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Standard Guide for Selecting Instruments and Methods for Measuring Air Quality in Aircraft Cabins[1]

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1. Scope

1.1 This guide covers information and guidance for the selection of instrumentation and test methods for measuring air quality in aircraft passenger cabins as well as in areas limited to flightcrew access.

1.2 This guide assumes that a list of pollutants to be measured, or analytes of interest, which are present, or may be present, in aircraft cabins is available.

1.3 This guide provides information and guidance to identify levels of concern pertaining to public and occupational exposures to relevant air pollutants. This guide does not address levels of concern, if any, related to degradation of materials or aircraft components because of the presence of air pollutants.

1.4 Based on levels of concern for public and occupational exposures for each pollutant of interest, this guide provides recommendations for developing three aspects of data quality objectives (*a*) detection limit; (*b*) precision; and (*c*) bias.

1.5 This guide summarizes information on technologies for measurement of different groups or classes of air pollutants to provide a basis for selection of instruments and methods. The guide also identifies information resources on types of available measurement systems.

1.6 This guide provides general recommendations for selection of instruments and methods. These recommendations are based on concepts associated with data quality objectives discussed in this guide and the information on available instruments and methods summarized in this guide.

1.7 This guide is specific to chemical contaminants and does not address bioaerosols, which may be present in the cabin environment.

1.8 This guide does not provide details on use or operation of instruments or methods for the measurement of cabin air quality.

1.9 This guide does not provide information on the design of a monitoring strategy, including issues such as frequency of measurement or placement of samplers.

1.10 Users of this guide should be familiar with, or have access to, individuals who have a background in (*a*) use of instruments and methods for measurement of air pollutants and (*b*) principles of toxicology and health-effects of environmental exposure to air pollutants.

1.11 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.12 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.13 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D1914 Practice for Conversion Units and Factors Relating to Sampling and Analysis of Atmospheres

D3162 Test Method for Carbon Monoxide in the Atmosphere (Continuous Measurement by Nondispersive Infrared Spectrometry)

D3631 Test Methods for Measuring Surface Atmospheric Pressure

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D4023 Terminology Relating to Humidity Measurements (Withdrawn 2002)[3]
D4490 Practice for Measuring the Concentration of Toxic Gases or Vapors Using Detector Tubes
D4861 Practice for Sampling and Selection of Analytical Techniques for Pesticides and Polychlorinated Biphenyls in Air
D5149 Test Method for Ozone in the Atmosphere: Continuous Measurement by Ethylene Chemiluminescence
D5156 Test Methods for Continuous Measurement of Ozone in Ambient, Workplace, and Indoor Atmospheres (Ultraviolet Absorption)
D5197 Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology)
D5466 Test Method for Determination of Volatile Organic Compounds in Atmospheres (Canister Sampling Methodology)
D6196 Practice for Choosing Sorbents, Sampling Parameters and Thermal Desorption Analytical Conditions for Monitoring Volatile Organic Chemicals in Air
D6245 Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation
D7034 Guide for Deriving Acceptable Levels of Airborne Chemical Contaminants in Aircraft Cabins Based on Health and Comfort Considerations

2.2 *Other Standards:*
14 CFR 25 Airworthiness Standards[4]
29 CFR 1910.1450 Occupational Exposure to Hazardous Chemicals in Laboratories[4]
40 CFR 50 National Ambient Air Quality Standards[4]
40 CFR 53 Ambient Air Monitoring Reference and Equivalent Methods[4]
40 CFR 60 Standards of Performance for New Stationary Sources—Appendix A: Test Methods[4]
RTCA/DO-160 Environmental Conditions and Test Procedures for Airborne Equipment[5]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, refer to Terminology D1356.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *analyte, n*—designated chemical species to be measured by a monitor or to be identified and quantitated by an analyzer.

3.2.2 *bioaerosol, n*—airborne material of biological origin, including viable microorganisms, pollens, spores, bacteria, viruses, allergens, and biological debris.

3.2.3 *ceiling limit, n*—a maximum allowable air concentration, established by the Occupational Safety and Health Administration (OSHA), that must not be exceeded during any part of the workday.

3.2.4 *concentration range, n*—a semiquantitative term referring to the extreme uppermost portion of the distribution of anticipated measurements.

3.2.4.1 *Discussion*—This term (and the dose or risk analogues) traditionally refers to the portion of the distribution that conceptually falls above about the 98th percentile of the distribution, but is not higher than the highest individual measurement.

3.2.5 *data quality objectives (DQOs), n*—qualitative and quantitative statements of the overall level of uncertainty that a decision-maker is willing to accept in results or decisions derived from environmental data.

3.2.5.1 *Discussion*—Minimum DQOs include method detection limit, precision, and bias.

3.2.6 *level of concern, n*—an exposure level or concentration that is not to be exceeded by regulation or, for unregulated pollutants, an exposure level or concentration that is believed to be associated with odor, sensory irritation, and other adverse health or toxic effects.

3.2.7 *lowest-observed-adverse-effect level (LOAEL), n*—the lowest dose of a chemical in a study or group of studies that produce statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control.

3.2.7.1 *Discussion*—See *A Review of the Reference Dose and Reference Concentration Processes* (**1**).[6]

3.2.8 *no-observed-adverse-effect level (NOAEL), n*—the dose of chemical at which there are no statistically or biologically significant increases in frequency or severity of adverse effects seen between the exposed population and its appropriate control.

3.2.8.1 *Discussion*—Effects may be produced at this dose, but they are not considered to be adverse. See *A Review of the Reference Dose and Reference Concentration Processes* (**1**).

3.2.9 *safety factor, n*—a dimensionless number, greater than unity, to account for incomplete understanding of errors encountered in extrapolating exposure or health effects derived for one set of conditions or basis to another.

3.2.10 *spacecraft maximum allowable concentrations (SMACs), n*—developed by the National Aeronautics and Space Administration and the Committee on Toxicology from the National Research Council, based on exposure duration of 1 h to 180 days.

4. Summary of Guide

4.1 This guide provides procedures and recommendations for the selection of test methods and equipment suited to measuring air quality in aircraft cabins.

4.2 Major steps in the selection process include identifying one or more levels of concern for each analyte to be monitored,

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

[5] Available from Radio Technical Commission for Aeronautics (RTCA), 1150 18th NW, Suite 910, Washington, DC 20036, https://www.rtca.org.

[6] The bold face numbers in parentheses refer to the list of references at the end of this standard.

selecting the most appropriate level of concern for each analyte, defining minimum data quality objectives that are compatible with the level of concern, defining desirable operating characteristics that are compatible with the aircraft cabin environment, and selecting instruments and test methods that meet these objectives.

5. Significance and Use

5.1 This guide may be used to identify instruments and methods for measuring air quality in aircraft cabins. Such measurements may be undertaken to:

5.1.1 Conduct monitoring surveys to characterize the aircraft cabin environment and to assess environmental conditions. Results of such measurements could then be compared with relevant standards or guidelines for assessment of health and comfort of passengers and flight attendants.

5.1.2 Investigate passenger and flight attendant complaints; or

5.1.3 Measure and compare the performance of new materials and systems for the aircraft cabin environment.

6. Identify Levels of Concern

6.1 Identification of the level of concern for each analyte of interest is essential for defining data quality objectives. The level of concern for each analyte is identified from review of applicable regulations, standards, and guidelines.

6.2 Use the following sources to compile levels of concerns for each analyte[7] identified for monitoring. Additional sources may apply outside of the US:

6.2.1 FAA Airworthiness Standards (14 CFR 21), which specify acceptable exposure levels for ozone, carbon dioxide, carbon monoxide, and cabin pressure that explicitly apply to the aircraft cabin environment;

6.2.2 Spacecraft Maximum Allowable Concentrations (SMACs), which have been defined for chemicals under exposure conditions ranging from 1 h to 180 days for the space program;

6.2.3 The Clean Air Act (40 CFR Part 50), which specifies acceptable limits for general population exposure to criteria pollutants (ozone, carbon monoxide, oxides of nitrogen, sulfur dioxide, particulate matter, and lead), and also regulates population exposure to emissions of nearly 200 hazardous air pollutants;

6.2.4 The Occupational Safety and Health Act of 1970 (29 CFR 1910), which establishes PELs and ceiling concentrations to protect workers against the health effects of exposure to approximately 200 hazardous substances;

6.2.5 ACGIH *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Values*, which gives TLVs and STELs to define acceptable limits for workplace exposure.

6.2.6 AIHA *Odor Thresholds for Chemicals with Established Occupational Health Standards* is a peer-reviewed document that contains odor thresholds for a wide variety of chemicals.

6.2.7 For analytes not covered by items 6.2.1 – 6.2.6, specialized databases may be consulted to develop levels of concern. Such resources include the Agency for Toxic Substances and Disease Registry (ATSDR), the Health Effects Assessment Summary Tables (HEAST), the Integrated Risk Information System (IRIS), and the Registry of Toxic Effects of Chemical Substances (RTECS) (**2**). Interpretation of these information resources requires input from a qualified toxicologist.

6.2.8 Table 1 gives an example of compilation of levels of concern for selected contaminants.

6.3 Refer to Guide D7034 for procedures to develop exposure scenarios and to define and calculate appropriate levels of concern for the population under consideration and the types of health impacts being assessed, for example, cancer effects, chronic non-cancer effects, acute effects, and odor concerns.

7. Define Minimum Data Quality Objectives

7.1 For each analyte, specify minimum data quality objectives in terms of concentration range, method detection limit, precision, and bias.

7.1.1 Specify an upper limit of the concentration range that is at least twice the level of concern.

7.1.2 Specify the precision and bias necessary to achieve acceptable statistical confidence when comparing a measured value with the level of concern. The 99 % confidence level is commonly used as a basis for comparison. For example, given a level of concern of 100 ppm and considering a measurement system having 10 % precision, the 99 % confidence interval (that is, 3 standard deviations) extends from 70 ppm to 130 ppm. Thus, a measured value of 69 ppm would be interpreted with 99 % confidence as being below the level of concern. On the other hand, a value of 71 ppm would be interpreted with 99 % confidence as being indistinguishable from the level of concern.

7.1.3 Specify the method detection limit (MDL) such that the MDL is well below the level of concern, considering the bias:

[7] Preparing a list of analytes of interest, if not available, requires considerable effort such as review of results of past studies on cabin air quality, assessment of sources of air contaminants, and consultation with toxicologists and health effects specialists (for example, physicians and epidemiologists) to assess potential causes of suspected or actual health effects or symptoms. As stated in the scope, the development of a list of analytes is not within the scope of this guide.

TABLE 1 Compilation Table of Levels of Concern for Various Air Pollutants and Parameters

Parameters Measured	Level of Concern[A]	Comment
CO_2	30 000 ppm	ACGIH STEL[B]
	30 000 ppm	FAA Airworthiness Standards (Title 14 CFR 25)
	13 000 ppm	1–24 h to SMACs[C]
	7 000 ppm	7–180 d SMACs[C]
	5 000 ppm	ACGIH TLV[B] , OSHA PEL (Title 29 CFR 1910)
	1 000 ppm	Guide 6245
CO	50 ppm	OSHA PEL (Title 29 CFR 1910)
	35 ppm	1-h NAAQS (Title 40 CFR 50)
	25 ppm	ACGIH TWA[B]
	9 ppm	8-h NAAQS (Title 40 CFR 50)
O_2	20.95 % at 2.4 km (8000 ft) cabin altitude equivalent to partial pressure of 16 kPa	FAA Airworthiness Standards (Title 14 CFR 25)
O_3	0.25 ppm	FAA Airworthiness Standards (Title 14 CFR 25)
	0.1 ppm	FAA Airworthiness Standards
	0.12 ppm	1-h NAAQS (Title 40 CFR 50)
	0.1 ppm	OSHA PEL (Title 29 CFR 1910)
	0.07 ppm	8-h NAAQS (Title 40 CFR 50)
Particulate matter		
PM_{10}	150 μg m^{-3}	24-h NAAQS (Title 40 CFR 50)
	50 μg m^{-3}	Annual NAAQS (Title 40 CFR 50)
$PM_{2.5}$	35 μg m^{-3}	24-h NAAQS (Title 40 CFR 50)
	15 μg m^{-3}	Annual NAAQS (Title 40 CFR 50)
Organic compounds	Chemical-specific	
	Consult listed sources	OSHA PEL (Title 29 CFR 1910) SMACs[C] ATSDR[D] AIHA odor thresholds[E]
Cabin air pressure		FAA Airworthiness Standards (Title 14 CFR 25)
	75.1 kPa	2.4 km pressure altitude
	37.6 kPa	7.6 km pressure altitude

[A] Level of concern may need to be adjusted for cabin pressure. See 8.5.
[B] *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure*, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 1997.
[C] *Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants*, Vols 1–3, Committee on Toxicology, National Research Council, National Academy of Sciences, Washington, DC, 1994–1996.
[D] Agency for Toxic Substances and Disease Registry (ATSDR), *Minimal Risk Levels for Hazardous Substances*, U.S. Public Health Service, Atlanta, GA. 1997.
[E] *Odor Thresholds for Chemicals with Established Occupational Health Standards*, American Industrial Hygiene Assoc., 1993.

where:

MDL = method detection limit,
LOC = level of concern,
= mean value of results of a number (n) of repeated measurements,
X_{ref} = true or accepted reference value of measurement result,
σ = standard deviation of a number (n) of repeated measurements, and
N = number of standard deviations from the mean. N generally takes value of 1, 2 or 3 corresponding to 68 %, 95 %, and 99 % confidence intervals, respectively. Since the desired confidence interval is often 90 % or more, a value of 1.7 or higher typically is used for N.
m = a variable whose value should be at least 2 to give sufficient ability to distinguish the level of concern from a non-detectable value (see example below).

7.1.4 When considering multiple levels of concern for a particular analyte (as could occur when interest is focused on odor threshold effects as well as compliance with regulatory criteria), use the smaller value to define the MDL, and use the larger value to define the upper limit of the concentration range.

8. Define Desirable Operating Characteristics

8.1 Define desirable operating characteristics for equipment based on practical details of the monitoring objectives as well as the level of experience, resources, and facilities available to the performing organization. Consider the following factors in making final decisions regarding selection of instrumentation and methods:

8.1.1 *Mode*—active (requiring a pump or aspirator to convey sample) or passive (relying on diffusion),

8.1.2 *Output*—continuous, point-in-time, or time-weighted average,

8.1.3 *Record*—electronic signal, field observation, or laboratory report,

8.1.4 *Mobility*—handheld (<1kg), portable (<5kg), or stationary (>5kg),

8.1.5 *Power*—battery, standard alternating current, or mechanical,

8.1.6 *Calibration*—standard atmospheres, co-located references, laboratory procedures or factory procedures, or both, and

8.1.7 *Ancillary Data*—temperature, relative humidity, and air pressure may be required to adjust data to a common basis (for example, sea-level equivalent).

8.2 All electronic equipment operated in the aircraft cabin must be certified for electromagnetic compatibility with avionic systems (see, for example, RTCA/DO-160).

8.3 Instrumentation selected for aircraft cabin monitoring must be sufficiently stable to allow for acceptable operation for 8 or more h. Calibrations and zero/span checks may be conducted in a ground facility before and after a flight. Calibrations generally are not performed aboard the aircraft because the use of pressurized gases and the handling of toxic materials is prohibited in the aircraft cabin.

8.4 All electronic equipment taken aboard the aircraft must be sufficiently stable to be turned off during ascent and descent without loss of calibration.

8.5 At a minimum, cabin pressure should be monitored to permit correcting data for reduced air density at altitude. Special equipment and procedures may be required to verify correction factors for some technologies. It should be noted that simple pressure-altitude corrections are not sufficient since monitoring technologies such as non-dispersive infra red (NDIR) have a systematic error caused by pressure differences which need to be addressed.

9. Select Instruments and Test Methods

9.1 For each analyte, identify available instruments and test methods using data quality objectives and operating characteristics, as described below.

9.2 For commonly monitored pollutants, select from the technologies listed in Tables 2-10 which give examples of technologies for each pollutant or pollutant group. These tables include a wide range of technologies to give readers a feel for what is available. Several of these technologies are appropriate for use in measuring cabin air quality. Those that are clearly not appropriate are so indicated in these tables. A set of recommendations are offered in a later section.

9.3 For analytes not covered by Tables 2-10, consult ASTM standard test methods as well as compilations published by organizations such as USEPA (**3**, **4**), NIOSH (**5**), and other publications (**6**, **7**, **8**, **9**, **10**) to identify instruments and test methods.

9.4 If available equipment does not meet one or more data quality objectives, then select technologies of lesser capabilities provided that changes to the affected data quality objectives do not increase statistical uncertainty to unacceptable levels.

9.4.1 It should be recognized that relationships defined in 7.1.2 and 7.1.3 using the level of concern to determine instrument performance represents an ideal that practical instrumentation sometimes cannot meet.

9.4.2 Less-than-ideal performance can be accommodated by accepting reduced statistical confidence or by reappraising measurement objectives. Given a level of concern at 100 ppm, for example, the 99 % confidence interval for an instrument or method characterized by ±20 % precision and bias would extend from 40 ppm to 160 ppm while the 90 % confidence interval would extend from 66 ppm to 134 ppm. Such a method or instrument would be acceptable for objectives focused on determining whether or not environmental concentrations exceed the level of concern, but results may be unacceptable if objectives seek definitive statements regarding low concentrations.

TABLE 2 Operating Characteristics of Instrumentation and Methods for Monitoring Aldehydes and Ketones

Technology	Guidance	Comments
Sorbent Tube – sample gases are collected using a cartridge with DNPH-coated sorbent that is returned to the laboratory for analysis of individual compounds by HPLC.	Test Method D5197 EPA Methods[A,B] Range: 0.01–5 ppm Bias: ±10 % Precision: ±10 % MDL: 0.0005 ppm	Field apparatus is compact. Requires external pump. Requires sophisticated laboratory. O_3 at high concentrations interferes negatively. Approximate costs: <$15 per tube plus pump (~$500) and laboratory analysis ($100 to $1000).
Liquid Impingement – sample is absorbed in DNPH solution and returned to the laboratory for analysis of individual compounds by HPLC.	EPA Methods[B] Range: 0.01–5 ppm Bias: ±10 % Precision: ±10 % MDL: 0.0005 ppm	Field apparatus is compact, but requires liquid-filled impinger. Requires external pump. Requires sophisticated laboratory. O_3 at high concentrations interferes negatively. Approximate costs: ~$50 for impinger plus pump (~$500) and laboratory analysis (~$100). Impractical for use in aircraft passenger cabins.
Colorimetric Tube – sample gases are drawn through a chemically treated sorbent bed that changes color in the presence of a specific aldehyde or ketone; length of color stain is correlated with concentration.	Practice D4490 Range: 0.2–100 ppm Bias: ±25 % Precision: - - MDL: - -	Requires external air pump (may be hand-powered). Disposable system (single use) that relies on factory calibration. Resolution is generally lower than other technologies. Separate type of tube required for each aldehyde and ketone of interest. Approximate costs: $10 per tube plus pump (~$300). Inappropriate for quantitative measurements of cabin air quality.

[A] *Compendium of Methods for the Determination of Air Pollutants in Indoor Air*, Report No. EPA/600/4-90/010, U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC, 1990, https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1004G22.txt.
[B] *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, 2nd ed., Report No. EPA/625/R-96/010b, U.S. Environmental Protection Agency, Cincinnati, OH, 1999.

TABLE 3 Operating Characteristics of Instrumentation and Methods for Monitoring Carbon Dioxide

Technology	Guidance	Comments
Non-Dispersive Infrared (NDIR) Spectrometry – absorption of infrared radiation by CO_2 in a sample cell is compared to that of a reference (CO_2-free) absorption path.	OSHA ID-172 Woebkenberg[A] Range: 20–500 000 ppm Bias: ±50 ppm Precision: ±50 ppm MDL: 200 ppm	Very specific for CO_2; portable units are available. Some units require an external pump. Approximate costs: $500 (handheld) $5 000 to $10 000 (portable or stationary).
Colorimetric Tube – sample gases are drawn through a chemically treated sorbent bed that changes color in the presence of CO_2; length of color stain is correlated with concentration.	Practice D4490 Range: 100–200 000 ppm Bias: ±25 % Precision: - - MDL: - -	Requires external air pump (may be hand-powered). Disposable system (single use) that relies on factory calibration. Resolution is generally lower than other technologies. Approximate costs: $10 per tube plus pump (~$300). Inappropriate for quantitative measurements of cabin air quality.

[A] Woebkenberg, M.L., and McCammon, C.S., "Direct-Reading Gas and Vapor Instruments." *Air Sampling Instruments*, Cohen, B.S., and Hering, S.V., eds., American Conference of Governmental Industrial Hygienists, Inc., Cincinnati, OH, 1995, pp. 439–510.

TABLE 4 Operating Characteristics of Instrumentation and Methods for Monitoring Carbon Monoxide

Technology	Guidance	Comments
Electrochemical – sample air is passed through a cell wherein oxidation of CO produces a signal that is proportional to concentration.	Nagda et al. 1989[A] Woebkenberg[B] Range: 0–500 000 ppm Bias: ±5 % Precision: ±5 % MDL: <1 ppm	Can be very specific for CO; portable units are available. Specificity is achieved by inlet scrubber of uncertain efficiency for some chemicals. Approximate costs: $500 (handheld) $5 000 to $10 000 (portable or stationary).
Non-Dispersive Infrared (NDIR) Spectrometry – absorption of infrared radiation by CO in a sample cell is compared to that of a reference (CO-free) absorption path.	Test Method D3162 EPA 40CFR53 Woebkenberg[B] Range: <1–100 ppm Bias: ±10 % Precision: ±10 % MDL: 0.5 ppm	Very specific for CO, EPA reference-grade measurement. Approximate costs: $5 000 to $10 000 (portable or stationary).
Colorimetric Tube – sample gases are drawn through a chemically treated sorbent bed that changes color in the presence of CO; length of color stain is correlated with concentration.	Practice D4490 Range: 5–100 000 ppm Bias: ±25 % Precision: - - MDL: - -	Requires external air pump (may be hand-powered). Disposable system (single use) that relies on factory calibration. Resolution is generally lower than other technologies. Approximate costs: $10 per tube plus pump (~$300). Inappropriate for quantitative measurements of cabin air quality.

[A] Nagda, N.L., Fortmann, R.C., Koontz, M.D., Baker, S.R., and Ginevan M.E., *Airliner Cabin Environment: Contaminant Measurements, Health Risks, and Mitigation Options*, Report No. DOT-P-15-89-5, U.S. Department of Transportation, Washington, DC, 1989.
[B] Woebkenberg, M.L., and McCammon, C.S., "Direct-Reading Gas and Vapor Instruments." *Air Sampling Instruments*, B.S. Cohen and S.V. Hering, eds., American Conference of Governmental Industrial Hygienists, Inc., Cincinnati, OH, 1995, pp. 439–510.

9.4.3 Collecting replicate samples and averaging results can reduce statistical uncertainty associated with time-weighted-average samples.

9.5 For each monitoring technology identified as meeting data quality objectives, evaluate operating characteristics compared to desirable characteristics listed under Section 8.

9.5.1 Portable and handheld monitoring systems featuring battery-power are generally preferred over larger and heavier stationary systems that require alternating current.

9.5.2 Monitoring systems featuring continuous output are generally preferred for monitoring objectives that involve examining the impacts of short-term and episodic sources.

9.5.3 Monitoring systems designed to collect samples for subsequent analysis in the laboratory are generally preferred for monitoring objectives that involve examining time-weighted average concentrations.

9.5.4 Not withstanding the considerations given in 9.5.1 – 9.5.3 related to operating characteristics, the first and foremost consideration should be toward meeting the primary requirements of detection limit, precision and accuracy. Thus, a heavier or nonportable equipment that meets these requirements would be preferred to a portable, battery powered instrument that does not satisfy the primary requirements.

9.6 Evaluate appropriateness of the measurement instruments and methods for suitability of their use in commercial aircraft cabins. For example, instruments requiring continuous gas supply are not appropriate as pressurized gas cylinders are not permitted on aircraft. For conducting measurements on passenger flights, the equipment should be safe for operating in the cabin environment, non-intrusive, and self sufficient in terms of power requirements. For ground testing or testing on non-revenue test flights, stationary or bench-top instruments may be appropriate, as 110–v power supply can be available.

9.7 *Document Final Decisions*—At a minimum, the measurement systems selection report should address the following topics:

9.7.1 *Monitoring Objectives*—Describe the purpose of the measurements and describe the analytes selected for measurement.

9.7.2 *Levels of Concern*—Summarize the basis for selecting levels of concern for each analyte.