEP	PFA	ETFE	ECTFE	PCTFE	PVDF
Specific Gravity	D792	-	2.17	2.15	2.15	1.74	1.7	1.7	1.78
Melting Point	D2236	deg F	621	518	581	527	464	410	352
Tensile Strength	D638	psi	2,900	4,350	4,570	6,960	6,960	6,060	7,830
Yield Strength	D638	psi	1,450	1,740	2,250	3,480	4,500	5,800	6,670
Elongation		%	200-500	250-350	300	200-500	200-300	80-250	20-150
Tensile Modulus	D638	ksi	87	72.5	101.5	217.5	240	218	348
Flex Modulus	D790	ksi	98	101.5	95	203	261	-	333.5
Izod Impact	D256	ft-lbs/in	3.2	-	-	-	-	-	2-4
Hardness	D2240	Shore D	60	57	62	75	75	90	79
HDT, @ 66 psi	D648	deg F	250	158	164	219	240	248	300
HDT, @ 264 psi	D648	deg F	122	129	118	160	169	-	239

All mechanical strength properties given at room temperature only. These properties decrease significantly with rise in temperature, at a different rate for different materials.

Teflon® - DuPont Company Trademarks for PTFE, FEP, PFA resins
Neofon® - Daikin, Inc. Trademark for PTFE, FEP, PFA resins
Hyflon® - Ausimont Trademark for MFA resin
Tefzel® - DuPont Company Trademark for ETFE resin
Halar® - Ausimont/Allied Chemicals Trademark for ECTFE resin
Kynar® - Atochem Trademark and Hylar® - Ausimont Trademark for PVDF resin

PTFE VERSUS FEP - PROPERTY COMPARISON

1. Chemical Structure: PTFE - homopolymer, FEP - copolymer
2. Continuous Use Temperature: PTFE - 500 deg F, FEP - 399 deg F
3. Melt Temperature: PTFE - Does not melt, softens at 625 deg F, FEP - 500 deg F
4. PTFE, being a homopolymer, has the best thermal and best chemical resistance compared to copolymers.
5. Tensile Strength at 23 deg C: PTFE - 2500 psi - 3553 psi* (see reference below) FEP 100 - 3335



psi*
In general PTFE has a tensile strength 15% to 20% lower than FEP; however, this difference may narrow at higher operating temperatures due to the higher sensitivity of FEP to increase to temperature.

6. See Fluorotherm brochure PB-7-93, for additional information on PTFE.

Ref: Encyclopedia, Polymer Science "Eng., Vol. 16, IInd Ed., 577, 1989, J. Wiley Sons".

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973-276-1931
FAX
973-575-0431
Postal address
22 P Commerce Road, Fairfield, NJ 07004-2204, USA
Electronic mail: sales@fluorotherm.com
Customer Support: sales@fluorotherm.com

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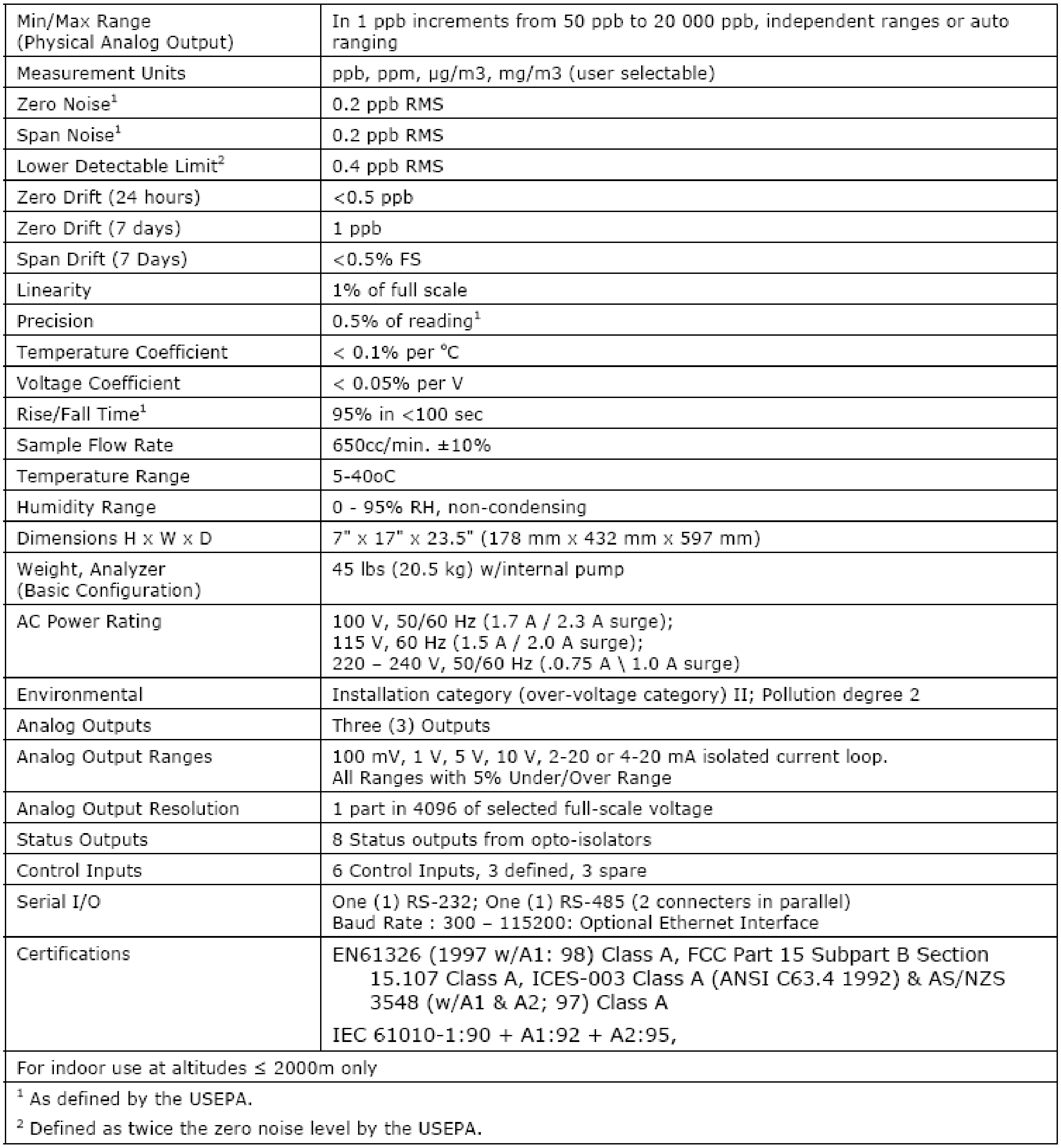
Send mail to webmaster@fluorotherm.com with questions or comments about this web site.

9. API UV Fluorescence Non-methane Hydrocarbon Analyzer

Table 2-1: Model 101E Basic Unit Specifications

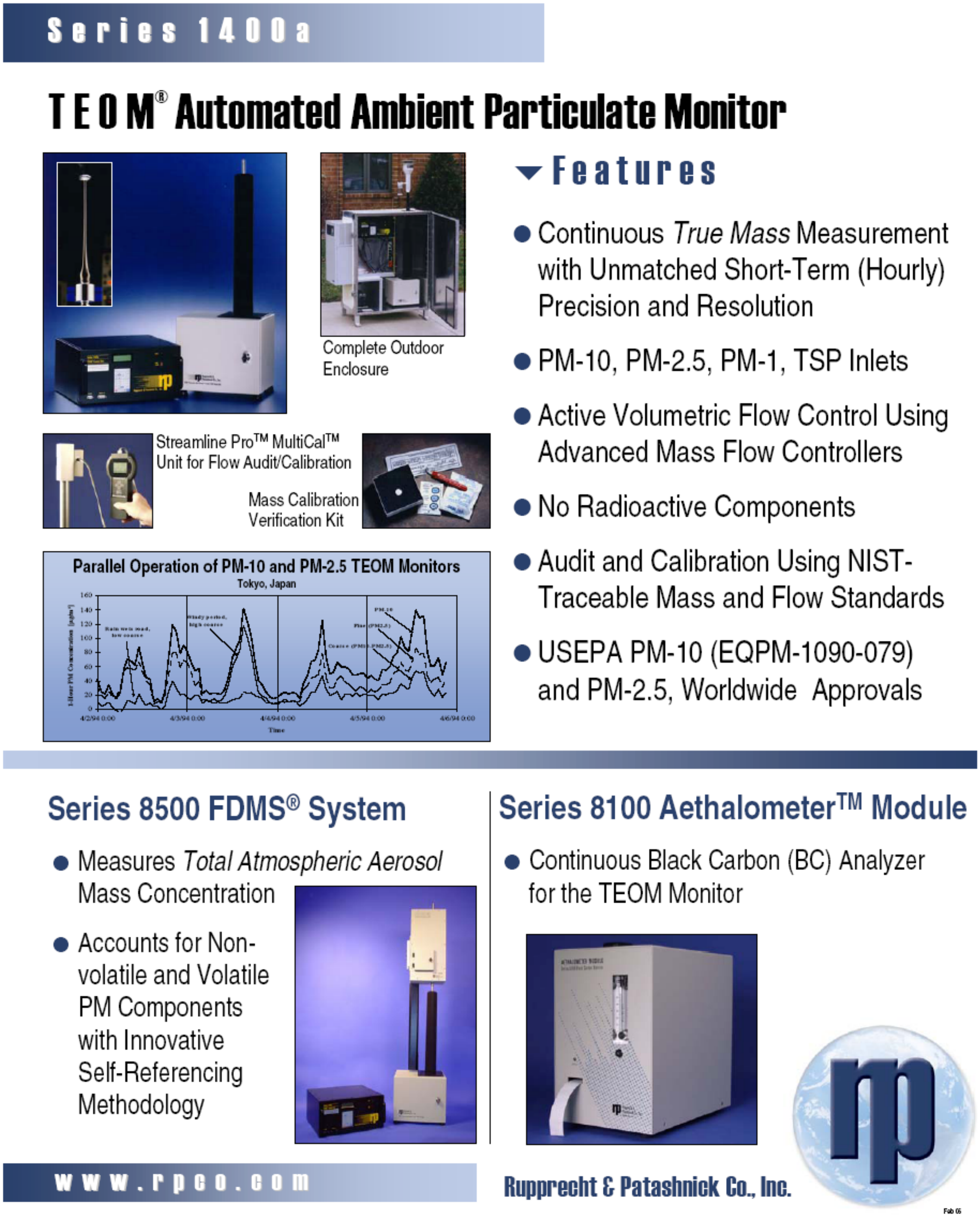


Min/Max Range (Physical Analog Output)	In 1 ppb increments from 50 ppb to 20 000 ppb, independent ranges or auto ranging
Measurement Units	ppb, ppm, µg/m3, mg/m3 (user selectable)
Zero Noise[1]	0.2 ppb RMS
Span Noise[1]	0.2 ppb RMS
Lower Detectable Limit[2]	0.4 ppb RMS
Zero Drift (24 hours)	<0.5 ppb
Zero Drift (7 days)	1 ppb
Span Drift (7 Days)	<0.5% FS
Linearity	1% of full scale
Precision	0.5% of reading[1]
Temperature Coefficient	< 0.1% per °C
Voltage Coefficient	< 0.05% per V
Rise/Fall Time[1]	95% in <100 sec
Sample Flow Rate	650cc/min. ±10%
Temperature Range	5-40oC
Humidity Range	0 - 95% RH, non-condensing
Dimensions H x W x D	7" x 17" x 23.5" (178 mm x 432 mm x 597 mm)
Weight, Analyzer (Basic Configuration)	45 lbs (20.5 kg) w/internal pump
AC Power Rating	100 V, 50/60 Hz (1.7 A / 2.3 A surge); 115 V, 60 Hz (1.5 A / 2.0 A surge); 220 – 240 V, 50/60 Hz (.0.75 A \ 1.0 A surge)
Environmental	Installation category (over-voltage category) II; Pollution degree 2
Analog Outputs	Three (3) Outputs
Analog Output Ranges	100 mV, 1 V, 5 V, 10 V, 2-20 or 4-20 mA isolated current loop. All Ranges with 5% Under/Over Range
Analog Output Resolution	1 part in 4096 of selected full-scale voltage
Status Outputs	8 Status outputs from opto-isolators
Control Inputs	6 Control Inputs, 3 defined, 3 spare
Serial I/O	One (1) RS-232; One (1) RS-485 (2 connecters in parallel) Baud Rate : 300 – 115200: Optional Ethernet Interface
Certifications	EN61326 (1997 w/A1: 98) Class A, FCC Part 15 Subpart B Section 15.107 Class A, ICES-003 Class A (ANSI C63.4 1992) & AS/NZS 3548 (w/A1 & A2; 97) Class A IEC 61010-1:90 + A1:92 + A2:95,
For indoor use at altitudes ≤ 2000m only	

[1] As defined by the USEPA.

[2] Defined as twice the zero noise level by the USEPA.

10. Tapered Element Oscillating Microbalance (TEOM)



Series 1400a

TEOM® Automated Ambient Particulate Monitor

Complete Outdoor Enclosure

Streamline Pro™ MultiCal™ Unit for Flow Audit/Calibration

Mass Calibration Verification Kit

Parallel Operation of PM-10 and PM-2.5 TEOM Monitors
Tokyo, Japan

Features

- Continuous *True Mass* Measurement with Unmatched Short-Term (Hourly) Precision and Resolution
- PM-10, PM-2.5, PM-1, TSP Inlets
- Active Volumetric Flow Control Using Advanced Mass Flow Controllers
- No Radioactive Components
- Audit and Calibration Using NIST-Traceable Mass and Flow Standards
- USEPA PM-10 (EQPM-1090-079) and PM-2.5, Worldwide Approvals

Series 8500 FDMS® System

- Measures *Total Atmospheric Aerosol* Mass Concentration
- Accounts for Non-volatile and Volatile PM Components with Innovative Self-Referencing Methodology

Series 8100 Aethalometer™ Module

- Continuous Black Carbon (BC) Analyzer for the TEOM Monitor

www.rpco.com

Rupprecht & Patashnick Co., Inc.

Feb 06

FEATURES SHEET

TEOM® SERIES 1400A AMBIENT PARTICULATE MONITOR

The Series 1400a monitor has the following features:

- Incorporates Thermo's "AB" technology for enhanced measurement stability–ideal for mobile installations. Alternate configurations for specialized applications: Sample Equilibration System (SES) and Series 8500 Filter Dynamics Measurement System (FDMS™ Unit).
- Filter-based direct mass monitoring using Thermo's patented TEOM® technology that *never* requires mass recalibration. The instrumentation contains *no* radioactive components. Industry-leading 2 year warranty.
- The only continuous dust monitor with USEPA approval (EQPM-1090-079) that complies with the California ARB 1-hour acceptance criteria for mass concentration precision. TEOM instrumentation has German EPA approval for TSP and PM-10 measurements.
- Unsurpassed mass and time resolution (mass transducer minimum detection limit of 0.01 μg). Precision of ±5.0 $\mu g/m^3$ for 10-minute averaged data and ±1.5 $\mu g/m^3$ for 1-hour averages.
- ActiVol™ flow control system maintains a constant volumetric flow at the flow rate specified by the user by incorporating ambient pressure and temperature sensors.
- NIST-traceable audit/calibration of mass determination and flow rate.
- Available with a choice of sample inlets for PM-10, PM-2.5, PM-1 or TSP measurements.
- Sample filters can be analyzed after exposure for heavy metals with laboratory techniques such as AA or ICAP.
- Flexible viewing and entry of instrument parameters made possible by a menu-driven user interface. Keypads are available in English, Spanish and German.
- Internal data logging of up to 40 weeks with one variable stored every hour. Each record may contain up to eight user-selectable variables.
- Three real-time analog outputs (0-1, 0-2, 0-5 or 0-10 VDC), and two user-defined contact closures alarm circiuts.
- Two levels of password protection–low and high lock. These can be used to restrict access to instrument functions.
- Advanced RS-232 support. This allows users to retrieve real-time and stored information and change instrument parameters, both remotely and at the sampling location.
- Seven built-in averaged analog inputs (scalable as ±2 or ±10 VDC) with user-defined conversions to engineering units. The averaging time is equal to the user-defined data storage interval. Averaged values may be logged internally.
- Analog inputs from a wind vane/anemometer are used to compute averaged wind speed, and vector-averaged velocity and direction.
- Built-in support for the optional ACCU™ system. The ACCU system is an intelligent sampler that offers the user great flexibility in the sampling of particulate and/or gases through filter cartridges or gas collection tubes.

TEOM® is a registered trademark of Thermo Electron Corporation. Activol™ and ACCU™ are trademarks of Thermo.

11. VIG Industries Hydrocarbon Analyzer

Heated Methane / NonMethane / Total Hydrocarbon Analyzer (NMHC)

Model-200

The VIG Industries, Inc. Model-200 is a microprocessor based, oven heated methane / nonmethane / total hydrocarbon gas analyzer designed for high accuracy, sensitivity and stability. The Model-200 uses two independent flame ionization detectors (FIDs), one to measure total hydrocarbons and the second coupled with a GC Column for the separation of the methane and nonmethane components. A sample is fed to the analyzer via an internal heated pump to the first FID for a real time total hydrocarbon reading. A portion of the sample is trapped and pushed through a column to separate the methane component and then to the second FID. Any remaining sample in the column is back flushed through the column to obtain the nonmethane component. All components that come in contact with the sample through analysis are maintained in a temperature-controlled oven to prevent condensation, and to provide repeatable, reliable performance in the analysis of a wide variety of hydrocarbon concentrations in gaseous mixtures or in ambient air.

Features

- Easy to use software
- Automatic start-up/ignition
- Heated sample pump heads
- Two stage sample filter with exchangeable sintered stainless steel elements
- Teflon isolated detectors (FIDs)
- Automatic fuel shut-off system
- Automatic flame-out indicators
- Adjustable alarm and oven settings
- Precision 1% of full scale
- 19" rack/bench mount

Options

- 4-20mA output - no extra charge
- Zero and calibration solenoids with software
- RS-232 interface
- Internal combustion air supply

Related Available Equipment

- Zero air generator (Reduces bottles)
- Hydrogen generator (Reduces bottles)
- Heated sample lines and controllers
- Strip chart recorders and data loggers
- NEMA rated enclosures

Applications

- *Compliance Monitoring* - U.S. E.P.A. Method 18 and Method 25A
- *Process Monitoring* - Continuous monitoring and alarm or control of: process gas streams utilizing organic solvents, crude oil, and other chemicals containing hydrocarbons.
- *Efficiency Monitoring* - Monitoring effluent of volatile organic compound (VOC) reduction equipment for environmental compliance, efficiency control of incinerators (Thermal or catalytic), scrubbers, carbon absorbers, and other abatement equipment, monitoring of catalytic converters, combustion and diesel engine efficiency.
- *Safety Monitoring* - Lower explosive limit (LEL) monitoring and/or control of ovens/dryers, fugitive emissions monitoring, personnel work area monitoring, leak detection of process equipment or solvent storage areas.
- *Stack Monitoring*

VIG INDUSTRIES, INC.

4051 E. La Palma #C Anaheim, CA 92807 • Toll Free (800)862-7844 • Phone (714)632-8200 • Fax (714)632-8201 • http://www.vigindustries.com

Standard Specifications

Measuring Method - 2 Oven Heated, Flame Ionization Detectors (FIDs)
Separation Method - GC Column
Measurement Range/Standard Ranges - (4 Ranges per amplifier, 2 amplifiers per analyzer, 1 amplifier for total and 1 amplifier for methane and nonmethane)
- 0-10, 0-100, 0-1000, 0-10000ppm (Lower detection limit 0.01ppm) or
- 0-100, 0-1000, 0-10000, 0-100000ppm (Lower detection limit 0.1ppm)
- Other ranges available upon request

Zero & Span Noise - Less than 0.2% of full scale
Zero & Span Drift - +/- 1% full scale per 24 hours
Linearity- Within 1% of full scale through all ranges
Repeatability - Within 1% of full scale through all ranges
Stability - Within 1% of full scale through all ranges
Oxygen Synergism - Within 1% of full scale within selected range
Response Time
- Total - Within 5 seconds to 90% of final reading (Continuous real time reading)
- Methane - Approximately 40 seconds, updated every 3 minutes
- Nonmethane - Approximately 70 seconds, updated every 3 minutes

Ambient Temperature - From 50°F to 120°F
Flow Rate - 4 Liters/Minute (Standard) or 10 Liters/Minute (Upon request)
Physical Dimensions - 19" Wide Front Panel, 16.75" Wide Chassis, 24" Deep Chassis, 27" Deep with fittings and handles, 9" High
Weight - 55 lbs to 65 lbs depending on options
Oven operating temperature - 275°F (Adjustable from 200°F to 300°F)
Safety - Flame-Out indicator lamp, flame-out alarm contacts on back panel, fuel shut-off, calibration and zero solenoid shut-off
Voltage Outputs - One of the following voltage outputs
- 0-10VDC (Standard), 0-1VDC or 0-5VDC (Optional – no extra charge)

Current Outputs - 4-20mA, Sourcing (Optional – no extra charge)
Flame-Out Alarms - Normally open, low current relay contacts (Close on alarm, latching)
Concentration Alarms - Normally open, low current relay contacts (Close on alarm, latching)
Ignition - Automatic (Can be set to manual by operator from front panel)
Glow Plugs - Main and spare glow plugs installed (Selectable by switch on back panel)
Warm-up Time
- Usable in approximately 45 minutes
- Stable in approximately 2 hours

Display - Graphic, backlit, 240W x 64H pixels, high contrast, wide viewing angle

Operation Requirements

Fuel - UHP Hydrogen @ 18psi incoming pressure
Combustion Air - Oil/Water/Hydrocarbon free instrument air @ 18psi incoming pressure
Zero Calibration Gas - UHP zero grade air or nitrogen @ 9psi incoming pressure
Span Calibration Gas - Known concentration of operator selected hydrocarbons balanced in either air or nitrogen @ 9psi incoming pressure (VIG recommends using a mixture of methane and propane balanced in air to save calibration time)
Carrier Gas - UHP nitrogen @ 30psi incoming pressure
Compressed Air - Oil/Water free air @ 50psi incoming pressure for column switching valve
Power Requirements - 115VAC @ 60Hz @ 720Watts or optional 220VAC @ 50Hz

Warranty

All instruments sold by VIG Industries, Inc. are warranted for a period of one (1) year from date of purchase against defects in materials and workmanship. The seller warrants that the product supplied conforms to the specifications assigned thereto. There is no other warranty either expressed or implied. Seller liability is limited specifically to the cost or assigned value of the items sold. Service contracts are available after the warranty expires.

12. Rotem RSC-2 Poultry Scale System

ROTEM

Take Control!

COMPUTERIZED CONTROLLERS

RSC-2

Automatic Live Bird Scale

For Broilers, Breeders, Pullets and Turkeys. Special program that weighs males and females separately, providing separate data on the same platform.

The RSC-2 is a stand-alone live bird scale center. It assures continuous accurate daily data collection of average bird weight, number of weighings, daily weight gain, standard deviation, CV and uniformity.

The RSC-2 can handle up to two bird scale platform placed on the litter in the same or different houses. It is very simple to use. Rotem's unique user-friendly Scale Center uses easy to understand menu.

The sophisticated software can accurately weigh the birds even if more than one bird is stepping on the platform at the same time.

You can link an unlimited number of Rotem bird scale centers to a nationwide communication network, controlled by one central PC via modem, using Rotem's advanced communication program for Windows.

The platforms are made of a high quality stainless steel and are completely sealed to prevent any damage to the excellent load cells installed inside. Rotem uses high quality cables to ensure long life in the harsh litter environment.

Features:

- Up to two bird scales.
- Five digit display.
- Up to 500 days data collection.
- User friendly 3 key programming.
- Weight displayed in Kg. or Lb.
- 115 / 230 VAC operation.
- Local or remote modem PC communication.
- Unerasable memory.
- Power surge protection.
- Water and dust resistant enclosure.
- Simple installation.

ISO 9001-2000
IQC

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Computerized Controllers

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Petach Tikva 49511
ISRAEL
Tel: +972-3-9206200
Fax: +972-3-9249834

www.rotem.com E-mail: rotem@rotem.com

13. Barometric Pressure Sensor

WATER

WE100 Barometric Pressure Sensor

- 4-20 mA output
- Marine grade cable with strain relief

Description

Global Water's highly accurate Barometric Pressure Sensor covers a pressure range from 800 to 1100 mb. The barometric pressure indicator is fully temperature compensated within an operating range of -40° to 65° C. The sensor is mounted on 25' of marine grade cable, with lengths up to 500' available upon request. The sensor output is 4-20 mA with a two wire configuration.

Specifications

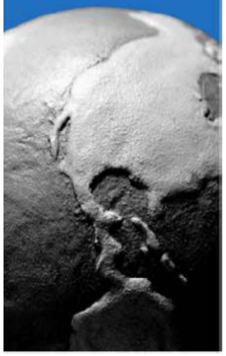
Output: 4-20 mA
Range: 800-1100 mb
Accuracy: ±1% of full scale
Linearity/Hysteresis: ± 0.1%
Operating Voltage: 10-36 VDC
Current Draw: Same as sensor output
Warm Up Time: 3 seconds minimum
Operating Temp: -40° to +55°C
Sensor Size: 3"x2"x1"
Weight: 0.13 lb.

Price List

WE100
Barometric Pressure Sensor.......$375

WQEXC Extra Cable
Cable length is measured from end of cable to bottom of sensor.
After 25', up to 500'...........................$1.10/ft

Contact Global Water for all your instrumentation needs:
Water Level
Water Flow
Water Samplers
Water Quality
Weather
Remote Monitoring
Control



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Appendix V: Project Team Vitas

Robert Thomas Burns, Ph.D., P.E., CCA

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Education:

Ph.D. in Civil Engineering. Environmental Engineering specialization. University of Tennessee, Knoxville. May 1995. GPA: 3.91/4.00. Dissertation title - Impact of Electric Vehicles on Ozone Formation in the Middle Tennessee Area.

M.S. in Environmental Engineering. Air Quality Management/Pollution Control concentration with a minor in mixed waste management. University of Tennessee, Knoxville. May 1992. GPA: 4.00/4.00 Thesis title - Preparation of Air Pollution Emission Inventories for Stationary Sources.

B.S. in Agricultural Engineering. Soil and Water Conservation concentration. University of Tennessee, Knoxville. May 1990.

Professional Experience:

Associate Professor, Iowa State University. Joint appointment between extension (55% appointment) and research (45% appointment). Environmental engineering specialization, including the design of animal waste management systems and nutrient management planning for livestock and poultry operations. August, 2004 - Present.

Associate Professor, University of Tennessee, Knoxville. Joint appointment between The Tennessee Agricultural Extension Service (70% appointment) and The Tennessee Agricultural Experiment Station (30% appointment). Environmental engineering specialization, including the design of animal waste management systems and nutrient management planning for livestock and poultry operations. July, 2000 – July, 2004.

Assistant Professor, University of Tennessee, Knoxville. Tennessee Agricultural Extension Service Water Quality Specialist, 100% Extension service appointment. June 1995 - 1998. Joint appointment (70% extension and 30% research). 1998 - July, 2000.

Research Associate, University of Tennessee, Knoxville. Civil & Environmental Engineering Air Pollution Control Laboratory. Full-time staff position. Worked directly with EPA and State agencies in the preparation of air pollutant emission inventories and computer modeling of ozone formation (EKMA and UAM modeling). 1992 - 1995.

Environmental Engineer, Sverdrup Technology Inc., Tullahoma, Tennessee. Responsible for identifying and classifying waste streams, and monitoring RCRA 90 day hazardous waste storage facility. Maintained Sverdrup air permits at Arnold Engineering Development Center facility. 1992.

Professional Registration:

Registered Professional Engineer in Tennessee (P.E. # 102322)

Certified Crop Advisor (CCA) in Tennessee (CCA # 34046)

USDA - NRCS Certified Technical Service Provider for CNMP Plan Development

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Grantsmanship:

Grants Funded

4/06 – 6/06. Training Workshop on Good Farming Practices to Reduce Environmental Pollution in Bulgaria. *R.T. Burns, R.S. Kanwar and E. Becerra. $35,000 awarded by the USDA.*

4/06 – 12/06. *Development of a Database for Environmental Management Practices Employed at Pork Production Facilities*. R.T. Burns, L. Moody, D. Raman, L. Meyer. $103,002 awarded by the National Pork Board.

03/06 – 02-07. *Laying hen manure characteristics and air emissions as affected by genetic strains.* H. Xin, R.T. Burns & Arthur. $27,160 awarded by MPRP and Hy-Line.

01/06 – 06-07. *Field verification of dietary manipulation on ammonia emission and hen performance in high-rise layer houses.* H. Xin, R. Burns & K. Bregendahal. $150,000 awarded by Eco-Cal Products and Iowa Egg Council.

2/06 – 12/06. *Bio-fuel Production from Bio-Dried Animal Manure to Improve Iowa Livestock Production Economy, Part 2 Farm scale biodrying of bedded back swine manure..* S. Sadaka, R.T.Burns & M. Hanna. 110,000 awarded by the Iowa State University Biotechnolgy Bioproducts Consortium.

10/05 – 10/07. *Total Suspended Particulate, PM10, PM2.5, Hydrogen Sulfide and Hydrocarbon National Consent Agreement Emissions Determination from Broiler Production Systems.* R.T. Burns, H. Xin, R. Gates and S. Hoff. $648,231 awarded by Tyson Foods.

10/05 – 9/07. *Development and Integration of A National Feed Management Education Program and Assessment Tools into a Comprehensive Nutrient Management Plan (CNMP)*. Joe Harrison, Alan Sutton, Galen Erickson, Robert Burns. $425,000 awarded by the USDA-NRCS Conservation Initiative Grant program.

9/05 - 9/09. *A National Learning Center for Animal Agricultural Water Quality Issues.* R. K. Koelsch, Frank Humenik, Mark Risse, Joe Harrison (R.T. Burns is project contributor). $300,000 awarded by the USDA 406 Water Quality Program.

9/05 – 9/06. *Bio-fuel Production from Bio-Dried Animal Manure to Improve Iowa Livestock Production Economy.* S. Sadaka, R.T.Burns & M. Hanna. $80,000 awarded by the Iowa State University Biotechnolgy Bioproducts Consortium.

7/05 – 6/06. *Monitoring of Alternative Technolgy Systems Using Setteling Benches For Beef Feedlot Run-off Control.* R.T.Burns, J.D. Lawrence, L.B. Moody. $100,000 awarded by the Iowa Department of Agriculture and Land Stewardship.

6/05 – 6/06. *Pathogen Monitoring from Alternative Beef Feedlot Run-Off Control Systems*. R.T. Burns, L.B. Moody and J.D. Lawrence. $30,000 awarded by the U.S. EPA.

5/05 – 11/08. Non-basin Technologies For Open Feedlot Runoff: Demonstration, Implementation, And Modeling. R.T. Burns, J.D. Lawrence, L.B. Moody and M.J. Helmers. $632,367 awarded by the Iowa Cattlemen's Association.

3/05 – 9/06. *Ammonia Emissions Determination from Broiler Production Systems.* R.T. Burns, H. Xin and R. Gates. $399,525 awarded by Tyson Foods.

9/03 - 9/06. *Development of A CNMP Core Training Curriculum.* R.T. Burns, L. B. Moody, N. Rector, A. Sutton and R. Sheffield. $290,000 awarded by the USDA 406 Extension Education Program.

12/03 – 12/06. *Concentration and Extraction of Phosphorus from Swine Manure Slurries.* R.T. Burns, L. B. Moody, F. R. Walker, W. M. Park, and J. R. Buchanan. $168,000. Awarded by USDA/NRI.

05/02 – 12/03. *Control of Ammonia and Litter Pathogen Levels in Broiler Production Facilities Treated with Alum as a Litter Amendment.* R.T. Burns, F.A. Draughon, L.R. Wilhelm and F.R. Walker. $27,914 awarded by the General Chemical Corporation.

07/01 – 06/02. *Animal Waste System Design Workshop.* R.T. Burns. $26,850 awarded by the Tennessee Department of Agriculture.

07/01 – 06/02. *Dairy Waste Management Field Day.* R.T. Burns., F.R. Walker, T. Woods, and J. Goddard. $12,540 awarded by the Tennessee Department of Agriculture.

7/01 – 7/03*. On-farm Demonstration of the Use of Aluminum Sulfate as an in-house amendment for Poultry Litter.* Walker, F.R., and R.T. Burns. $45,030 awarded by the TN 319 Pollution Control Program.

7/01 – 7/03. Control of Ammonia and Litter Pathogen Levels in Broiler Production Facilities Treated with Alum as a Litter Amendment. R.T. Burns., A. Draughon, F.R. Walker, L. Wilhelm. $25,625 awarded by the Food Safety Center of Excellence.

Grants Funded (continued):
11/00 – 01/04. *Agricultural Engineering Water Quality Technical Support.* R.T. Burns. $225,000 awarded by the Tennessee Department of Agriculture.

07/00 – 06/01. *Animal Waste System Design Workshop.* R..T. Burns. $50,608 awarded by the Tennessee Department of Agriculture.

01/00 - 12/00. Walker, F.R., and R.T. Burns. *Demonstration of Phosphorus Binding in Swine Waste using Alum*. $10,000 awarded by the Tennessee Department of Agriculture.

11/99-11/01. Raman, D. R., A.C. Layton, M.D. Mullen, R.T. Burns and G. S. Sayler. *Quantifying and minimizing 17 Beta-estradiol emissions from dairy and swine*. $215,500 awarded by the USDA / NRI.

3/99 B 8/00. Raman, D. R., and R. T. Burns. *High-Rate Anaerobic Pretreatment of Animal Wastewater : Impact on Traditional Anaerobic Animal Waste Treatment System Performance and Economics.* $38,680 awarded by The United States Geological Service Water Resources Research Program.

07/99 - 06/00. R.T Burns and H.H. Dowlen. Dairy Manure Solids Separation project: Animal Waste Management Information & Education Project. $7,000 awarded by The Tennessee Department of Agriculture.

07/98 - 06/99. R.T. Burns, R.E. Yoder, M.J. Buschermohle, and G.S. Honea. *Soil Moisture Measurement of Plasticulture on Tomatoes and Cantaloupes.* UT Vegetable Initiative grant request. $1,800 awarded by the Knox Experiment Station. Work Plan Number TN-050-KES-02.

07/97 - 06/98. R.T. Burns and M.J. Buschermohle. *Alternative Livestock Watering Systems for Limited Access Situations*. $5,000 awarded by The Tennessee Department of Agriculture.

07/97 - 06/98. R.T. Burns and R.E. Yoder. *Soil Moisture Measurement Equipment for Irrigation Scheduling at Knoxville, Crossville, Greenville.* UT Vegetable Initiative grant request. $2,500 awarded by the Knox Experiment Station. Work Plan Number TN-050-KES-01.

07/97 - 06/98. R.T. Burns, R.E. Yoder, and M.J. Buschermohle. *Soil Moisture Data Monitoring in Support of TN-058-KES-01-1 and TN-058-KES-24-1.* UT Vegetable Initiative grant request. $5,400 awarded by the Knox Experiment Station. Work Plan Number TN-050-KES-02.

07/97 - 06/98. R.T. Burns and R.E. Yoder. *Drip Irrigation Filter Demonstration System Plant Sciences Unit - Knoxville.* UT Vegetable Initiative grant request. $5,500 awarded by the Knox Experiment Station. Work Plan Number TN-050-KES-03.

07/97 - 06/98.. R.T. Burns and R.E. Yoder. *Drip Irrigation Fertigation Demonstration System Plant Sciences Unit - Knoxville.* UT Vegetable Initiative grant request. $2,400 awarded by the Knox Experiment Station. Work Plan Number TN-050-KES-04.

10/96 - 09/97. R.T. Burns. Funding to support the Level II Agent In-Service *Animal Waste Management Training. Environmental Education Project*. Course taught in Spring 1997. $5,000 awarded by the U.S. Environmental Protection Agency.

07/96 - 06/97. R.T. Burns. Applied research work in swine waste manure application: *Application of Swine Waste*. $4,000 awarded by the Tennessee Department of Agriculture.

07/95 - 06/97. Yoder, R.E., D.C. Yoder, C.R. Mote, M.J. Buschermohle, R.T. Burns and N.S. Eash. *Cattle Access to Streams: Research and Demonstration.* $22,400 awarded by The Tennessee Department of Agriculture.

Web Site Development:

Iowa State University Animal Waste Management Website co-developed by Lara B. Moody and R.T. Burns. 2004 - Present. Web address: http://www.iastate.edu/

University of Tennessee Animal Waste Management Website co-developed by Lara B. Moody and R.T. Burns. 2001 - 2004. Web address: http://wastemgmt.ag.utk.edu/

Short-Courses Developed:

Training Workshop on Good Farming Practices to Reduce Environmental Pollution in Bulgaria. *May 27-30, 2006. Sofia, Bulgaria. R.T. Burns Course Co-Coordinator.*

Comprehensive Nutrient Management Plan Development Course. Feb. 13-15, 2005. Kansas City, MO. R.T. Burns Course Coordinator.

Comprehensive Nutrient Management Plan Development Course. Nov. 15-17, 2005. Portland, OR. R.T. Burns Course Coordinator.

Anaerobic Treatment of High-Strength Industrial and Agricultural Wastes. September 22-23, 2005 Milwaukee, WI. R.T. Burns course Co-Coordinator with D. Zitomer (Marquette University).

Comprehensive Nutrient Management Plan Development Course. Nov. 16-18, 2004. Indianapolis, IN.. R.T. Burns Course Coordinator.

Comprehensive Nutrient Management Plan Development Course. Feb. 12-14, 2003. Nashville, TN. R.T. Burns Course Coordinator.

Anaerobic Treatment of High-Strength Industrial and Agricultural Wastes. Feb. 19-20, 2004 Nashville, TN. R.T. Burns course Co-Coordinator with D. Zitomer (Marquette University).

Comprehensive Nutrient Management Plan Development Course. Nov. 17-19, 2003. Knoxville, TN. R.T. Burns Course Coordinator.

NRCS Anaerobic Treatment of Agricultural Wastes. Nov. 3-5, 2003 Nashville, TN. R.T. Burns Course Coordinator.

Anaerobic Treatment of High-Strength Industrial and Agricultural Wastes. Sept. 22-23, 2003. Milwaukee, WI. D. Zitomer (Marquette University) course Co-Coordinator with R. T. Burns.

Anaerobic Treatment of High-Strength Industrial and Agricultural Wastes. April 7-8, 2003. Knoxville, TN. R.T. Burns course Co-Coordinator with D. Zitomer (Marquette University).

Comprehensive Nutrient Management Plan Development Course. Feb. 12-14, 2003. Nashville, TN.. R.T. Burns Course Coordinator.

Animal Waste Management Systems: Comprehensive Nutrient Management Plan Development Course. Feb. 20-22, 2002. Nashville, TN. R.T. Burns Course Coordinator.

Manure Utilization Planning for CAFOs. July 28, 2001 Sacramento, CA. Continuing Professional Development Course (CPD) taught at 2001 ASAE meeting. R.T. Burns Course Coordinator.

Animal Waste Management Systems: Comprehensive Nutrient Management Plan Development Course. Feb. 19-21, 2001Nashville, TN Feb. R.T. Burns Course Coordinator.

Animal Waste Management Training: Level II Agent In-Service . March (Taught over a five week period), 1997 Nashville. R.T. Burns Course Coordinator.

Professional Service:

Iowa State University CNMP TSP Certification Program:
Serve as the Designated Technical Leader for the ISU Comprehensive Nutrient Management Plan Technical Service Provider certification program. Iowa State University serves as a national certification program from the United States Department of Agriculture. (2004 - Present).

Tennessee CNMP Third Party Certification Program:
Serve as the Designated Technical Leader for the Tennessee Comprehensive Nutrient Management Plan Technical Service Provider certification program. The University of Tennessee Agricultural Extension Service serves as a national certification program from the United States Department of Agriculture. (2000 - 2004).

Proceedings Chair - ISAAFPW 2003
Served as proceedings chair for The Ninth International Symposium on Animal, Agricultural and Food Processing Wastes held in Raleigh, NC on October 11-14, 2003.

ASAE Committee Service:

T-09 *Environmental Quality Group* member.
SE - 412 *Structures & Environment* committee member, Chair 2004 / 05 Vice Chair 2003 / 04, Secretary 2003 / 04, Session Chair - 2001 ASAE International Meeting
P - 414 *Professional Engineering Licensure* member, Chair for 2003 / 2005 (two -year term)
414 Vice-Chair 2001 - 2003

ASAE Manure Utilization Planning for CAFOs Short-Course:
Coordinated an ASAE national short-course titled "Manure Utilization Planning for CAFOs " held in conjunction with the 94th International ASAE meeting in Sacramento, CA in July, 2001.

2006 Chair - Iowa Section of the ASAE
Served as 2005 Chair of the Iowa Section of ASAE.

2005 Vice Chair for Programs - Iowa Section of the ASAE
Served as 2005 Chair of the Iowa Section of ASAE.

2002 Chair - Tennessee Section of the ASAE
Served as 2002 Chair of the Tennessee Section of ASAE.

Southern Region Chair - National Animal Waste Initiative
Served as the 2001-2002 Southern Region Chair of the National Animal Waste Initiative.

USDA Grant Reviews:

Served as a member of the 2004 USDA Conservation Effects Assessment Program CSREES competitive grant review panels held in Washington, DC.

Panel Manager for the 2002 USDA 406 Water Quality CSREES competitive grant review panel.
Served as a member of the 2000 and 2001 USDA 406 Water Quality CSREES competitive grant review panels held in Washington, DC.

Provide reviews of NRI and SBIR grants within the water quality area on request. 1999 – present.

Preparation of the PE Exam:

Assist with preparation of the national professional engineers exam (Agricultural Engineering exam). 1998 – Present.

Membership on Graduate Degree Candidate Committees: As Major Professor:

Timothy Shepard M.S., Agricultural Engineering In-Progress
Thesis Title: Development of a Pilot-Scale Struvite Recovery System for Phosphorus Recovery from Swine Manure Slurries.

Ishadeep Khanijo M.S., Agricultural Engineering In-Progress
Thesis Title: Modeling and Monitoring of Alternative Technology Beef Feedlot Run-Off Control Systems.

Ipek Celen Ph.D., Biosystems Engineering In-Progress
Dissertation Title: Optimization of Phosphorus Precipitation from Swine Manure Slurries to Enhance Recovery.

Ken Armstrong M.S., Biosystems Engineering Technology Completed 2003.
Thesis Title: Effect of Alum addition to Broiler Litter on Pathogen levels, Soluble Phosphorus and In-house Ammonia Levels on Broiler Production Systems.

Adam Daughtery M.S., Biosystems Engineering Technology Completed 2001
Thesis Title:: Economic Comparison of Animal Waste Transport and Application Methods.

Membership on Graduate Degree Candidate Committees: As Committee Member:
Asli Isci Ph.D. Agricultural Engineering In-Progress
Comparison Of Environmental Impacts Of Biofuel Production From Different Biomasses

Hong Li Ph.D. Agricultural Engineering In-Progress
Dissertation Title: Gaseous Emissions from Stored Poultry Manure

Wei Wu M.S., Animal Science In-Progress
Thesis Title: Influence of Diet on Ammonia and Hydrogen Sulfide Emissions from Laying Hens

Elizabeth Williams M.S., Biosystems Engineering Technology Completed 2003.
Thesis Title: Presence of 17-Beta Estradiol and Estrone in Dairy and Swine Manures.

Alexandra Maria Pinto Ph.D. Biosystems Engineering Completed 2001
Dissertation Title: Fuzzy-Logic Based Toxicity Detector for Upflow Anaerobic Sludge Bed Reactors.

A. Renea Peters M.S., Biosystems Engineering Technology Completed 2001
Thesis Title:: Runoff Masses of 17-Beta Estradiol from Plots Amended with Dairy Manure.

Theresa Louise Ervin M.S., Biosystems Engineering Completed 2001
Thesis Title:: Reservoirs of *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Salmonella* species on a Tennessee dairy farm.

Gary Hawkins Ph.D. Biosystems Engineering Completed 2000.
Dissertation Title: Kinetics of High-Rate Anaerobic Digestion of Dairy Waste.

Catherine R. Mayhew M.S., Biosystems Engineering Technology Completed 1999.
Thesis Title: *Mosquito Control and Pollutant removal in Constructed Wetlands: A Mesocosm Study Using Dairy-Wastewater.*

Jeffery Russell Powell M.S., Biosystems Engineering Technology Completed 1998.
Thesis Title: *Water Quality and Ecological Impacts of Watering Cattle Adjacent to a Small Middle Tennessee Stream.*

Joseph Cole Reagan M.S. Biosystems Engineering Technology Completed 1997.
Thesis Title: *An Examination of Methodologies to Assess High-Resolution Noninvasive Sensing of Near-Surface Perched Water.*

International Experience:

Republic of Korea.
Named a Senior Scientist in the Livestock Waste area for a three year term by The National Livestock Research Institute, RDA, South Korea, beginning in 2005. Provide consultation to the Animal Science Research Institute in the Republic of Korea on the development of a 100,000 head swine finish facility.
2004. Seoul National University - Invited Speaker. Presented lectures on Developing Sustainable Animal Production Systems. 2004 and 2005.
Konkuk University - Invited Speaker. Presented lectures on Environmental Engineering Aspects of Animal Production Systems. 2005. Chungju, South Korea.

Zambia. Mpongwe Development Company - Agricultural engineering support in the areas of post-harvest grain drying / storage and irrigation expansion planning for Mpongwe Development Company (MDC). The MDC operates the largest arable farm (60,000 ha) in Africa. The farm is operated in north central Zambia under a partnership between the Commonwealth Development Corporation and the Government of Zambia. 2003.

Consulting: Have provided agricultural and environmental engineering consulting services to various groups including the U.S. EPA, Mopongwe Development Corporation, America's Clean Water Foundation, The Tennessee Department of Environment and Conservation as well as numerous individuals and farming operations.

Membership in Professional and Honorary Societies

Air and Waste Management Association

American Society of Agricultural Engineers

American Society of Engineering Educators

Chi Epsilon (National Civil Engineering Honor Society)

Tau Beta Pi Engineering Honor Society (National member and Alpha Chapter member)

Phi Kappa Phi Honor Society (National Member and UTK Chapter member)

Gamma Sigma Delta (Honor Society of Agriculture)

Honors & Awards:

- **2006 Iowa Section of the ASABE Young Engineer of the Year.** Presented by the Iowa Section of the American Society of Agricultural and Biological Engineers to recognize an outstanding engineer less than 40 years of age in the Iowa Section.
- **2005 Honorary Senior Scientist.** Named a Senior Scientist in the Livestock Waste area for a three year term by The National Livestock Research Institute, RDA, South Korea.
- **2003 Nolan Mitchell Young Extension Worker Award**. Awarded by the American Society of Agricultural Engineers for distinguished educational programming in the areas of water quality and animal waste management.
- **2003 NACAA "Learning Module" National Winner Award**. Presented by the National Association of County Agricultural Agents, R. T. Burns, L. Moody and G. Grandle for the Comprehensive Nutrient Management Plan (CNMP) Certification Program Notebook.
- **2002 ASAE Blue Ribbon Award**. Awarded by the American Society of Agricultural Engineers in the Extension Methods Category for the TN CNMP Certification Program for TSPs. 2002.
- **2001 Outstanding Young Agent**. Awarded by the Tennessee Association of Agricultural Agents and Specialists. 2001.
- **Best Publication.** 1st Place statewide winner for best extension publication recognized

by the Tennessee Association of Agricultural Agents and Specialist for *Solar Livestock Watering Systems*. (PB 1640 Co-authored with M.J. Buschermohle). April, 2000.

- **Outstanding Speaker** by USDA-NRCS for paper *Mass Balance Approach to Long Term Nutrient Management Planning* at the Southeast Animal By-Product Utilization Workshop. September 3, 1999.
- **Epsilon Sigma Phi State Team Award -** Member of the Sustainable Dairy Systems Team that received the 1998 Epsilon Sigma Phi State Team Award. 1998.
- **Tennessee Higher Education Environmental Stewardship Award**. Member of the Extension Environmental Stewardship Priority Team that received the 1998 award.
- **Friend To CFW** - Award given by the Coffee-Franklin-Warren Animal Waste Utilization Association for Continued Support and Interest to the Association's Dairy and Swine Producers. 1998.
- **Exceptional Service Award**. Presented by The University of Tennessee Department of Civil and Environmental Engineering. 1995.
- **Undergraduate Student with Professional Promise -** Recognition awarded by the faculty of the University of Tennessee Agricultural Engineering Department. 1990
- **ASAE Student Honor Award** - Tennessee Student Engineering Branch. Given in Recognition of Conspicuous Student Activity. 1990.

Hongwei Xin, Ph.D., Professor

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Education

Ph.D.	Engineering (Bio-environmental Engineering Field) University of Nebraska-Lincoln (UNL), Lincoln, NE	1989
M.S.	Agricultural Engineering, UNL, Lincoln, NE	1985
B.S.	Agricultural Engineering, Shenyang Agr University, China	1982

Professional Experience

2002 – present	*Professor*, Department of Agricultural and Biosystems Engineering, Iowa State University (ISU), Ames, Iowa
2002 – present	Courtesy appointment, Department of Animal Science, ISU
1998 – 2002	*Associate Professor*, Department of Agricultural and Biosystems Engineering, ISU
1993 – 1998	*Assistant Professor*, Department of Agricultural and Biosystems Engineering, ISU
1990 – 1993	*Post-doctoral Research Associate*, Department of Biological and Agricultural Engineering University of Arkansas, Fayetteville, Arkansas
1990	*Post-doctoral Research Associate*, Department of Biological Systems Engineering, University of Nebraska-Lincoln (UNL), Lincoln, Nebraska
1984 – 1989	Graduate Research Assistant, Department of Agricultural Engineering, UNL
1982 – 1983	Instructor, Department of Agricultural Engineering, Shenyang Agr University, China

Research (70%) and Extension (30%) Activities

Impacts of biophysical factors on production performance, bioenergetics, behavior, physiology, and well-being of livestock and poultry; application of biosensors for enhanced animal well-being and production sustainability; livestock and poultry housing systems; and air quality issues related to concentrated animal feeding operations with emphasis on quantification and mitigation of aerial pollutant emissions.

Selected Awards and Honors

- Chair of the United Egg Producers Environmental Scientific Panel on Air Emissions (July 2004 –)
- Honorary Scientist of the Rural Development Administration of the Republic of Korea (2004-2006)
- Member of EPA National Air Emission Study Advisory Committee (2003-2004)
- New Holland Young Researcher Award of the ASAE (2001)
- Young Member of the Year Award, Mid-Central Section of the ASAE (2001)
- Young Engineer of the Year Award, Iowa Section of the ASAE (2001)
- Research Award for Foreign Specialist, Ministry of Ag, Forestry and Fisheries, Japan (2000)
- Invited member of USDA delegation to China for assessing environmental issues related to intensive animal production (2000)
- Eight ASAE Superior & Honorable Mention Paper Awards (1997 – 2005)
- Newcomer Engineer of the Year Award, Iowa Section of the ASAE (1997)
- Honorary Professor of the Chinese Academy of Agricultural Sciences (1998)
- Honorary Professor of China Agricultural University (1996)
- ASAE Educational Blue Ribbon Award (1995)

- Invited speaker at 20+ national conferences (USDA, ASAS, ASSP, Midwest Poultry Federation, United Egg Producers) and 20+ international conferences/ workshops (Belgium, Brazil, China, Costa Rica, France, Holland and Japan) (since1995)
- Sigma Xi Scientific Research Society Travel Award (1987)
- University of Nebraska Widaman Trust Distinguished Graduate Student Award (1986)

Publications

82 refereed journal articles, 40+ invited talks, 50+ conference proceedings, 120+ technical papers and presentations, 40+ extension publications

Contracts and Grants

Principal investigator (PI), Co-PI or collaborator of over $6.6 millions competitive grants for research, extension and undergraduate education.

Graduate students, post-docs, and visiting professors mentored/hosted

18 graduate students (9 MS, 9 PhD); 6 post-doc/research associates; 12 visiting professors/researchers

Refereed Journal Publications (2000-2006) (in chronological and alphabetical order)

1. Cai, L., J. A. Koziel, J. D. Davis, Y. C. Lo, and **H. Xin**. Characterization of VOCs and odors by *in vivo* sampling of beef cattle rumen gas using solid phase microextraction and gas chromatography-mass spectrometry-olfactometry: implications for gaseous emissions from concentrated animal feeding operations. *Journal of Chromatography* (in review)
2. Cai, L., J. A. Koziel, Y. Liang, A.T. Nguyen, and **H. Xin**. Evaluation of zeolite for control of odorants emissions from simulated poultry manure storage. *Journal of Environmental Quality* (in review)
3. Casey, K.D., R.S. Gates, E.F. Wheeler, **H. Xin**, Y. Liang, A.J. Pescatore, and M.J. Ford. On-farm fan performance: implications for ventilation and operating cost. *Applied Poultry Res.* (in review)
4. Casey, K.D., R.S. Gates, E.F. Wheeler, **H. Xin**, Y. Liang. Quantifying uncertainty in whole-building ammonia emissions from mechanically ventilated broiler houses. *Transactions of the ASAE* (in review).
5. Casey, K.D., R.S. Gates, E.F. Wheeler, **H. Xin**, Y. Liang. Determining whole-building ventilation rate of mechanically ventilated broiler houses. *Transactions of the ASAE* (in review).
6. Cook, R.N., **H. Xin**, and D. Nettleton. 2006. Effects of cage stocking density on feeding behaviors of group-housed laying hens. *Transactions of the ASAE* 49(1): 187-192.
7. Dong, H., Z. Zhu, B. Shang, G. Kang, H. Zhu, and **H. Xin**. 2006. Emissions of greenhouse gases from a typical Chinese swine farrowing house. *Transactions of the ASAE* (in review).
8. Gates, R. S., K.D. Casey, E.F. Wheeler, **H. Xin** and A.J. Pescatore. U.S. broiler ammonia emissions inventory model. *Transactions of the ASAE* (in review).
9. Gates, R.S. and **H. Xin**. 2006. Extracting poultry behavior from time-series weigh scale records. *Computer and Electronics in Agriculture* (accepted for publication)
10. Liang, Y., **H. Xin**, H. Li, R.S. Gates, E.F. Wheeler and K.D. Casey. 2006. Effect of measurement interval on estimation of ammonia emission rates for layer houses. *Transactions of the ASAE* 49(1): 183-186.

11. Panetta, D.M., W. J. Powers, **H. Xin**, B. J. Kerr, and K. J. Stalder. 2006. Nitrogen excretion and ammonia emissions from pigs fed modified diets. *Journal of Environmental Quality* 35 (4):1297-1308.
12. Shao, B. and **Xin, H**. 2006. A real-time computer vision assessment and control of thermal comfort of group-housed Pigs. *Computer and Electronics in Agriculture* (accepted for publication)
13. Tao, X., Z. Zhang, H. Dong, H. Zhang and **H. Xin**. 2006. Responses of thyroid hormones of market-size broilers at thermoneutral constant and warm cyclic temperatures. *Poultry Science* (in press)
14. Topper, P.A., E.F. Wheeler, J.S. Zajaczkowski, R.S. Gates, **H. Xin**, Y. Liang, K.D. Casey. Ammonia emissions from two empty broiler houses with built-up Litter. *Transactions of the ASAE* (in review).
15. Wheeler, E.F., K.D. Casey, R.S. Gates, **H. Xin**, J.L. Zajaczkowski, P.A. Topper, Y. Liang, A. J. Pescatore. 2006. Ammonia emissions from twelve U.S.A. broiler chicken houses. *Transactions of the ASAE* (accepted for publication).
16. Gates, R. S., **H. Xin**, K. D. Casey, Y. Liang, and E.F. Wheeler. 2005. A method for measuring ammonia emissions from poultry houses. *Applied Poultry Res.* 14: 622-634.
17. Li, H., H. Xin, Y. Liang, R. S. Gates, E. F. Wheeler, and A.J. Heber. 2005. Comparison of direct vs. indirect ventilation rate determinations in layer barns using manure belts. *Transactions of the ASAE* 48(1): 367-372.
18. Liang, Y., **H. Xin**, E. F. Wheeler, R. S. Gates, J. S. Zajaczkowski, P. Topper, H. Li and K. D. Casey. 2005. Ammonia emissions from U.S. laying hen houses in Iowa and Pennsylvania. *Transactions of the ASAE* 48(5): 1927-1941.
19. Zhang, Q. and **H. Xin**. 2005. Resting behavior of piglets in farrowing crates equipped with heat mats. *Applied Engineering in Agriculture* 21(6): 1067-1071.
20. Brown-Brandl, T.M., J. A. Nienaber, **H. Xin**, and R.S. Gates. 2004. A literature review of swine heat and moisture production. *Transactions of the ASAE* 47(1): 259-270. (**Superior Paper Award**)
21. Chepete, H. J. and **H. Xin**. 2004. Heat and moisture production of poultry and their housing systems*: Molting layers*. *Transactions of the ASHRAE* 110(2): 274-285.
22. Chepete, H. J., **H. Xin**, M.C. Puma, and R.S. Gates. 2004. Heat and moisture production of poultry and their housing systems*: Pullets and layers*. *Transactions of the ASHRAE* 110(2): 286-299.
23. Chepete, H. J. and **H. Xin**. 2004. Ventilation rates of laying hen houses based on new vs. old heat moisture production data. *Applied Engineering in Agriculture* 20(6): 835-842.
24. Dong, H. X. Tao, **H. Xin**, and Q. He. 2004. Enteric methane emissions in China estimated with different IPCC methods and production schemes. *Transactions of the ASAE* 47(6): 2051-2057.
25. Gates, R. S., K. D. Casey, **H. Xin**, E. F. Wheeler, and J. D. Simmons. 2004. Fan assessment numeration system (FANS) design and calibration specifications. *Transactions of the ASAE* 47(5): 1709-1715.
26. Liang, Y., **H. Xin**, S. J. Hoff, and T. L. Richard. 2004. Performance of Single Point Monitor in measuring ammonia and hydrogen sulfide gases. *Applied Engineering in Agriculture* 20(6): 863-872.

27. Persyn, K.E., **H. Xin**, D. Nettleton, A. Ikeguchi, and R.S. Gates. 2004. Feeding behaviors of laying hens with or without beak-trimming. *Transactions of the ASAE* 47(2): 591-596 (**Superior Paper Award**)
28. Pedersen, S., G. J. Monteny, **H. Xin** and H. Takai. 2004. Progress in research into ammonia and greenhouse gas emissions from animal production facilities. CIGR E-Journal Vol 6. http://cigr-ejournal.tamu.edu/Volume6.html.
29. Brown-Brandl, T.M., T. Yanagi, Jr., **H. Xin**, R.S. Gates, R. Bucklin, and G. Ross. 2003. A new telemetry system for measuring core body temperature in livestock and poultry. *Applied Engineering in Agriculture* 19(5): 583-589.
30. Tao, X. and **H. Xin**. 2003. Surface wetting and its optimization to cool broiler chickens. *Transactions of the ASAE* 46(2): 483-490.
31. Tao, X. and **H. Xin**. 2003. Acute, synergistic effects of air temperature, humidity and velocity on homeostasis of market-size broilers. *Transactions of the ASAE* 46(2): 491-497.
32. Chepete, H. J. and **H. Xin**. 2002. Heat and moisture production of poultry and their housing systems*: Literature review*. *Transactions of the ASHRAE* 108(2): 448-466.
33. Chinkuyu, A.J., R.S. Kanwar, J.C. Lorimor, **H. Xin**, and T.B. Bailey. 2002. Effects of laying hen manure application rate on water quality. *Transactions of the ASAE* 45(2): 299-308
34. Tabler, G. T., I. L. Berry, and **H. Xin**, and T. L. Barton. 2002. Spatial distribution of mortality in broiler flocks. *Applied Poultry Res.* 11: 388-396.
35. **Xin, H.**, Puma, M.C., R.S. Gates, and D. U. Ahn. 2002. Effects of drinking water temperature on laying hens subjected to warm cyclic environments. *Poultry Science* 81:608-617.
36. Yanagi, Jr., T., **H. Xin**, and R. S. Gates. 2002. A research facility for studying poultry responses to heat stress and its relief. *Applied Engineering in Agriculture* 18(2): 255-260.
37. Yanagi, Jr., T., **H. Xin**, and R. S. Gates. 2002. Optimization of partial surface wetting to cool caged laying hens. *Transactions of the ASAE* 45(4): 1091-1100 (**Honorable Mention Paper Award**).
38. Dong, H. X. Tao, J. Lin, Y. Li, and **H. Xin**. 2001. Comparative evaluation of cooling systems for farrowing sows. *Applied Engineering in Agriculture* 17(1): 91-96.
39. Ikeguchi, A. and **H. Xin**. 2001. Field evaluation of a sprinkling system for cooling commercial laying hens in Iowa. *Applied Engineering in Agriculture* 17(2): 217-221.
40. Puma, M.C., **H. Xin**, R.S. Gates, and D. J. Burnham. 2001. An instrumentation system for measuring feeding and drinking behavior of poultry. *Applied Engineering in Agriculture* 17(3): 365-374.
41. Zhang, Q. and **H. Xin**. 2001. Responses of piglets to creep heat type and location in farrowing crate. *Applied Engineering in Agriculture* 17(4): 515-519 (**Honorable Mention Paper Award**).
42. **Xin, H**., I. L. Berry, G. T. Tabler, and T. A. Costello. 2001. Heat and moisture production of poultry and their housing system: *Broilers*. *Transactions of the ASAE* 44(6): 1853-1859.
43. Chepete, H.J. and **H. Xin**. 2000. Alleviating heat stress of laying hens by intermittent partial surface cooling. *Transactions of the ASAE* 43(4): 965-971.
44. Han, T. and **H. Xin**. 2000. Effects of intermittent lighting on limited-fed neonatal chicks. *Transactions of the ASAE* 43(6): 1767-1770.
45. Hu, J. and **H. Xin**. 2000. Image-processing algorithms for swine postural behavior analysis. *Behavior Research Methods, Instruments & Computers* 32(1): 72-85.

46. Ibarra, J. G., Y. Tao, and **H. Xin**. 2000. Combined IR imaging – neural network for the estimate of internal temperature in cooked chicken meat. *Optical Engineering* 39(11): 3032-3048.
47. **Xin, H.**, Q. Zhang, M. Puma, J.D. Harmon, D.H. Harris, and M.L. Gramer. 2000. Effects of fluctuating temperatures on isowean pigs. *Transactions of the ASAE* 43(2): 433-438.
48. Yang, P., J.C. Lorimor, and **H. Xin**. 2000. Nitrogen loss from laying hen manure in high-rise layer houses. *Transactions of the ASAE* 43(6): 1771-1780 (**Honorable Mention Paper Award**).
49. Ye, W. and **H. Xin**. 2000. Measurement of surface temperature and postural responses of group-housed pigs to thermal conditions by thermography. *Transactions of the ASAE* 43(6): 1843-1851.
50. Zhang, Q. and **H. Xin**. 2000. Static and dynamic temperature distribution of heat mats for swine farrowing creep heating. *Applied Engineering in Agriculture* 16(5): 563-569.
51. Zhang, Q. and **H. Xin**. 2000. Modeling of heat mat operation for piglet creep heating. *Transactions of the ASAE* 43(5): 1261-1267.

Dr. Steven J. Hoff, Professor

Department of Agricultural and Biosystems Engineering
212 Davidson Hall
Iowa State University
515/294-6180 (voice)
515/294-2255 (facsimile)
e-mail: hoffer@iastate.edu

PERSONAL DATA……………………………………………………………

Born January 16, 1961	Registered Professional Engineer
Warren, Minnesota USA	State of Iowa Certificate No. 14637
Married, 2 Children Ages 20 and 17	

EDUCATION…………………………………………………………………

Degree	Major	Institution	Date
Ph.D.	Agricultural Engineering	University of Minnesota	10/90
M.S.	Agricultural Engineering	University of Minnesota	05/87
B.Ag.Eng.	Agricultural Engineering (with **High Distinction**)	University of Minnesota	06/85
B.S.	Agricultural Engineering Technology	University of Wisconsin River Falls	06/83

PROFESSIONAL EXPERIENCE………………………………………………

Professor, Iowa State University, 2005 to present
Associate Professor, Iowa State University, July 1995 to 2005
Assistant Professor, Iowa State University, November 1990 to June 1995

REFEREED PUBLICATIONS………………………………………………….

Hoff, S.J. and B.C. Zelle. 2006. Hydrogen Sulfide and Ammonia Concentrations in the Community of Multiple Agricultural Sources. (*accepted, Atmospheric Environment*).

Jerez, S.B., Y. Zhang, J.M. McClure, L.D. Jacobson, A.J. Heber, S.J. **Hoff**, J. Koziel, D. Beasley. 2006. Comparison of Measured Total Suspended Particulate Matter Concentration Using Tapered Element Oscillating Microbalance and a TSP Sampler. *J. Air & Waste Management Assoc., 56: 261-270.*

Hoff, S.J., D.S. Bundy, M.A. Huebner, B.C. Zelle, L.D. Jacobson, A.J. Heber, J. Ni, Y. Zhang, J. Koziel, D. Beasley. 2005. Emissions of Ammonia, Hydrogen Sulfide, and Odor Before, During and After Slurry Removal from a Deep-Pit Swine Finisher. *J. Air & Waste Management Assoc., accepted for publication.*

Cai, L., J.A. Koziel, Y.C. Lo, and S.J. **Hoff**. 2005. Characterization of volatile organic compounds and odorants associated with swine barn particulate matter using solid-phase microextraction and gas chromatography-mass spectrometry-olfactometry. J of Chromatography A, 1102(Issues1-2):60-72.

Alimardani, R. and S.J. **Hoff**. 2005. Development of Multiple Velocity and Temperature Probe Sets for Ventilation Spaces. International *Agrophysics Journal*, 19(1): 1-6.

Hoff, S.J. 2004. Automated Control Logic for Naturally Ventilated Agricultural Structures. *Applied Engineering in Agriculture, 20(1): 47-56.*

Yu, H. and S.J. **Hoff**. 2002. Criteria for Ceiling Slot-Ventilated Agricultural Enclosures: Non-Isothermal. *Transactions of the ASAE, 45(1): 201-214.*

Van Utrecht, D.M., S.J. **Hoff**, and J.D. Harmon. 2002. Variable Rate Heater Control for Livestock Space Heating. *Applied Engineering in Agriculture, 18(2): 245-253.*

Harmon, J.D. and S.J. **Hoff**. 2002. NPB Swine Care Handbook Chapter 4: Facilities and Equipment. National Pork Board, Des Moines, IA.

Hoff, S.J. 2002. Psychrometrics of Animal Environment. The Encyclopedia of Agricultural, Food, and Biological Engineering. Dennis R. Heldman, Ph.D., Editor. Marcel Dekker, Inc. New York.

Hoff, S.J., K.C. Hornbuckle, P.S. Thorne, D.S. Bundy, and P.T. O'Shaughnessy. 2002. Chapter 4: Emissions and Community Exposures from CAFOs, In: *Iowa Concentrated Animal Feeding Operation Air Quality Study. http://www.public-health.uiowa.edu/ehsrc/CAFOstudy.htm.*

Hoff, S.J. 2001. Assessing Air Infiltration Rates of Agricultural-Use Ventilation Curtains. *Applied Engineering in Agriculture, 17(4): 527-531.*

Harmon, J.D., D. Levis, J. Zulovich, S. **Hoff**, and G. Bodman. 2001. Swine Breeding and Gestation Handbook. MWPS-43. Midwest Plan Service, Ames, IA. 103 pages.

Hoff, S.J. 2000. The Environment in Swine Housing. *Pork Industry Handbook, PIH-54.* Purdue University Extension Service.

Hoff, S.J., D.M. Van Utrecht, J.D. Harmon and D.W. Mangold. 2000. A General Purpose Laboratory for Evaluating Livestock Ventilation Systems. *Applied Engineering in Agriculture 16(6): 701-714.*

Oberreuter, M.E. and S.J. **Hoff**. 2000. Quantifying Factors Affecting Sidewall Air Inlet Performance. *Transactions of the ASAE, 43(3): 707-716.*

Hoff, S.J. and C.G. Wu. 2000. Establishing Criteria for Sidewall Air Inlet Performance and Evaluation of Four Commercial Inlets on this Criteria. *Transactions of the ASAE, 43(3): 735-743.*

Yu, H. and S.J. **Hoff**. 1999. Airflow Pattern Similarity Criteria for Ceiling Slot-Ventilated Agricultural Enclosures Under Isothermal Conditions. *Transactions of the ASAE, 42(2): 459-469.*

Chen, Y., D.S. Bundy and S.J. **Hoff**. 1999. Development of the Relationship Between Odor Intensity and Threshold Dilution Ratio for Swine Units. *J. Air & Waste Manage. Assoc. 49: 1082-1088.*

Hoff, S.J. and P. Sundberg. 1999. Breakage and Deformation Characteristics of Hypodermic Devices Under Static and Dynamic Loading. *American Journal of Veterinary Research, Vol. 60(3):292-298.*

Chen, Y., D.S. Bundy and S.J. **Hoff**. 1999. Using Olfactometry to Measure Intensity and Threshold Dilution Ratio for Evaluating Swine Odor. *J. Air & Waste Manage. Assoc. 49: 847-853.*

Chen, Y., D. S. Bundy, and S. J. **Hoff**. 1998. Development of a Model of Dispersion Parameters for Odour Transmission from Agricultural Sources. *Journal of Agricultural Engineering Research*, 69: 229-238.

Chen, Y., D. S. Bundy, and S. J. **Hoff**. 1998. Modeling the Variation of Wind Speed with Height for Agricultural Source Pollution Control. *ASHRAE Transactions. Vol.*104.

Chen, Y., S.J. **Hoff**, and D. S. Bundy. 1998. The Dispersion Parameters Modeling and Evaluation for Odor Control from Agricultural Sources. *Journal of Environmental Systems. 26: 27-39.*

Perez-Munoz, F., S.J. **Hoff**, and T.E. Van Hal. 1998. A Quasi-Adlibitum Electronic Feeding System for Gestating Sows in Loose Housing. *Computers and Electronics in Agriculture. 19: 277-288.*

Buiter, J. and S.J. **Hoff**. 1998. Ammonia Distribution in a Pit-Ventilated Confinement Building: One-Half Scale Model Study. *Transactions of the ASAE*, 41(6): 1817-1827.

Hoff, S.J. and D.S. Bundy. 1996. Comparison of Contaminant Dispersion Modelling Approaches for Swine Housing. *Transactions of the ASAE, 39(3):1151-1157.*

Liu, Q., S.J. **Hoff**, G.M. Maxwell, and D.S. Bundy. 1996. Comparison of Three k-ε Turbulence Models for Predicting Ventilation Air Jets. *Transactions of the ASAE, 39(2):689-698.*

Li, X., S.J. **Hoff**, D.S. Bundy, J.D. Harmon, and H. Xin. 1996. Biofilter- A Malodor Control Technology for Livestock Industry. *J. Environ. Sci. Health, A31(9):2275-2285.*

Hoff, S.J. and J. Li. 1995. Simulated and Measured Effect of Rectangular Obstructions on Carbon Dioxide Gas Dispersion in a Scaled Swine Building. *Transactions of the ASAE, 38(5):1519-1532.*

Hoff, S.J. 1995. Isothermal Airflow Characteristics in the Animal Occupied Zone of a Slot-Ventilated Swine Facility. *Transactions of the ASAE, 38(6):1843-1852.*

Hoff, S.J. 1995. A Simplified Turbulence Model for Describing Airflow in Ceiling Slot-Ventilated Enclosures. *Transactions of the ASAE, 38(6):1853-1862.*

Hoff, S.J., K.A. Janni and L.D. Jacobson. 1995. Evaluating the Performance of a Low Reynold's Number Turbulence Model for Describing Mixed-Flow Airspeed and Temperature Distributions. *Transactions of the ASAE, 38(5):1533-1541.*

Li, Q., D.S. Bundy, and S.J. **Hoff**. 1995. A Study on the Air Flow and Odor Emission Rate From a Simplified Open Manure Storage Tank. *Transactions of the ASAE, 38(6): 1881-1886.*

Hoff, S.J., K.A. Janni and L.D. Jacobson. 1993. Defining the Newborn Piglet's Thermal Environment with an Effective Environmental Temperature. *Transactions of the ASAE, 36(1):143-150.*

Hoff, S.J., K.A. Janni and L.D. Jacobson. 1993. Modelling New-Born Piglet Thermal Interactions with a Surface Energy Balance Model. *Transactions of the ASAE, 36(1):151-159.*

Hoff, S.J., K.A. Janni and L.D. Jacobson. 1992. Three-Dimensional Buoyant Turbulent Flows in a Scaled-Model, Slot-Ventilated, Livestock Confinement Facility. *Transactions of the ASAE, 35(2):671-686.*

Hoff, S.J. and K.A. Janni. 1989. Monte Carlo Technique for the Determination of Thermal Radiation Shape Factors. *Transactions of the ASAE, 32(3): 1023-1028.*

PATENTS AND DISCLOSURES……………….……………………………………..

UNITED STATES PATENT NO. 6,360,955 Received March 26, 2002.

*Method and Means for Automated Variable Heater Control for Agricultural Unit Heaters (**Hoff**, S.J, J.D. Harmon, and D. VanUtrecht)*

> Current agricultural heaters use on/off heat control much like a home heating system. This strategy results in significant temperature swings for young animals susceptible to chilling effects. This patent was received for a technique that we developed to provide automated variable output control for LP-gas based livestock housing space heaters. Our design reduced animal level temperature swings from in excess of 14 degrees Fahrenheit to less than 1 degree Fahrenheit.

UNITED STATES PATENT NO. 5,813,599 Received September 29, 1998.

*Automated Controller for Naturally Ventilated Livestock and Poultry Facilities (**Hoff**, S.J.)*

> Many livestock housing systems consist of natural ventilation where fans are not used to provide fresh air to livestock and poultry. This strategy can be very cost effective. To control this method of ventilation requires a coordinated strategy between openings used for natural ventilation. This patent was received for the logic developed in controlling ridge vents and sidewall vents using multiple zones and strategic placement of feed-back sensors in a barn. A significant reduction in environmental temperature variation was demonstrated with the developed logic compared to traditional natural ventilation control methods.

UNITED STATES PATENT NO. 5,767,385 Received June 16, 1998.

*Automated Forced-Choice Dynamic-Dilution Olfactometer and Method of Operating the Same (D.S. Bundy, W. Huang, S.J. **Hoff**, Q. Liu, and X. Li)*

> Iowa State University has been a national leader in odor measurement and general livestock odor-related topics. This work started in roughly 1990 with Dr. Dwaine Bundy. In 1993 a graduate student under my supervision (Mr. Wen-Yu Huang) developed an olfactometer specific for livestock odors. This work originated with an AE404/504 design project. The olfactometer developed can deliver a diluted odor sample to four panelists simultaneously in 12 dilutions between 2^3 and 2^{15} (fresh-air volume to odor sample volume). The entire system including all

electronic hardware and software control along with dynamic dilution theory was developed for which we received a patent.

UNITED STATES PATENT NO. 5,707,283 Received January 13, 1998.
Dual Baffle System in Automatic Air Inlets for Livestock Facilities (Oberreuter, M.E., S.J. ***Hoff****, and F. perez-Munoz)*

Current livestock housing systems utilize fresh-air intakes similar in many ways to diffusers used in office buildings. Many designs utilize an automated baffle inlet control system where the inlet opening changes opening area in response to airflow delivery rates. These automated systems have a weakness in that the inlet area generally increases at a level that is too large relative to the ventilation rate causing low operating pressures and therefore poor air distribution characteristics. This patent was received for a method we developed on baffle control that better adjusted inlet opening area as a function of airflow that allowed higher operating static pressures at low airflow rates thus maintaining better fresh-air distribution characteristics.

UNITED STATES PATENT NO. 5,579,719 Received December 3, 1996.
*Method and Means for Quasi Ad-Libitum Feeding for Gestation Sows in Loose Housing (****Hoff****, S.J., M.S. Honeyman, J.D. McKean, E.J. Stevermer, D.S. Bundy, F. Perez-Munoz, S.E. Bryce, and W.E. Backhaus)*

Housing pigs in bedded situations is a strategy that is gaining popularity. Much of this is in response to animal welfare issues. Gestating sows represent a unique challenge in that control of a sow's growth curve during gestation is beneficial. This can be a very difficult challenge with sows grouped together in a loose housing, bedded situation. The patent that we received was for the electronic sensing and controls, gating design, housing arrangement, and control software to track an individual sow's growth curve and to gate each animal to two specific diets depending upon current growth curve targets. This patent was received eight years ago. Within the past three years, "new" pig sorting systems have been developed and marketed that use many of the features we developed in our patent. I have asked ISURF to determine how much of our strategy is in fact being used with these new systems.

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In addition to the five patents received, software has been disclosed to the Iowa State University Research Foundation for protection for projects that I developed. A summary of these is given below.

ISURF #02478; Submitted and disclosed on September 21, 1998.
*A Community Assessment Model for Site Selection and Odor Management for Swine Operations (****Hoff****, S.J. and D.S. Bundy)*

We have been developing since about 1998 a model to describe the dispersion of odors from swine production systems. This model was initially disclosed to ISURF in 1998 and was recently associated with a current agreement established between ISURF and the Iowa Farm Bureau (August 2002).

ISURF #02714; Submitted and disclosed on July 31, 2000.
Automated Variable Cycling Algorithm for Animal Cooling (S.J. ***Hoff****)*

Pigs do not sweat. As an industry practice, pigs are allowed to artificially sweat through the application of water to their skin. Current practices increase water usage with temperature without regards to current environmental evaporation potential. This disclosure protects logic that I have developed for changing this strategy and significantly reducing water usage for pig cooling.

GRANTS AND CONTRACTS……………………………………………………………………

A total exceeding $6.5 million awarded for projects where I have served as a Co-Investigator or above status. Of this $6.5 million total, I served as PI or Co-PI for $3.5 million.

Richard S. Gates, Ph.D.

Professor and Chair of Department
Biosystems & Agricultural Engineering
University of Kentucky
Email: gates@bae.uky.edu

Administrator for the teaching, research and cooperative extension services of the department.

Teaching undergraduate and graduate courses in probability and statistics, numerical methods, heat and mass transfer, psychrometrics, environment control, data acquisition and control, instrumentation, nonlinear optimization.

Research includes air quality, interior environmental analysis, control and simulation; greenhouse engineering, vapor pressure deficit control systems, livestock production models for real-time economic optimization, and manipulating livestock diets to reduce gaseous emissions and environment impacts.

Extension and **Consulting** related to applications of research, including greenhouse and livestock environment control systems, livestock heat stress reduction, and control systems.

Education

B.S. Agricultural Engineering, University of Minnesota, 1978.
M.S. Agricultural Engineering, Cornell University, 1980.
Ph.D. Biological Engineering, Cornell University, 1984.

Professional Experiences

Senior Systems Analyst, 1983-1984
Assistant Professor, December 1985 – June 1990
Associate Professor, July 1990 – June 1996
Professor, July 1996 to present
Chair, April 2002 to present

Patent

Method for controlling environment conditions based upon time integrated variables. U.S. Patent No. 5,573,199. M.B. Timmons, co-inventor.

Professional and Honor Society Memberships

Registered Professional Engineer: KY PE-14892
United Egg Producers, Environmental Scientific Panel, Research Committee Chair.
Poultry Science Association, Environmental Technical Committee.
Society memberships include:

> American Society of Agricultural and Biological Engineers (ASABE), American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), Federation of Animal Science Societies (FASS), Poultry Science Association (PSA), World Poultry Association (WPA), Sigma Xi (Research) (1982-present), Alpha Epsilon (Agricultural Engineering) (1977-present), Gamma Sigma Delta

Recent Awards

Henry Giese Structures and Environment Award, ASABE, 2006.
Patriotic Employer Award, National Committee for Employer Support of the Guard and Reserve.
ASABE Outstanding Paper Awards:

1. Feeding behaviors of laying hens with or without beak trimming, 2005. Trans ASAE, 47(2):591-596.
2. A literature review of swine heat production, 2005. Trans ASAE, 47(1):259-270.

Selected Current Extramural Funding

Biosystems and Agricultural Engineering -- Educational Consortium for Sustainable Plant and Animal Production Systems. $204,000 (year 1, $29,850 funded). Project leader. With Iowa State University, and four Brazilian Universities. U.S. Department of Education's Fund for the Improvement of Postsecondary Education (FIPSE), 2003-2007

Kentucky Rural Energy Supply Program, C. Metcalf (University of Louisville, $1,984,000 US Department of Energy). R.S. Gates, S.E. Nokes, D.G. Colliver and M.D. Montross $268,600 (subcontract awarded by University of Louisville for competitive grants administration), 2005-2007

Total Suspended Particulate, PM10, PM2.5, Hydrogen Sulfide and Hydrocarbon National Consent Agreement Emissions Determination from Broiler Production Systems. R.T. Burns, H. Xin, R. Gates and S. Hoff. $648,231 awarded by Tyson Foods.10/05 – 10/07

Ammonia Emissions Determination from Broiler Production Systems. R.T. Burns, H. Xin and R. Gates. $399,525 awarded by Tyson Foods.3/05 – 9/06

Effect of enzyme inhibitors on ammonia emission from broiler houses. $18,000. R.S. Gates, A. Singh, K. Casey and A. Pescatore. North Carolina Animal and Poultry Waste Management Center. 7/04-6/06

Demonstration of Intensive Marine Shrimp Production Using Microbial Floc Based Technology at an Inland Location. Proposal to National Oceanographic and Atmospheric Administration, February 2006. $400,000 per year, 2-years. (Ebeling, Anderson and Boudreau, PI's; Tidwell, Gates, Timmons, Cooperators)

Development of Marine Shrimp Genetic Lines for High Microbial Systems. Proposal to National Oceanographic and Atmospheric Administration, February 2006. $400,000 per year, 2-years. (Boudreau, Anderson and Ebeling, PI's; Tidwell, Gates, Cooperators)

Selected Publications

Publications in Refereed Journals 91
In Review: 6
In Preparation: 9

- Liang, Y., H. Xin, H. Li, R.S. Gates, E.F. Wheeler and K.D. Casey. 2006. Effect of measurement interval on estimation of ammonia emission rates for layer houses. Transactions of the ASAE. accepted for publication.
- Purswell, J.L., R.S. Gates, L.M. Lawrence, J.D. Jacob, T.S. Stombaugh and R.J. Coleman. 2006. Air exchange rate in a horse trailer during road transport. Transactions of the ASAE accepted for publication.
- Liang, Y., H. Xin, E.F. Wheeler, R.S. Gates, H. Li, J.S. Zajaczkowski, P. A. Topper, K.D. Casey, B.R. Behrends, D.J. Burnham and F.J. Zajaczkowski. 2005. Ammonia emissions from U.S. laying houses in Iowa and Pennsylvania. Transactions of the ASAE. 48(5):1927-1941.
- Gates, R.S., H. Xin, Y. Liang, K.D. Casey, E.F. Wheeler and. 2005. Method for measuring ammonia emissions from poultry houses. J Appl Poult Res. 14:622-634.
- Green, A.R., R.S. Gates and L.M. Lawrence. 2005. Measurement of horse core body temperature. J. Thermal Biol. 30(1):370-377.

Dr. Douglas G. Overhults, P. E.

Associate Extension Professor
University of Kentucky
Biosystems & Agricultural Engineering Department

Registered Professional Engineer
State of Kentucky

Professional Specialty:

Planning, analysis, and engineering design for animal production facilities, environmental control systems, and manure management

Educational Background:

B. S. and M. S. in Agricultural Engineering from the University of Kentucky

Ph.D. in Bio-environmental Engineering from the University of Nebraska

Experience

7/88 – present	Associate Extension Professor, Agricultural Engineering, U. of KY
4/82 – 6/88	Assistant Extension Professor, Agricultural Engineering, U. of KY
6/78 – 4/82	Instructor & Research Asst., Agricultural Engineering, U. of NE
11/72-5/78	Extension Specialist, Agricultural Engineering, U. of KY
1/71-10/72	Research Assistant, Agricultural Engineering, U. of KY

Current Assignment:

University of Kentucky, Cooperative Extension Service

Located at the UK Research & Education Center in Princeton, KY

Professional Activities

Local arrangements chair for 2001 International Livestock Environment Symposium

- Past Chairman of ASAE SE-302, Environment of Animal Structures Committee
- Past Chair – ASAE SE-02 (Structures & Environment Division Steering Committee)
- Member – ASAE SE-404 (Swine Housing) and SE-405 (Poultry Housing) committees
- Technical reviewer for articles published in 2 ASAE peer reviewed journals
- Instructor for 3 ASAE continuing professional development sessions
- Previously served as Chairman of the Swine Housing and Animal Environment committees and the Structures and Environment Division of the American Society of Agricultural and Biological Engineers
- Served on Planning Committee for the 2001 International Livestock Environment Symposium

Consulting

- Consultant to Lewis-King, Attorneys at Law , Nashville, TN. Litigation involving dairy cattle facilities, Defendant. 1999-2000.
- Court appointed expert for a special judge in litigation regarding the construction of broiler production houses. 1997.

Awards and Honors

- ASAE Blue Ribbon Awards for Educational Aids (6)
- American Society of Agronomy “Certificate of Excellence,” Extension publication
- “Outstanding Service Award” from the Kentucky Pork Producers Association, 1997

Current Extension Education/Training Programs

Livestock and Poultry Facilities

- Environmental modification and control systems with emphasis on mechanical ventilation, cooling systems, and energy use in swine and poultry barns
- Testing fans as installed in broiler barns to determine ventilation rates under field operating conditions
- Engineering design and analysis related to swine and poultry production systems, including structures, equipment, manure management, and feed processing

Swine & Poultry Manure Management

- Providing technical information to assist with the development of design and construction information for poultry litter storages, liquid manure storages, lagoons, and composters.
- Part of research team measuring gaseous and particulate emissions from broiler barns

Hay Storage Structures

- Providing educational program support for the Kentucky Ag. Development Board's model program on hay storage facilities

Recent Publications

Overhults, Douglas G. 2004. Measuring hay temperatures. In 24th Kentucky Alfalfa Conference Proceedings, p 12-17. University of Kentucky Cooperative Extension Service.

Bridges, T.C., L. W. Turner, R. S. Gates, D. G. Overhults. 2003. Assessing the benefits of misting–cooling systems for growing/finishing swine as affected by environment and pig placement date. Applied Engineering in Agriculture 19(3): 361–366.

McNeill, S. G. and D. G. Overhults. 2002. Moisture and handling shrink factors for grain. Electronic publication at URL: http://www.bae.uky.edu/ext/GrainStorage/shrink_factors.htm

Coffey, R.D., G. R. Parker, K. M. Laurent, and D. G. Overhults. 2000. Sampling Animal Manure. University of Kentucky, Cooperative Extension Service. No. ID-148.

Bridges, T.C., L. W. Turner, R. S. Gates and D. G. Overhults. 2000. Swine performance enhancement with cooling as influenced by summer growth period and weather. In Swine Housing, Proc. First Int. Conf. (October 9-11, 2000, Des Moines, Iowa), pp. 348-356, ASAE, St. Joseph, MI.

Animal Waste Focus Group. 1999. Assessment of the Potential for Livestock and Poultry Manure to Provide the Nutreints Removed by Crops and Forages in Kentucky. University of Kentucky Cooperative Extension Service. No. IP-56.

Lara Beal Moody, P.E.

Iowa State University
3165 NSRIC
Ames, IA 50011
515-294-7355
lmoody@iastate.edu

Education

M.S. Biosystems Engineering, The University of Tennessee, Knoxville. Thesis: Laboratory Scale Testing of an Anaerobic Waste Treatment System for a Confectionery Wastestream. August 1998. GPA: 3.6/4.0
B.S. Agricultural Engineering, The University of Tennessee, Knoxville. December 1996.
GPA: 3.2/4.0

Employment History

Department of Agricultural & Biosystems Engineering, Iowa State University, Ames, IA
- Extension Program Specialist, October 2004 - Present

America's Clean Water Foundation, Washington, D.C.
- Consulting Engineer, April 2004 – March 2005

Department of Agricultural & Biosystems Engineering, The University of Tennessee, Knoxville
- Extension Associate, Water Quality Engineer, June 2001 – August 2004
- Research Associate, September 1998 – May 2001
- Graduate Research Assistant, January 1997 – August 1998
- Undergraduate Research Assistant, June 1995 - December 1996

Research Areas

- Alternative technologies for beef feedlot runoff control
- Forced precipitation of phosphorus for soluble nutrient reduction in swine waste
- Chemical amendment to manure for increased performance of mechanical solids separators
- Field-testing of solids separation equipment for dairy wastewater
- Quantification and minimization of estrogen discharges to the environment from dairy waste
- Feasibility of confectionery waste treatment using high rate anaerobic digestion

Professional Registration

- Registered Professional Engineer in Tennessee, 2002
- Registered Professional Engineer in Iowa, 2006

Professional Service

- SE-412. Agricultural Waste Management. ASAE. 2003 – 2007
- FPE-707. Food Processing Waste Management and Utilization. ASAE. 2002 - 2006

Honors & Awards

- NACAA Communication Award, Learning Module Competition, 2003
- The ASAE Blue Ribbon Award, Educational Aids Competition, 2002
- Agricultural Engineering Undergraduate Student with Professional Promise, 1996
- First place, Padnos Team Engineering National Design Competition, 1996
- Agricultural Engineering Scholarship, 1995 & 1996
- Jo Mac Alphin Scholarship, 1994 & 1995
- Joe and Margaretta Wheeler Scholarship, 1994

Grants

- 09/03 – 09/06. *Development of a CNMP Core Training Curriculum*. R.T. Burns, L.B. Moody, N. Rector, A. Sutton, R. Sheffield. **$290,000. Awarded by USDA 406 Extension Education Program**.

- 12/03 – 12/06. *Recovery and Agronomic Recycling of Phosphorus from Swine Manure Slurries*. R.T. Burns, **L.B. Moody**, F.R. Walker, W. Park, J. Buchanan. **$168,000. Awarded by USDA NRI.**

- 05/05 – 05/08. *Non-Basin Technologies for Open Feedlot Runoff: Demonstration, Implementation, and Modeling*. R. Burns, J. Lawrence, L. Moody, M. Helmers. **$631,000. Subcontract from Iowa Cattleman's Association via the U.S.EPA.**

- 6/05 – 6/06. *Pathogen Monitoring from Alternative Beef Feedlot Run-Off Control Systems*. R.T. Burns, L.B. Moody and J.D. Lawrence. **$30,000 awarded by the U.S. EPA.**

- 4/06 – 12/06. *Development of a Database for Environmental Management Practices Employed at Pork Production Facilities*. R. Burns, L. Moody, D. Raman, L. Meyer. **$103,002 awarded by the National Pork Board**.

Publications

Refereed:

Oh, I., R.T. Burns, **L.B. Moody**, J. Lee. 2005. Optimization of phosphorus partitioning in dairy manure using chemical additives with a mechanical solids separator. *Transactions of ASAE*. 48(3).

Burns, R.T.; **L.B. Moody**; I. Celen; J.R. Buchanan. 2003. Optimization of phosphorus precipitation from swine manure slurries to enhance recovery. *Water Science Technology*. 48(1): 139-146.

Raman, D.R.; A.C. Layton; **L.B. Moody**; J.P. Easter; G. Saylor; R.T. Burns; M.D. Mullen. 2001. Degradation of estrogens in dairy waste solids: effects of acidification and temperature. *Transactions of ASAE*. 44(6): 1881-1888.

Burns, R.T.; **L.B. Moody**; F.R. Walker; D.R. Raman. 2001. Laboratory and in-situ reductions of soluble phosphorus in swine waste slurries. *Environmental Technology.* 22(11): 1273-1278.

Moody, L.B. and D.R. Raman. 2001. A dual reactor anaerobic system for complete treatment of a food processing waste. *Journal of Agricultural Engineering Research*. 80(3): 293 – 299.

Beal, L.J. and D.R. Raman. 2000. Sequential two-stage anaerobic treatment of confectionery wastewater. *Journal of Agricultural Engineering*. 76(2), 211-217. doi:10.1006/jaer.2000.0555.

Beal, L.J., F.H. Moody, J.T. Wesner, T.L. Ogle, B.A. Peters, M.L. Orr, J.A. Crouch, D.R. Raman, and R.E. Yoder. 1997. Feasibility of an Alternative Dairy Waste Management System. *Technology: Journal of the Franklin Institute. 334A*.

Extension Publications:

AWM-01-01, *Press Tech Agri-Press 600* Solids Separator Performance Tests Results Using the University of Tennessee Testing Protocol. R.T. Burns and **L.B. Moody**.

AWM-01-02, *Vincent KP-6L* Solids Separator Performance Tests Results Using the University of Tennessee Testing Protocol. R.T. Burns and **L.B. Moody**.

Sampling Dairy Manure for Nutrient Management, in Comprehensive Nutrient Management Planning for Your Dairy, field day proceedings (pp 77-79). **L.B. Moody**.

Non-refereed:

Burns, R.T., **L. B. Moody**, G. Considine, B. Gramig, T. Hebert, J.K. Meeker and A. Stokes. 2005. Developing the Model of Animal Waste System Risk (MAWSR) for Livestock Waste Storage Facilities. *Proceedings of the 98th Annual Air & Waste Management Association Conference*. Paper # 1305.

Burns, R.T. and **L.B. Moody**. 2003. Tennessee comprehensive nutrient management plan third party element writer certification program. Proceedings of the Ninth International Symposium on Animal, Agricultural and Food Processing Wastes, Raleigh, NC.

Grandle, G.F., **L.B. Moody**, R.T. Burns. 2003. Experiences in preparing a CNMP Emergency Response Plan for a Tennessee Dairy Farm. Proceedings of the Ninth International Symposium on Animal, Agricultural and Food Processing Wastes, Raleigh, NC.

Burns, R.T and **L.B. Moody**. 2003. CNMP certification for third party technical service providers. ASAE # 038027. ASAE St. Joseph, MI.

Burns, R.T. and **L.B. Moody**. 2003. Development of a standard method for testing mechanical manure solids separators. *ASAE Paper # 034131*. ASAE St. Joseph, MI.

Oh, I.; **L.B. Moody**, I. Celen, J. Lee; R.T. Burns. 2003. Optimization of phosphorus partitioning in dairy manure using aluminum sulfate with a mechanical solids separator. *ASAE # 032266*. ASAE St. Joseph, MI.

Burns, R.T. and **L.B. Moody**. 2001. Performance testing of screw-press solid separators: comprehensive solids analysis and nutrient partitioning. Presented at the International Symposium addressing animal production and environmental issues, Oct. 3-5, Raleigh, North Carolina.

Dyer, A.R.; D.R. Raman; M.D. Mullen; R.T. Burns; **L.B. Moody**; A.C. Layton; G.S. Saylor. 2001. Determination of 17b-estradiol concentrations in runoff from plots receiving dairy manure. ASAE Paper #012107. ASAE St. Joseph, MI.

Pinto, A.M.; D.R. Raman, **L.B. Moody**. 2000. Using fuzzy logic to determine failure modes in a biological sensor for UASB reactors. *ASAE Paper # 006127*. ASAE St. Joseph, MI.

Beal, L.J., R.T. Burns, K.J. Stalder. 1999. Effect of anaerobic digestion on struvite production for nutrient removal from swine waste prior to land application. *ASAE Paper # 994042*. ASAE St. Joseph, MI.

Beal, L.J. and D.R. Raman. 1998. Comparison of high-rate anaerobic processes for confectionery wastewater treatment. *ASAE Paper #986109*. ASAE St. Joseph, MI.

Raman, D.R., **L.J. Beal**, S.W. Rye, A.C. Stiles, R.E. Yoder, and N.S. Eash. 1997. Kinetics of COD and N removal from a highly loaded constructed wetlands. *ASAE Paper #975025.* ASAE St. Joseph , MI.

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EDUCATION:

- B.S. in Electrical Engineering (Power; Optoelectronics) Pennsylvania State University, 1978.
- A.S. in Electrical Technology, Williamsport Area Community College, 1976

BACKGROUND:

- 1978 to 2004, Major US Army, Status Retired. Significant positions included:
  - Survey Recon Commander
    - Commanded a topographic survey and reconnaissance 20 man platoon in support of a combat Field Artillery Battalion
    - Responsible for tactical deployment, equipment maintenance, and operations associated with the platoon
    - Supervision of the maintenance operations of a 210 man Headquarters Battery and all associated tactical equipment.
  - Battery (Unit) Commander
    - Commanded a 200 man capable combat Field Artillery Battery
    - Responsible for tactical deployment, equipment maintenance, personnel management and operations of a nuclear capable unit deployed in Western Europe.
  - Deputy Installation Coordinator (Equivalent to a position of a small City Manager)
    - Supervised both the coordination between and operations of eighteen major staff directorates and ten assigned tactical units. Ensured the effective, cohesive execution of the objectives of the community.
    - Supervised the maintenance and operation of facilities and all construction projects of large military community. Ensured that both the needs and requirements of the community were satisfied and that the objectives of the Community Commander were met.
    - Supervised the implementation of a community Master Development Program which will effectively meet all requirements until Fiscal Year 1999. Plan was fully supported by utility upgrades, both major and minor construction projects, beautification plans and traffic management studies at a total program cost of $36.2 million.
- 1989 to 1990, Assistant Water Superintendent
  - Supervised the successful construction of a major sewer collection project and water main distribution project built for the City of Princeton, Kentucky.
- 1989 to Present, Police Officer (Part time), Princeton Police Department, Princeton KY.
  - As a Kentucky Certified Police Officer, duties include those of

  - Collision Reconstructionist Level V
  - School Extracurricular Activities Officer
  - Information Technology Coordinator

- 1990 to Present, Technical Engineer, Biosystems and Agricultural Engineering, University of Kentucky
  - Designed and built specialized agricultural equipment to include ATV Towed Plot Boom Sprayer,
  - Designed and installed specialized electrical and motor control projects. Significant projects included fruit sorting facility, cattle processing and weighting facilities, automated water pumping facility, and swine mature pump and spray facility.
  - Provided technical support to an extensive, multi-year energy study of a chicken broiler houses over a period of 72 barn months. Results of the study provided the basis for temperature and energy control procedures which are used throughout the poultry industry.
  - Developed and maintain a detailed Geographic Information Database that is used as an example for Precision Agriculture databases.
  - Provided technical support in a multi-University research project which developed insect and environment control guidelines for use in grain storage facilities.
  - Demonstrated skills include operation and utilization of electrical test, power generation, light and heavy construction and material handling, automotive diagnostic, hand and power tools, automated motor control, pneumatic, hydraulic, geographical and topographical survey, geographical positioning systems, geographical information systems, semi-automatic and arc welding, automated data recoding equipment, and computer/automated data collection and processing equipment.
  - Served as an elected representative of the University Staff on the University Staff Senate.
  - Serve as a Information Technology advisor to the University of Kentucky Research & Education Center

HONORS:

- Outstanding Staff Award, College of Agriculture, University of Kentucky – 2005
- Army Meritorious Service Medal – 1985; 1989
- Army Commendation Medal – 1982; 1985
- Dean’s List – Pennsylvania State University and Williamsport Area Community College.

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EDUCATION

Ph.D. in Agricultural and Biosystems Engineering, Iowa State University, USA
August 2002 – May 2006

M.S in Agricultural and Bioenvironmental Engineering, China Agricultural University, China,
September 1998 – July 2001

B.S in Agricultural and Bioenvironmental Engineering, China Agricultural University, China,
September 1994 -- July 1998

PROFESSIONA EXPERIENCES

Present	*Post-doc Research Associate,* Department of Agricultural and Bioenvironmental Engineering, Iowa State University, Ames, Iowa
2005- 2006	*Pre-doctoral Research Associate,* Department of Agricultural and Bioenvironmental Engineering, Iowa State University, Ames, Iowa
2002- 2005	*Research Assistant*, Department of Agricultural and Bioenvironmental Engineering, Iowa State University, Ames, Iowa
2001- 2002	*Engineer*, Jingwei Textile Machinery Co., Ltd., Jinzhong, Shanxi, China
1998- 2001	*Research Assistant*, China Agricultural University, Beijing, China

PROFESSIONAL MEMBERSHIPS

American Society of Agricultural and Biological Engineers (ASABE)

Air and Waste Management Association (AWMA)

Association of Overseas Chinese Agricultural, Biological and Food Engineers (AOCABFE)

AWARDS AND HONORS

First Place in 2004 AOCABFE paper competition

China Agricultural University Scholarship from 1995-1998

SERVICE ACTIVITIES

ITF-10 section chair, AWMA annual meeting (2006)

Graduate student organization of Horticulture (Chair, '00; Vice Chair, '99)

University graduate student Senate at China Agricultural University (1998-2000)

REFEREED PUBLICATIONS

Li, H., H. Xin, Y. Liang, R. S. Gates, E. F. Wheeler, and A.J. Heber. 2005. Comparison of direct vs. indirect ventilation rate determinations in layer barns using manure belts. Transactions of the ASAE 48(1): 367-372

Y. Liang, H. Xin, **H. Li**, R. S. Gates, E. F. Wheeler and K. D. Casey. 2006. Effects of Measurement Intervals on Estimation of Ammonia Emissions from Layer Houses. Transactions of the ASABE 49(1): 183-186

Y. Liang, H. Xin, E. F. Wheeler, R. S. Gates, **H. Li**, J. S. Zajaczkowski, P. A. Topper, K. D. Casey, B. R. Behrends, D. J. Burnham, F. J. Zajaczkowski. 2005. Ammonia emissions from U.S. laying hen houses in Iowa and Pennsylvania. Transactions of the ASAE 48(5): 1927-1941

Chen, Q. Y., **H. Li**. 2001. Study on the Expert System of Cucumber Culture Management in Greenhouse. Transactions of the CSAE 17(6):142-146

Wang, Y. X., D.S. Chen, T.Z. Zhang, **H. Li**. 1999. Double Skin Inflated Greenhouse Inner Local Climate Control Characteristics in Higher Cold Area. Transactions of the CSAE 15(4):167-171

CONFERENCE PROCEEDINGS

Li, H., Hongwei Xin, Robert T. Burns, Yi Liang. 2006. Reduction of Ammonia Emission from Stored Poultry Manure Using Additives: Zeolite, Al^+clear, Ferix-3 and PLT. 2006 ASABE Annual Meeting, Portland, Oregon, American Society of Agricultural and Biological Engineers, St. Joseph, MI: ASAE

H. Xin, **H. Li**, R. T. Burns, R. S. Gates, D. G. Overhults, J. W. Earnest, L. B. Moody, and S. J. Hoff. 2006. Use of CO_2 Concentrations or CO_2 Balance to Estimate Ventilation Rate of Modern Commercial Broiler Houses. 2006 ASABE Annual Meeting, Portland, Oregon, American Society of Agricultural and Biological Engineers, St. Joseph, MI: ASAE

R. T. Burns, H. Xin, **H. Li**, R. S. Gates, D. G. Overhults, J. W. Earnest, Z. Zhu, J. Davis and C. Peterson. 2006. Measurement of TSP, PM_{10} and $PM_{2.5}$ Emissions from Commercial Broiler Houses. 2006 ASABE Annual Meeting, Portland, Oregon, American Society of Agricultural and Biological Engineers, St. Joseph, MI: ASAE

Li, H., R. Burns, H. Xin, L. Moody, R. Gates, D. Overhults, J. Earnest. 2006. Development of a Continuous NH_3 Emissions Monitoring System for Commercial Broiler Houses. Paper #485, Air and Waste Management Association

Burns, R. T., H. Xin, **H. Li**, S. Hoff, L. Moody, R. S. Gates, D. Overhults and J. Earnest. 2006. Monitoring system design for the southeastern broiler gaseous and particulate matter air emissions monitoring project. Symposium on Air Quality Measurement Methods and Technology, May 9 - 11, 2006, Durham, NC.

Moody, L.B., **H. Li**, R. T. Burns, H. Xin, and R. S. Gates. 2006. AWMA QAPP paper. Quality Assurance Project Plan (QAPP) implementation for the southeastern broiler gaseous and particulate matter air emissions monitoring project. Symposium on Air Quality Measurement Methods and Technology, May 9 - 11, 2006, Durham, NC.

Muhlbauer, R. V., T. A. Shepherd, **H. Li**, R. T. Burns, H. Xin. 2006. Development and Testing of a Fan Monitoring System using Induction Operated Current Switches. ASABE Technical Paper, St. Joseph, MI: ASABE

Li, H., H. Xin, and Y. Liang. 2005. Effects of stack surface to volume ratio and air exchange rate on ammonia emission of laying hen manure storage. Paper #1157, Air and Waste Management Association

Li, H., H. Xin, and Y. Liang. 2005. Moisture production of commercial manure-belt laying hen houses. Proc of the 7th International Livestock Environment Symposium, May 18-20, 2005, Beijing, China. St Joseph, MI: ASAE

Li, H., Hongwei Xin, Yi Liang , Comparison of Direct vs. Indirect Ventilation Rate Determination for Manure Belt Laying Hen House, Paper number 044177, 2004 ASAE/CSAE Annual International Meeting ,Ottawa, Ontario, Canada, American Society of Agricultural Engineers, St. Joseph, MI: ASAE

Li, H., H. Xin, Y. Liang, R.S. Gates and E.F. Wheeler. Determination of Ventilation Rates for a Manure-Belt Laying Hen Housing Using CO_2 Balance. Mid-Central Conference of the ASAE, St. Joseph, Missouri, March 25-26, 2004. American Society of Agricultural Engineers, St. Joseph, MI: ASAE

Liang, Y. H. Xin, **H. Li**, J. Koziel, L. Cai. 2005b. Evaluation of treatment agents and diet manipulation for mitigating ammonia and odor emissions from laying hen manure. Paper # 054160. American Society of Agricultural and Biological Engineers, St. Joseph, MI: ASABE

Liang, Y., H. Xin, A. Tanaka, S. H. Lee, **H. Li**, E. F. Wheeler, R. S. Gates, J. S. Zajaczkowski, P. Topper and K. D. Casey. 2003. Ammonia Emissions from U.S. Poultry Houses: Part II – Layer Houses. In Proc. Third International Conference on Air Pollution from Agricultural Operations. Oct 12-13, 2003, Raleigh, NC, pp147-158

Xin, H., Y. Liang, A. Tanaka, R.S. Gates, E. F. Wheeler, K. D. Casey, A. J. Heber, J. Ni, and **H. Li**. 2003. Ammonia emissions from U.S. poultry houses: Part I - Measurement system and techniques. Proceedings of the 3rd International Conference on Air Pollution from Agricultural

Operations, Raleigh, NC, October 2003. American Society of Agricultural Engineers, St. Joseph, MI: ASAE

Liang, Y., H. Xin, A. Tanaka, S. H. Lee, **H. Li**, E. F. Wheeler, R. S. Gates, J. S. Zajaczkowski, P. Topper and K. D. Casey. 2003. Ammonia emissions from layer houses in Iowa. Proc of the Gaseous and Odor Emissions from Animal Production Facilities, Scandic Hotel Bygholm Park, Horsens, Denmark, June 1-4, 2003

EXTENSION PUBLICATIONS & POPULAR PRESS ARTICLES DERIVED FROM RESEARCH

Li, H., H. Xin, and Y. Liang. 2004. Indirect Measurement of Building Ventilation Rate for Manure-belt Laying Hen House Using CO_2 Balance. College of Agriculture Research Report, ASL # 520, Iowa State University

Liang, Y., H. Xin, and **H. Li**. 2004. Dietary manipulation to reduce ammonia emission from high-rise layer houses. College of Agriculture Research Report, ASL # 517, Iowa State University

Liang, Y., H. Xin, **H. Li**, and E. F. Wheeler. 2004. Ammonia emissions from layer houses. College of Agriculture Research Report, ASL # 518, Iowa State University