## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>3</td>
</tr>
<tr>
<td>1. Overview</td>
<td>4</td>
</tr>
<tr>
<td>2. Equipment Specification Sheet</td>
<td>5</td>
</tr>
<tr>
<td>3. Specification Definitions</td>
<td></td>
</tr>
<tr>
<td>3.1. General Information</td>
<td></td>
</tr>
<tr>
<td>3.2. Performance</td>
<td></td>
</tr>
<tr>
<td>3.3. Operating Conditions</td>
<td></td>
</tr>
<tr>
<td>3.4. Error-state Notification</td>
<td></td>
</tr>
<tr>
<td>3.5. Readings</td>
<td></td>
</tr>
<tr>
<td>3.6. Cross-Interferents</td>
<td></td>
</tr>
<tr>
<td>3.7. Maintenance</td>
<td></td>
</tr>
<tr>
<td>3.8. Data Management</td>
<td></td>
</tr>
<tr>
<td>3.9. Safety</td>
<td></td>
</tr>
<tr>
<td>5. References</td>
<td>9</td>
</tr>
</tbody>
</table>
Preface

This manual was developed to provide a standardized approach to the definitions and methods used to develop an equipment specification sheet. When this manual was developed, real-time detection equipment specification sheets differed between manufacturers in their content, definition of terms, and methods used to develop specifications. These inconsistencies can lead to end users’ misinterpretation of information provided by manufacturers, which may ultimately increase risk to life and health. It is our hope that the adoption of the American Industrial Hygiene Association’s (AIHA) Standardized Equipment Specification Sheet Program will provide a common language with which the manufacturer and end user can effectively communicate, thereby allowing the end user to better understand the capabilities and limitations of the instruments.

This manual describes the programmatic approach to developing an AIHA Standardized Equipment Specification Sheet. It describes the definitions for the specifications to be included, the methods for determining the specification parameters, and a template for the specification sheet.

The information provided in this manual was developed by a consensus-based subcommittee of the AIHA’s Real-time Detection Systems Committee. The subcommittee included stakeholders representing equipment manufacturers, military, government, academia, emergency response, and commercial end users.
1 Overview
Instrument may be purchased for a variety of uses; daily personal exposure monitoring, hazardous material response, or continuous area monitoring. Users may have different instrument requirements: accuracy, calibration requirements, long-term storage. This guide includes the most important criteria for selecting an instrument. Users should find useful the information provided by a manufacturer in the specification sheet. In some cases, manufacturers may already have completed the sheet, and in other cases, user may request a manufacturer to provide a copy of their specification sheet(s).

2 Equipment Specification Sheet
Manufacturers shall provide the specifications for each sensor type available for the instrument. This may be completed using one or multiple specification sheets.

3 Specification Definitions
The specification definitions are divided into the subsections found in alphabetical order on the Standardized Specification Sheet. For each specification, both a general and/or technical definition is given. If a standardized method for determining the specification parameters is recommended, it is listed as well. In this document, “NTP” stands for normal temperature and pressure, which is defined as 68°F and 1 atm. There may be a few definitions included in this manual for reference only and are not listed on the Standardized Equipment Specification Sheet.

3.1 General Information Definitions
3.1.1 Instrument Name
General Definition: As determined by the manufacturer.

3.1.2 Instrument Manufacturer
General Definition: As determined by the manufacturer.

3.1.3 Hazard Type
General Definition: The physical or chemical hazard the instrument is designed to monitor, e.g., noise (SLM, octave band, dosimeter), single gas, multi-gas, radiation, particulate.

3.1.4 Sensor Type
General Definition: The following are some examples, but these examples are not limited to: colorimetric, electrochemical, photoacoustic IR, PID, Fourier transform infrared spectroscopy (FTIR), IR, Raman, ion mobility spectrometry (IMS), FID.

3.1.5 Display
General Definition: As described by the manufacturer. Characteristics to mention: backlight, screen size, characters, color/black and white, etc.
3.1.6 Battery Type
General Definition: For example, Ni-Cad, NiMH, Li-ion, alkaline, standard (AA, AAA, C, D, 9-volt).

3.1.7 Dimensions
General Definition: Units in metric and standard. Length, width, height are based on maximum point to point distance in each dimension. Other units may be listed in addition.

3.1.8 Weight
General Definition: Units in grams and ounces (pounds). Include batteries (lightest weight battery option may be used).
*Other units may be listed in addition.

3.1.9 Warranty
General Definition: For instruments and sensors, list the specific components covered by the warranty and the length of the warranty coverage, when the instrument is stored, and when it is used according to the manufacturer's instruction.

3.1.10 Designed to Standard(s)
General Definition: List applicable published standards to which the instrument complies (e.g., ISA, EN, ISO, IEC, ASTM).

3.1.11 Specialty Training Recommended
General Definition: List recommended training, such as review of the instrument manual, vendor-supplied training, AIHA Registry, etc.

3.1.12 Detector
General Definition: A detector responds to a chemical or physical characteristic in a consistent way to detect, identify, or quantify a contaminant.
NIOSH Definition: Detector is that part of the direct-reading instrument that sees and/or measures and/or quantifies and/or ascertains the dimensions, quantity, or concentration of the gas or vapor of interest. Direct-reading instruments frequently consist of interrelated components that perform a series of functions including sampling, separation, detection, data handling, and readout. Not all direct-reading instruments perform all of these functions, but all direct-reading instruments have some sort of detector and are capable of detection. A detector can be chemical, electrical, mechanical, or physical in nature. A detector may provide a qualitative or quantitative determination of the gas or vapor of interest.

3.2 Performance Definitions
3.2.1 Measuring Range
General Definition: The concentration range (minimum and maximum value) that the instrument is designed to measure.

* Specification is listed for reference only and is not listed on the Standardized Equipment Specification Sheet.
Technical Definition: The concentration range of the test analyte over which the monitor meets a specified accuracy criterion.

3.2.2 Minimum Detection Limit

General Definition: The lowest non-zero detectable concentration within the specified accuracy.

NIOSH Definition: Limit of detection (LOD) and limit of measurement (LOM) are defined in the current version of the Comprehensive Dictionary of Measurement and Control [ISA 1995]. The Instrumentation, Systems, and Automation Society (ISA) LOD is stated to be the smallest value of the measured quantity that produces discernible movement of the monitor indicator. The ISA LOM definition states this value is the smallest value of the measured quantity that can be accurately indicated or recorded.

3.2.3 Resolution (Total)

General Definition: The minimum difference between two data points that can be discerned and displayed to the user.

3.2.4 Accuracy

General Definition: Closeness to the true value of the concentration.

Technical Definition: The degree of agreement of a measurement, X, with an accepted reference or true value, T, usually expressed as the difference between the two values, X – T, or the difference as a percentage of the reference or true value, 100(X – T)/T, and sometimes expressed as a ratio, X/T.

NIOSH Definition: Accuracy is the ability of a monitor to determine the true concentration of the environment sampled. Accuracy describes the closeness of a typical measurement to the quantity measured although it is defined and expressed in terms of the relative discrepancy of a typical measurement from the quantity measured. The term inaccuracy has also been used interchangeably with the term accuracy in the literature. In this document, only the term accuracy will be used. Accuracy can be a characteristic of a monitor when measurements follow a statistical distribution, such as the normal distribution. Normal distribution is assumed to be useful; it is reasonable as a model for analytical errors—which are measurement errors—even though the distribution of measured environmental concentrations may be log-normal. Unpublished results for the methods studied in Anderson et al. [1981], Busch and Taylor [1981], and NIOSH [1980] indicate that there is little empirical inconsistency with that assumption. Normal theory results are often applicable for other cases or as good first approximations. Moreover, aside from the relative standard deviation estimates, the analysis is means based. Finally, the authors’ unpublished results show that relationships among the method accuracy, precision, and bias that follow from normal theory assumptions hold extremely well for several other distributions, e.g., log-normal, gamma, etc. The special sense of accuracy for a monitor is embodied in the following definition and criterion:
• The accuracy of a monitor is the theoretical maximum error of measurement, expressed as the proportion or percentage of the amount being measured, without regard for the direction of the error, which is achieved with 0.95 probability by the method.
• The accuracy criterion (AC), used in the previous documents (Anderson et al. 1981; Busch and Taylor 1981; NIOSH 1980) and in this document, requires that a monitor give a result that is within ±25% of the true concentration, having a probability of 95% for an individual observation (i.e., that the accuracy of an acceptable monitor is no greater than 25%).

For a monitor to be accepted as fulfilling the AC, the data from the evaluation study must provide 95% confidence that the accuracy of the monitor is not greater than the AC (25%). To obtain 95% confidence that the accuracy of a monitor satisfies the AC, the 95% confidence limit estimate of the accuracy must be less than 25%. For a monitor to be rejected for not meeting the AC, the 5% confidence limit estimate of the accuracy must be greater than 25%. If neither of these conditions can be met, the results are inconclusive and more research will be required to reach a definite acceptance or rejection of the monitor.

3.2.5 Precision

General Definition: Closeness between repeat measurements at the same contaminant concentration. Percent agreement. The repeatability or reproducibility of individual measurements expressed as percent agreement.

NIOSH Definition: Precision is the relative variability of measurements from a homogeneous atmosphere about the mean of the population of measurements. It is calculated by dividing σ, the standard deviation of the measurements, by the measurement mean at a given concentration, designated by μ. The term imprecision has also been used interchangeably with the term precision in the literature. In this document, only the term precision will be used. Precision is expressed by the relative standard deviation, S_r, or true relative standard deviation, S_rT, of a series of measurements. It reflects the ability of a monitor to replicate measurement results. The statistical definition of the precision is given by \( S_r = \sigma / \mu \); \( S_{rT} = \sigma / C_T \).

If μ represents the true concentration, C_T, then \( S_r \) is considered the \( S_{rT} \). These components assume that the \( S_r \) or \( S_{rT} \) of the evaluated monitor is constant or homogeneous over all concentrations tested for the monitor evaluation. This assumption does not imply that the \( S_r \) of the monitor is constant over all concentrations, only in those selected for the study.

3.2.6 Linearity

NIOSH Definition: Linearity is the closeness of a monitor’s calibration curve to a mathematically defined straight line.

3.2.7 Sensitivity
General Definition: Minimal detectable difference of the contaminant concentration.
Technical Definition: Sensitivity is the smallest change in the measured analyte concentration that will produce a reproducible change in a monitor’s readout.
NIOSH Definition: Sensitivity is the smallest change in the measured analyte concentration that will produce a reproducible change in a monitor’s readout.

3.2.8 Recovery Time
NIOSH Definition: The time required to return from a peak concentration to 10% of the initial challenge level (baseline).

3.2.9 Operating Time
General Definition: Shortest duration that an instrument will operate until any consumables are depleted under ideal conditions (e.g., battery, carrier gas, data-logging memory, etc.).

3.2.10 Battery Operating Time
General Definition: Typical duration that an instrument will operate on a fully charged battery at 68°F (20°C) and at the minimum specified operating temperature.

3.2.11 Sampling Rate
General Definition: The pump flow rate (for an active sampling device). The diffusion rate (for passive sampling devices).
NIOSH Definition: Sampling rate or uptake rate is the volumetric (or equivalent) rate that the air containing the analyte is introduced into the monitor.

3.2.12 Response Time
General Definition: The time for a sensor to reach a certain level of its stable reading.
NIOSH Definition: Response time is the time required for a monitor’s response to a measurand (gas, temperature, pressure) to reach a specified fraction (some definitions specify 63.4%, but others may be > 90%) of its final response. This lag time depends on the monitor type and measurement conditions. For example, the response time of an amperometric gas sensor for CO depends on both the rate of diffusion of the gas and the electrical time constant of the working electrode.

3.2.13 Response Time (t50)
General Definition: The time for a sensor to reach 50% of its stable reading.

3.2.14 Response Time (t90)
General Definition: The time for a sensor to reach 90% of its stable reading.

3.2.15 Start-up to t90 after 24-hour Storage
General Definition: The time for a sensor to reach 90% of its stable reading after it has been shut down for 24 consecutive hours.
3.2.16 **Start-up to t90 after 7-day Storage**
General Definition: The time for a sensor to reach 90% of its stable reading after it has been shut down for 7 consecutive days.

3.2.17 **Start-up to t90 after 30-day Storage**
General Definition: The time for a sensor to reach 90% of its stable reading after it has been shut down for 30 consecutive days.

3.2.18 **Linearity Range**
General Definition: The variation from a straight-line response over the full detection range of the monitor. Given in percent variation.

3.2.19 **Bias (Instrument Uncertainty)**
General Definition: The sum of inherent sampling error within the instrument.
NIOSH Definition: Bias is the relative discrepancy between the mean of the distribution of measurements from a monitor, $\mu$, and the true concentration being measured, $C_r$, expressed as a fraction. It is given by $B = (\mu / C_r) - 1$. To meet the AC, acceptable monitors should have an absolute bias no greater than 10%.
Calibrants used also have a small amount of error that is usually defined in the data sheet accompanying the calibrant. It may be expressed as a concentration with a plus/minus value, where the value refers to the uncertainty. The interpretation is that over many calibrant preparations, the bias relative to the designated concentration will be zero, but there can be variability of the actual concentration due to the uncertainty. The uncertainty may be expressed as either a measure of variability or as a multiple of the measure, which should be expressed in the data sheet. In either case, the true concentration is thought to lie between the designated concentration and plus/minus the uncertainty, though the probability with which this statement holds depends on the multiple of the uncertainty that is used. These components assume that the evaluated monitor bias is constant over all concentrations tested. The assumption of a constant bias applies only to the range of concentrations tested for the evaluation study and not in general.

3.3 **Operating Conditions Definitions**

3.3.1 **Temperature Range**
General Definition: The range of temperature where the sensor and its readings are within the stated accuracy.

3.3.2 **Effect of Temperature**

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* Specification is listed for reference only and is not listed on the Standardized Equipment Specification Sheet.
General Definition: How the instrument responds outside the stated temperature range and the means of compensation or correction.
Note: If the temperature can affect the sensor or the sensed characteristics of the air significantly, the extent of the effect should be noted and a correction should be made. If there is a range of temperatures where the temperature does not affect the readings of the sensor, it should be noted as the useful operating temperature range of the instrument. Temperature sensing and compensating circuits may be incorporated in the instrument to enable it to give corrected reading as the temperature varies.

3.3.3 Humidity Range
General Definition: The range of relative humidity where the sensor and its readings are within the stated accuracy.

3.3.4 Effect of Humidity
General Definition: How the instrument responds outside the stated humidity range and the means of compensation or correction.
Technical Definition: If the amount of water vapor in the air can affect the sensor or the sensing properties of the air, an error in the response of the target contaminant could be noted. If the effect is great enough to change the readings at a certain concentration by more than the normal variability of the sensor, the extent of the effect should be noted. If there is a range of humidity where the sensor and its readings are not affected significantly, this could be noted and reported as the range of humidity for normal operation. If the water vapor can mimic a signal equivalent to a response of the contaminant or interfere with the response of the detector to the contaminant, the amount of interference should be determined and a correction fact for different humidities should be reported.

3.3.5 Pressure Range
General Definition: The range of atmospheric pressure and/or elevation where the sensor and the readings are within the stated accuracy.

3.4 Error-state Notification Definitions

3.4.1 High/Low Temperature
General Definition: If and how the instrument notifies the user in real time that the ambient temperature conditions may be adversely affecting the contaminant concentration displayed.

3.4.2 High/Low Humidity
General Definition: If and how the instrument notifies the user in real time that the ambient humidity conditions may be adversely affecting the contaminant concentration displayed.

3.4.3 Over Range
General Definition: If and how the instrument notifies the user in real time that the ambient contaminant concentrations may be adversely affecting the contaminant concentration displayed.

3.4.4 Pump Flow
General Definition: If and how the instrument notifies the user in real time that the flow to the instrument sensor may be restricted.

3.5 Readings Definitions
3.5.1 Instantaneous Reading Frequency
General Definition: How frequently a new distinct reading is displayed and the method for how it is calculated (e.g., ten 0.10-second readings are averaged every second).

3.5.2 STEL
General Definition: Short-term exposure limit. Average exposure over the last 15 minutes.
Technical Definition: Time-weighted average concentration measured over a limited sampling period (usually 15 minutes unless otherwise noted).
NIOSH Definition: Time-weighted average concentration measured over a limited sampling period (usually 15 minutes unless otherwise noted).

3.5.3 TWA (TWA Concentration)
General Definition: Time-weighted average. The cumulative measured average concentration over the course of a given period (generally an 8-hour work shift).
NIOSH Definition: Concentration measured over a defined time period (e.g., 15 minutes [min], 8 hours [h], 10 h).
TWA calculation method: Specify how the TWA is calculated.

3.5.4 Peaks
General Definition: The highest measured value for any given parameter (e.g., LEL, toxics) since the instrument started its current run or has been manually cleared.

3.5.5 Exposure Limits
General Definition: Exposure limit is the concentration of an analyte above which worker exposure is prohibited or not recommended for a specified period of time during the workday.
For any given analyte, there may be a number of different exposure limits based on regulations or recommendations from agencies, such as the NIOSH recommended exposure limit (REL) [NIOSH 1992], the OSHA permissible exposure limit (PEL) [29 CFR* 1910.1000], the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV®)

[ACGIH 1992], the Mine Safety and Health Administration (MSHA) PEL [30 CFR 56.5001; 57.5001; 71.700 (2003)], etc. These limits may also be international in scope and usually are expressed in one or more of the following terms:

- **Time-weighted average (TWA) concentration**: Concentration measured over a defined time period (e.g., 15 minutes [min], 8 hours [h], 10 h).
- **Short-term exposure limit (STEL)**: Time-weighted average concentration measured over a limited sampling period (usually 15 min unless otherwise noted).
- **Ceiling limit (Ceil)**: Concentration that is not to be exceeded over any time period (e.g., instantaneous to about 5 min).
- **Immediately dangerous to life and health (IDLH)**: A situation that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment [NIOSH 1987]. Failure of an instrument in this situation may contribute to a catastrophic outcome.

3.5.6 **Alarm Limit, Programmable**
General Definition: If fixed, the level at which the instrument will alarm. If programmable, the range and increment over which the instrument can be programmed and how (instrument or computer).

3.5.7 **Alarms/Indicators**
General Definition: A signal such as a loud noise or flashing light that warns or alerts the user that some action is required. Alarming events could include a fault with the unit, a low battery, exceeding a preset exposure limit, or other such useful information for the user.

3.6 **Cross-Interferents at NTP Definitions**
3.6.1 **Commonly Known Cross-Sensitivities at NTP.**
General Definition: The known additive or subtractive effect on the true value of the gas being measured as related to the apparent calibration gas concentration (instrument reading).
Technical Definition: True concentration = (reading X correction factor).

3.6.2 **Interferences @ NTP**
General Definition: The effect produced by any chemical or physical interaction with the instrument sensor that reduces the instrument’s accuracy or precision.
NIOSH Definition: Interferences can be other compounds or conditions that are present with the analyte in the sampled environment that can create difficulties in the determination of the analyte by the monitor. Potential interferences are listed below:
- Compounds that interfere with representative sampling of the analyte.
• Compounds that interfere with accurate analysis of the analyte by the detection system of the monitor.
• Conditions that interfere with representative sampling of the analyte.
• Conditions that interfere with accurate analysis of the analyte by the detection system of the monitor.

3.7 Maintenance Definitions

3.7.1 Recommended Bump Test Interval
General Definition: Bump test (function check): A qualitative function check where a challenge gas is passed over the sensor(s) at a concentration and exposure time sufficient to activate all alarm indicators to present at least their lower alarm setting. The purpose of this check is to confirm that gas can get to the sensor(s) and that all the alarms present are functional.

3.7.2 Recommended Calibration Interval
General Definition: The manufacturer’s recommended frequency for calibration of the instrument to provide assurance of measurement accuracy (e.g., daily, weekly, monthly).
Calibration check: A quantitative test utilizing a known traceable concentration of test gas to demonstrate that the sensor(s) and alarms respond to the gas within the manufacturer’s acceptable limits. This is typically ±10–20% of the test gas concentration applied unless otherwise specified by the manufacturer, internal company policy, or a regulatory agency.
Full calibration: The adjustment of the sensor's (or sensors') response to match the desired value compared to a known traceable concentration of test gas. This should be done in accordance with the manufacturer's instructions.

3.7.3 Recommended Factory Service Interval
General Definition: The amount of time between returning the instrument to the manufacturer for service. This can be stated in hours, months, or years.

3.7.4 Detector (Sensor) Life Expectancy
General Definition: The amount of time a sensor is expected to properly function when following the manufacturer’s guidelines for calibration and use.
NIOSH Definition: Detector life describes, in general, the time over which a detector can operate within acceptable parameters. As a detector reaches the end of its useful life, its performance degrades beyond acceptable limits. Detector life varies according to the properties of the detector type (e.g., semiconductor, photothermal, optical- and fiber optic-based, piezoelectric, pyroelectric, and thermal). The detector manufacturer (or the manufacturer whose instrument incorporates a given sensor) should provide an indication of the useful detector life. Whether or not a given detector has passed its
useful lifetime can be determined from a quality control graph. When detector response is repeatedly out of control, the user should consider replacing the detector.

3.7.5 Instrument Life Expectancy
General Definition: The amount of time the instrument is expected to properly function when following the manufacturer’s guidelines for use.

3.8 Data Management Definitions
3.8.1 Data Logging Memory
General Definition: Number of unique measurements able to be stored in memory, and hours of operation based on one-minute data log. Note if additional memory cards can be used (e.g., SD flash cards).

3.8.2 Computer Interface
General Definition: System by which the instrument communicates with a computer (e.g., USB, IR, wireless).

3.8.3 Software Required to Access Data
General Definition: Software necessary to operate the instrument, obtain data from memory, or perform any other instrument function.

3.9 Safety Definitions
3.9.1 Hazardous Area Ratings & Classifications
General Definition: The intrinsic safety certifications/approvals this instrument has obtained and the issuing organization(s).

3.9.2 Ingress Protection
General Definition: The instrument resistance rating to dust and water penetration, and the organization issuing the rating.

4 Methods for Establishing Equipment Specifications
The equipment specifications in this were suggested by the team of AIHA volunteers. Some of the volunteers included specifications from the NIOSH document “Components for Evaluation of Direct Reading Monitors”.

5 References


