Designation: D4490 – 23

Standard Practice for the Use of Detector Tubes in the Measurement of Toxic Gases and Vapors[1]

This standard is issued under the fixed designation D4490; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the detection and measurement of concentrations of toxic gases or vapors using detector tubes (**1, 2**).[2] A list of some of the gases and vapors that can be detected by this practice and their measurement ranges are provided in Annex A1. This list is given as a guide and should be considered neither absolute nor complete.

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

1.3 *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.*

1.4 *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:*[3]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D5337 Practice for Flow Rate Adjustment of Personal Sampling Pumps

2.2 *Other Documents:*

29 CFR 1910 Federal Occupational Safety and Health Standard Title 29[4]

ISO 13137 Workplace Atmospheres – Pumps for Personal Sampling of Chemical and Biological Agents – Requirements and Test Methods[5]

3. Terminology

3.1 For definitions of terms used in this method, refer to Terminology D1356.

4. Summary of Practice (3)

4.1 Detector tubes may be used for either short-term sampling (grab sampling; 1 min to 10 min typically) or long term sampling (actively or passively; 1 h to 8 h) of atmospheres containing toxic gases or vapors.

4.1.1 *Short-Term Sampling (Grab Sampling)* (**4-18**)—A given volume of air (specified by the manufacturer) is pulled through the tube by a pump also specified by the manufacturer in a time period on the order of 1 min to 10 min. The length-of-stain is related to the amount of air sampled and the contaminant concentration during the sample period. For most detector tubes the concentration is determined by interpreting the length of color change compared to the calibration curve affixed to the glass tube. There are some detector tubes which rely on the interpretation of the intensity of a color change compared to a color standard or standards provided by the manufacturers. The resultant color reaction may change over time and must be evaluated immediately by the user.

4.1.2 *Long-Term Active Sampling (Long-Term Tubes)* (**19-22**)—A sample is pulled through the detector tube at a slow, constant flow rate specified by the manufacturer by a pump over a 1 h to 8 h period. The length of color change and the sampling time are used to determine the time weighted average (TWA) concentration of the contaminant.

[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.04 on Workplace Air Quality.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

[3] 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.

[4] *Code of Federal Regulations*, Part 1910.1000 Subpart 2 and Part 1926.55 Subpart D.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

4.1.3 *Length-of-Stain Dosimeter Tubes* (**23**)—The contaminant molecules move into the tube according to Fick's First Law of Diffusion. The driving force is the concentration differential between the ambient air and the inside of the tube. The time-weighted average concentration of the gas or vapor is determined by dividing the indication on the tube by the number of hours sampled (typically 1 h to 10 h according to the manufacturer's instructions).

5. Significance and Use

5.1 The Federal Occupational Safety and Health Administration, in 29 CFR 1910, designates that certain gases and vapors must not be present in workplace atmospheres at concentrations above specific values.

5.2 This practice will provide a means for the determination of airborne concentrations of certain gases and vapors given in 29 CFR 1910.

5.3 A partial list of chemicals for which this practice is applicable is presented in Annex A1.

5.4 This practice also provides for the sampling of gaseous atmospheres to be used for process control or other purposes (**2, 24-23**).

5.5 *Advantages of the Detector Tube Method:*

5.5.1 As the detector tube method requires no chemical analyzers, external reagents, etc., advance preparations are not needed; detector tubes are always ready for use.

5.5.2 The detector tube method is well-suited for use at the work site because it is small, lightweight, and needs only a small sample volume to determine the concentration of gas or vapor in a sample.

5.5.3 The operating procedures are simple.

5.5.4 The results of measurements are available in just minutes, so fast action can be taken when needed.

5.5.5 Where no electrical power source is required, detector tubes can be used even when flammable gases are present.

5.5.6 Different types of detector tubes are available for different gases and measuring ranges, from 0.01 ppm to more than 10 %, depending on analyte and tube design, making the system flexible tor different sampling situations.

6. Apparatus and Operation (**26-29**)

6.1 *General*—Short-term detector tubes are used for grab-sampling, capturing a concentration in a defined moment in time. They allow for the determination of contaminant concentrations, typically in the period of 1 min to 10 min with most measurements under 5 min.

6.2 *Apparatus:*

6.2.1 The detector tube method is a two-component system comprised of the detector tubes and pump(s) calibrated as a unit by the manufacturers. Detector tubes made by one manufacturer must not be used with pumps made by a different manufacturer due to the flow characteristics and physical relationship of the detector tubes and pumps.

6.2.2 In some sampling situations, particularly when testing for hazardous contaminant concentrations in confined spaces, a remote sampling line and adapter can be used. This allows placement of the detector tube in the potentially hazardous area to be tested while the operator is in a safer area (for example, sampling from a confined space prior to entry).

6.3 *Detector Tube*—A detector tube consists of a glass tube containing an inert granular material that has been impregnated with a chemical system which reacts with the gas or vapor of interest. As a result of this reaction, the impregnated chemical changes color. The granular material is held in place within the glass tube by porous plugs of a suitable inert material. The ends of the glass tube are flame-sealed to protect the contents during storage.

6.4 *Pumped Systems* (**30**)*:*

6.4.1 *Short-Term Sampling*—A mechanical, hand-operated, aspirating pump is used to draw the sample through the detector tube during the short-term sampling. Two types of pumps are commercially available: piston-operated and bellows-operated. The pumps have a capacity of 100 mL for a full pump stroke, and offer an option for collection of 50 mL. By varying the number of pump strokes, the sample volume is controlled. The pumps contain a flow-finish indicator that alerts the user to sampling completion. Sampling pumps shall be maintained and the sampling volume checked periodically according to the manufacturer's instructions. The pumps shall be accurate to ±5 % of the volume stated.

6.4.2 *Long-Term Sampling*—Small electrical pumps having stable low flow rates (2 mL/min to 50 mL/min), are required for long-term sampling. Flow rates to be used with each detector tube are given by the manufacturers. As with the mechanical pumps, the electrical pumps shall be maintained and the flow checked regularly. Maintenance and flow determination are performed using the instructions supplied by the manufacturer of the pump. The pump flow rate, and, therefore, the sampled volume, shall be accurate to ±5 % of the stated flow rate. With this system either area or personal monitoring can be accomplished.

6.5 *Diffusive Systems*—Unlike pumped systems, neither a mechanical nor electric pump is required. Measurement is initiated as soon as the sampling end is broken, and is completed when re-sealed. Tubes are typically calibrated in terms of ppm.hours, where the reading is divided by the number of hours to provide the time-weighted average concentration in ppm. Because the diffusion coefficient (a component of Fick's Law) is affected by both pressure and temperature, corrections for these are required for accurate results.

6.6 *Accessories*—Several accessories are provided with detector tubes for special applications:

6.6.1 *Reactor Tubes*—These are tubes that are used in conjunction with detector tubes. Some gases and vapors, because of their low reactivity, are not easily detected by detector tubes alone. The reactor tubes consist of very powerful chemical reactants, which break down the unreactive compound into other more readily detectable substances, which standard detector tubes can detect. Thus, the reactor tube is placed upstream of the detector tube and the combination must be used for certain compounds as a detector tube system.

6.6.2 *Dryer Tubes*—Water vapor interferes with the detection of certain substances; therefore, dryer tubes are used upstream of the detector tube as a pretreatment dehumidifier to remove the water vapor.

6.6.3 *Pyrolyzer*—A pyrolyzer is a hot wire instrument operated by batteries. Instructions for its use and maintenance are given in the manufacturers' instruction manuals. The purpose of the pyrolyzer, as with reactor tubes, is to break down difficult-to-detect compounds into other compounds more easily detected. The breakdown in this case is caused by heat. The pyrolzyer is particularly useful for organic nitrogen compounds, one of the products of breakdown being nitrogen dioxide, which is easily monitored.

6.6.4 *Remote Sampling Line*—When the sampling point is remote from the pump location, a length of nonreactive tubing can be attached to the pump with the detector tube attached to the other end of the tubing. This is useful for sampling in inaccessible or dangerous places.

6.6.5 *Cooling Unit*—The cooling unit consists of a length of metal tubing through which the sampled gas is pulled. Because of the high thermal conductivity of the metal tubing, the hot sampling gas is cooled sufficiently so that it will not destroy the indicator in the detector tube. The cooling unit must be placed upstream from the detector tube. Cooling units are particularly useful when sampling flue gases.

6.6.6 *Pipeline Sampling Kit*—The pipeline sampling kit provides representative gas and vapor sampling from pressurized systems. Made of chemically resistant materials, the sampler design allows the user to draw a detector tube sample from the center of the flow-through chamber. Ambient air cannot dilute the sample as long as a positive flow is maintained.

6.6.7 *Personal Sampling Pump*—When using long-term pumped tubes (6.4.2) a sampling pump is required. The pump should meet the specifications of ISO 13137 and have its flow rate set and verified in accordance with Practice D5337 before and after sampling.

6.6.8 *Sample Holder*—To be used with long term pumped tubes or diffusive tubes to attach the tube to the person whose breathing air is being sampled.

7. Procedure

7.1 Detector tubes made by one manufacturer must not be used with pumps made by a different manufacturer (**31**). Each lot of detector tubes is calibrated at the manufacturer's plant, using their equipment. The pumps of other manufacturers have different flow characteristics that cause different lengths-of-stain, resulting in erroneous readings.

7.2 Use of detector tubes should be conducted under the supervision of a trained professional such as a chemist or an industrial hygienist. Carefully follow the instruction sheet of the manufacturer for the proper use of each detector tube. Check the pump for leaks, total volume, and flow rate in accordance with the instruction manual for the pump. Also check the sampling line for leaks (if used).

7.3 Remove one detector tube from the box and break off both tips for pumped tubes or the sampling end of a diffusive tube.

7.3.1 For pumped tubes, insert the detector tube into the pump inlet or onto the sample line, making sure that it is properly oriented with the arrow pointed toward the pump inlet. For some chemicals, reactor tubes (6.6.1) or dryer tubes (6.6.2) may need to be added in front of the detector tube as part of the sampling train. Other methods may require the use of a pyrolyzer (6.6.3).

7.3.1.1 Face the mounted detector tube into the atmosphere to be tested. Sample an appropriate volume of air by pulling the pump handle out for the required number of strokes if using a piston pump, or squeezing the pump the proper number of times if using a bellows-type or bulb-type pump, or if using a long-term pumped detector tube, attaching the personal sampling pump and tube in a holder (6.6.8) to the person whose breathing air is being sampled and switching on the pump. Consult the manufacturer's instruction sheet on how much volume is required for your desired sampling range (8.2).

7.3.1.2 Allow the sample volume to pass through the tube as indicated by pump's flow-through indicator or switch off the personal sampling pump after the desired sampling interval and calculate the volume passed. Wait the specified time as directed on the tube instruction sheet prior to reading the length-of-stain.

7.3.1.3 If the contaminant is present, the indicator chemical in the tube will change color (refer to the instruction sheet). The length of stain, correlated with the volume of air sampled, will indicate the concentration. Most detector tubes now have direct reading concentration scales printed on the tube.

7.3.2 For diffusion tubes, insert the tube into its holder (6.6.8) and attach to the person whose breathing air is being sampled. Record the time of the commencement of sampling and record the time when sampling is finished. The time elapsed can be used with the scale to calculate the concentration. Temperature and pressure corrections may be necessary (6.5).

7.4 Detector tubes use chemical reagents that inevitably deteriorate over time. Because of this, if detector tubes are used after the stated shelf life expiration date (stamped on each box of tubes), they may not show an accurate gas or vapor concentration

7.5 Detector tubes should be stored in a cool, dark place to ensure adequate shelf life, that is, at a temperature of 25 °C or less and out of direct sunshine even if a specific temperature is not shown on a box. Detector tubes stored at high temperatures or in direct sunlight may show deterioration in performance even if they are within the stated shelf life. Some detector tubes are required to be stored under refrigeration until use at a temperature between 0 °C and 10 °C or as otherwise stated on the box.

8. Conditions That Affect Detector Tube Results

8.1 *Interferences and Cross Sensitivity*—Virtually all methods of gas and vapor detection (detector tubes, electrochemical sensors, PIDs) must cope with the potential interference by other contaminants present in the atmosphere being tested. The following are some common examples particular to detector tubes. It is not the intent of this subsection to elaborate all possible scenarios. Some common interferences and cross