X.XX Exhaust Fan Monitoring and Control System

A. OVERVIEW
   1. The Exhaust Fan Monitoring and Control System (EFMCS) system architecture shall utilize duct and outside air probes networked to distributed Air Data Routers and Sensors Suites communicating over a data and air sampling network. The air sampling network shall consist of an air packet transportation network that shall transport air samples from the environment being monitored via electrically conductive MicroDuct® network Structured Cable to distributed Sensor Suites located throughout the facility.
   2. With an active Assurance Services Commitment, the EFMCS shall provide protected information access via a web-based user interface to analytical summaries, and in on-screen graphical form, system reports and analysis-based notifications. Web-based utilities are to be included to export EFMCS data as a comma separated values (.csv) file format.
   3. The EFMCS specified herein, shall be by Aircuity, Inc. No other manufacturers are allowed.

B. SYSTEM REQUIREMENTS
   1. The system shall have the ability to make true differential measurements by utilizing the same suite of sensors to evaluate both the contaminant levels of a test area and the source of the ventilation air.
   2. For the purposes of generating analytical data and reports based off actual system performance, the EFMCS shall have the ability to take in third party feedback data by one or both of the following methods:
      a. Feedback data is regularly written to the EFMCS by the BAS or EFS via hardwired inputs or BACnet over IP connections at regular intervals.
      b. EFMCS obtains feedback data by actively querying for known, exposed feedback data values over the BACnet network at regular intervals.

C. SYSTEM HARDWARE
   1. The Exhaust Fan Monitoring Contractor (EFMC) shall provide the following:
      a. All Air Data Routers, Sensor Suites, Sensor Suite Sensors, Duct, and Outside Air Probes, Information Management Systems, Vacuum Pumps, Structured Cable, MD Tubing, and Transformers to perform the functions listed.
   2. Air Data Routers
      a. The Air Data Router shall be furnished as a complete, self-contained, unit housing all electronics, air solenoid valves, sampling manifolds, firmware, and software. Unit shall be furnished with all internal devices and wiring assembled and tested at the factory.
      b. Air Data Routers shall be capable of sampling of up to four locations.
   3. Sensor Suite
      a. The Sensor Suite shall be a distributed, network based, multipoint sensing device. The Sensor Suite shall be furnished as a complete, self-contained unit housing all electronics, sensing card cage, sampling manifolds, flow regulators, pressure regulators, firmware, and software.
      b. The Sensor Suite shall have the ability to “multitask” by concurrently drawing an air sample from one limb while sensing the parameters of the air sample in the other limb.
   4. High Flow Vacuum Pump
      a. EACH Sensor Suite will be equipped with a High Flow Vacuum Pump (HFP) that will draw samples from the sampling ports in the system, through the Sensor Suite, and then discharge them. Samples will be discharged **[CHOOSE ONE] [into the pump room.] OR [into the nearest exhaust duct so the samples may be discharged directly from the building.]**
      b. EACH Sensor Suite will be provided with a Pump Control Module (PCM) card for monitoring system vacuum pressure and, for systems featuring dual pump systems, controlling automatic pump switchover upon primary pump failure.
      c. The HFP106/206 will meet the following specifications:

1. Minimum Vacuum Pressure: -8.5 PSIg
2. Minimum Flow Rate: 29 LPM (1.02 SCFM)
3. Standby Pump with Automatic Switchover: Secondary pump, identical to the first, with an automatic switchover controller that will automatically take over should the on-line pump stop for any reason other than a complete failure of all local AC power.

5. Information Management System
    a. The Information Management System shall provide network management of Sensor Suites, integration to the EFS/BAS, and interface to a web-based user interface and data management system for viewing and outputting graphs, charts, and data derived from the EFMCS.
    b. The System shall be located within 25' (6.4 m) of the nearest Sensor Suite and be connected to the System through the RS-232 serial port.
    c. To mitigate potential damage to the IMS, the IMS shall not be mounted to the same support structure as the vacuum pumps.
6. OSC Structured Cable
    a. The EFMCS shall utilize a pre-engineered system of Structured Cable to facilitate network wide communications, distribution of low voltage power to Air Data Routers and Sensor Suites, and provide a sampling conduit for air samples from Air Data Routers to Sensor Suites, all within a single cable.
    b. The cable shall contain the necessary wires to distribute communications, data, and low voltage power throughout the FMS. As a minimum, Structured cable shall consist of:
        1. Communications – 22 AWG twisted shield pair with drain wire
        2. Low Voltage Power – 18 AWG, 3 wire
    c. An inner pathway, MicroDuct, shall be furnished as an integral part of the OSC Structured Cable to facilitate collection of zone air samples. MicroDuct shall be lined with a smooth, electrically conductive, chemically inert surface to ensure air samples remain pure and uncorrupted and do not adhere to the wall lining during transport.
7. MD Tubing
    a. The EFMCS may utilize MD Tubing as a low-cost sampling conduit for air samples from Probe locations to Air Data Routers.
    b. The pathway, MicroDuct, shall be lined with a smooth, electrically conductive, chemically inert surface to ensure air samples remain pure and uncorrupted and do not adhere to the wall lining during transport.
8. Vacuum Pump System Tubing
    a. Vacuum Tubing shall be 0.5" OD x 0.375" ID, dimensionally stable, and shall conform to NFPA 90A flame and smoke spread indices for return air plenum installations
9. Duct, Outdoor Air Mount, and Outside Air Probes
    a. A duct air sample probe is to be contained within one enclosure. Duct sample probe to accept integral MicroDuct from Structured Cable and MD Tubing.
    b. Internal coarse filter to screen out large particulate matter from entering the MicroDuct.
    c. Outdoor Air Locations – NEMA 4X weatherproof enclosure shall be provided.
    d. Outdoor Air Locations – Probe is to be mounted in a location where it will not be exposed to direct sunlight.
10. Sensors
    a. The EFMCS shall incorporate an enhanced version of the photoionization detector (PID) and a metal oxide sensor (MOS) to provide broad chemical detection.
        1. Calibration: The PID and MOS shall be calibrated on isobutylene.
        2. Resolution: The PID and MOS shall have a resolution of 0.025 ppm and 0.2 ppm, respectively.

b. Sensors are the property of the EFMC whose warranty is covered under the Assurance Services Commitment agreement.
c. For each set of installed sensors, a certificate of calibration shall be made available for viewing online at the EFMC's web-based user interface and data management system.
d. Sensors shall be physically removed from the sensor suite, and replaced with freshly calibrated sensors from EFMC's Calibration Laboratory, a minimum of every 6 months after the initial sensor installation. Installation, removal, and replacement will be performed by a factory trained EFMC representative.
e. Immediately after replacement, sensors are to be shipped back to EFMC's Calibration Laboratory in the postage paid return box provided by the EFMC.

D. SYSTEM SOFTWARE
1. The EFMC shall provide all software required for configuration, operation, and commissioning of the EFMCS system specified herein:
a. Database Creation and Modification:
1. All changes shall be done utilizing standard procedures. The system shall allow changes to be made at the local site through the Information Management System.
2. The database required for implementation shall include test sequences and reports and point summaries.
3. The EFMC shall provide and create the database using the latest software release, at the time of Shop Drawing approval.
4. The EFMC shall be capable of providing a BACnet or hardwired compatible integrated system and software to interface with the EFS/BAS.
b. Web-Based User Interface and Data Management System:
1. Included with the system shall be a fully integrated web-based user interface and data management system. The data management system shall be password protected and shall be able to store sampled data from all zones for online viewing and reporting.
2. The data management system will be sized to record and retain every sample taken by the system, along with other data gathered from other systems or direct interface points. The current calendar year plus two previous complete calendar years will be accessible in an active high-performance database. All data older than that will be archived and made available upon request.

E. WARRANTY
1. Repair or replace any defective product not covered by Assurance Services Commitment (see Section F.1.b) and correct any defect in material or workmanship for a period of 36 months following date of shipment.

F. ASSURANCE SERVICES COMMITMENT AGREEMENT
1. At the time of sensors are shipped from the factory as described later in this specification, the EFMC will transmit an agreement for annual services to the owner marked "PAID IN FULL" that will provide services for the system for a period of **[XX]** years. Under this agreement the EFMC will provide the following services: BI-ANNUAL SENSOR CALIBRATION, HARDWARE ASSURANCE, MONITORING, and DATA REPORTING AND ANALYTICS.
a. Bi-Annual Sensor Calibration: Every six months during the term of the Agreement, freshly NIST traceable calibrated sensors will be installed by the EFMC.
b. Hardware Assurance: The replacement of all critical consumable components (Air Data Routers, Sensor Suites, Vacuum Pumps, Information Management Systems, and Sensors) will be covered and the EFMC will be performing the field installation of all replacement hardware.
c. Monitoring: For cloud-connected systems, the EFMC will be alerted to communication issues lasting longer than 24 hours and of pump and sensor failure/non-functioning issues lasting longer than 12 hours by the EFCMS. The EFMC

will be responsible for investigating, confirming, and resolving the failures at the customer site.

d. Data Reporting and Analytics: Cloud-connected systems will have access to air quality and energy savings data in both System Dashboards and room-level Graphing, covering the current year and the two previous calendar years (older data will be archived and remain available for retrieval when requested). The data can also be shared for external viewing and benchmarking via Mobile/Web APIs or BACnet Data Sharing.

G. GENERAL INSTALLATION

1. Install all equipment and systems specified herein in accordance with the manufacturer's most current version of the installation guide. In the event of conflicting information between this document and the installation guide, the most stringent requirement shall apply.
2. Connect and configure equipment and software to achieve sequence of operation specified.

H. WIRING INSTALLATION

1. Install systems and materials in accordance with manufacturer's instructions, rough-in drawings, and equipment details. Install electrical components and use electrical products complying with requirements of applicable Division **[XX]** sections of these specifications.

I. CONTROL POWER

1. Class 2 step-down transformers shall provide 24VAC power for all Air Data Routers, Sensor Suites, and associated EFMCS components from nearest electrical power panel noted below or as indicated on the electrical drawings—coordinate the installation and location thereof with Electrical Contractor and all other trades.

J. ASSOCIATED EXHAUST FAN REQUIREMENTS

1. The Exhaust Fan system (EFS) shall incorporate a bypass or inlet damper system, used to maintain the fan's minimum exit velocity setpoint, or
    a. If the EFS does not have a bypass or inlet damper system, the EFS exit velocity reduction shall be performed by exhaust fan staging, or
    b. The EFS exit velocity reduction shall be performed by a reduction in lab minimum ventilation, when the EFMCS has determined that the lab exhaust is clean.
2. The EFS shall incorporate a VFD to control the speed of each fan in the EFS.

K. SEQUENCE

1. The EFMCS shall sequentially sample from up to 6 Exhaust Fan monitoring locations and up to 2 Supply or Outdoor Air reference locations per sampling cycle and route all air samples through the combination PID & MOS sensor found in the Sensor Suite.
    a. The EF monitoring location shall be at the inlet to the exhaust fan or when not possible, within the exhaust fan plenum and sufficiently distanced away from any bypass dampers.
    b. The Supply or Outdoor Air reference location(s) shall be handled by their own Air Data Router, connected to the Sensor Suite on its own limb, separate from the limb serving the EF monitoring locations.
2. The Exhaust Fan Control module shall provide a high-selected, differential measurement output by comparing the absolute contaminant values sensed at the associated EF monitoring location(s), selecting the highest value, and performing the differential calculation with the absolute contaminant values sensed by the associated supply or outdoor air reference probe.
3. At a rate of once a minute, the EFMCS shall update the Exhaust Fan Control module output signal(s) based on the calculated differential measurement signal.
    a. When the Exhaust Fan Control module's output signal is below the chosen normalized threshold value (typically 1 ppm as isobutylene – or as determined by the project's exhaust fan dispersion consultant), the EFMCS will communicate a setback signal to enter a "Low-Dilution Mode".
        1. While in this mode, using the BAS or other control system, the EFS shall continue to respond to other signals such as total building exhaust flow,

pressurization, etc. as needed to help maintain a safe working environment within the occupied building areas and in the areas surrounding the EFS outside of the building.

b. When the Exhaust Fan Control module's output signal is at or above the chosen normalized threshold value, the EFMCS will communicate a purge signal to enter a "High-Dilution Mode".
    1. While in this mode, using the BAS or other control system, the EFS shall continue to respond to other signals such as total building exhaust flow, pressurization, etc. as needed to help maintain a safe working environment within the occupied building areas and in the areas surrounding the EFS outside of the building.
    2. Once the EFS enters this High-Dilution mode, the EFS shall remain in this mode of operation for a minimum of 15 minutes before being allowed to drop back into the Low-Dilution Mode to both protect the sensors in the Sensor Suite, and to protect the EFS and its various components from rapidly cycling between modes of operation.
    3. After 15 minutes, if the determination is made that the EF monitoring location(s), as sensed the EFMCS, contain a contaminant concentration that is below the normalized differential threshold value, the EFS shall be allowed to enter the "Low-Dilution Mode" as described above.

4. A failsafe state shall be entered to safely accommodate scenarios where the EFMCS is produces no data (such as during a sensor swap) or loses communications (such as equipment malfunction).
    a. When the EFMCS is integrated with the EFS/BAS via BACnet:
        1. The EFS/BAS shall read the present values and reliability of each BACnet point generated by the EFMCS.
        2. When operating in any mode, if the reliability property relating to the control of the EFS switches from a "Reliable" state to an "Unreliable" state, the EFS/BAS shall issue an alarm for those affected exhaust fan system(s), ignore any value produced by the EFMCS for the EFS, and command the EFS into the High-Dilution Mode control sequence for each affected EFS. The EFS shall remain in this mode for at least 15 minutes and until after the reliability properties of all associated BACnet points have switched back to a 'reliable' state and are within their normal specified ranges.
    b. When the EFMCS is integrated with the EFS/BAS via hardwired analog control signals:
        1. The specified control ranges shall be: 4-20mA, 1-5V, or 1-10V (forward or reverse acting).
        2. With any of those approaches, during any mode of operation, any analog signal read by the EFS/BAS of 0mA or 0V shall be interpreted as a loss of communication or malfunction of the EFMCS.
        3. When this occurs, the EFS shall issue an alarm for those affected exhaust fan system(s) and command the EFS into the High-Dilution Mode control sequence for each affected EFS. The EFS shall remain in this mode for at least 15 minutes and until the control signals are back within their normal specified ranges.