



National Institute of Justice
Technology Assessment Program

**Portable Organic
Vapor Detectors**

NIJ Standard-0606.00

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James K. Stewart, Director
National Institute of Justice

Technology Assessment Program

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for
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National Institute of Justice*

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**U.S. Department of Justice
National Institute of Justice**

**U.S. DEPARTMENT OF JUSTICE
National Institute of Justice**

James K. Stewart, Director

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This standard was formulated by the Law Enforcement Standards Laboratory of the National Bureau of Standards under the direction of Paul H. Krupenic, Program Manager for Forensic Science, and Lawrence K. Eliason, Chief of LESL. James E. Brown of the NBS Center for Fire Research prepared the standard and did the research upon which it is based. The standard has been reviewed and approved by the Technology Assessment Program Advisory Council (TAPAC) and adopted by the International Association of Chiefs of Police (IACP) as an IACP standard.

FOREWORD

This document, NIJ Standard-0606.00, Portable Organic Vapor Detectors, is an equipment standard developed by the Law Enforcement Standards Laboratory of the National Bureau of Standards. It is produced as part of the Technology Assessment Program of the National Institute of Justice. A brief description of the program appears on the inside front cover.

This standard is a technical document that specifies performance and other requirements equipment should meet to satisfy the needs of criminal justice agencies for high quality service. Purchasers can use the test methods described in this standard themselves to determine whether a particular piece of equipment meets the essential requirements, or they may have the tests conducted on their behalf by a qualified testing laboratory. Procurement officials may also refer to this standard in their purchasing documents and require that equipment offered for purchase meet the requirements. Compliance with the requirements of the standard may be attested to by an independent laboratory or guaranteed by the vendor.

Because this NIJ standard is designed as a procurement aid, it is necessarily highly technical. For those who seek general guidance concerning the selection and application of law enforcement equipment, user guides have also been published. The guides explain in nontechnical language how to select equipment capable of the performance required by an agency.

NIJ standards are subjected to continuing review. Technical comments and recommended revisions are welcome. Please send suggestions to the Program Manager for Standards, National Institute of Justice, U.S. Department of Justice, Washington, DC 20531.

Before citing this or any other NIJ standard in a contract document, users should verify that the most recent edition of the standard is used. Write to: Chief, Law Enforcement Standards Laboratory, National Bureau of Standards, Washington, DC 20234.

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NIJ STANDARD FOR PORTABLE ORGANIC VAPOR DETECTORS

CONTENTS

	Page
Foreword.....	iii
1. Purpose	1
2. Scope.....	1
3. Definitions.....	1
4. Requirements	1
4.1 Minimum Performance.....	1
4.2 User Information.....	1
4.3 Portability.....	2
4.4 Precision	2
4.5 Accuracy	2
4.6 Sensitivity	2
4.7 Temperature and Humidity Requirements	3
4.8 Battery Power Requirement	3
4.9 Ruggedness.....	3
4.10 Safety	3
5. Test Methods.....	3
5.1 Test Conditions	3
5.2 Sampling.....	3
5.3 Test Equipment.....	3
5.4 Optional Preparation of Vapor Standards	5
5.5 Test for Sensitivity	6
5.6 Temperature Tests.....	7
5.7 Humidity Test	7
5.8 Test for Battery Power	8
5.9 Test for Ruggedness.....	8
Appendix A—References.....	9

NIJ STANDARD FOR PORTABLE ORGANIC VAPOR DETECTORS

1. PURPOSE

This standard establishes performance requirements and test methods for evaluating portable organic vapor detectors, instruments that may be used by arson investigators to locate fire debris that may contain residues of a liquid accelerant. Reliable identification of a specific class of accelerants is possible only in a laboratory using more sophisticated equipment, and is not included in the performance criteria. This standard includes methods by which a detector's sensitivity to selected organic vapors may be determined. It also includes methods by which the instrument's responses to fire debris vapor with and without residues of a liquid accelerant can be compared.

2. SCOPE

This document addresses portable organic vapor detectors whose sensor is one of the following types: catalytic combustion, flame-ionization, photoionization, or spectrophotometric.

3. DEFINITIONS

3.1 Accelerant

A chemical substance, most commonly a flammable liquid, used to start a fire or promote or direct its spread.

3.2 Dynamic Vapor Standards

A reference mixture of hydrocarbon vapor in flowing air.

3.3 Sensitivity

The smallest detectable amount of organic vapor measurable or smallest detectable change in its concentration.

3.4 Sensor

That component of a vapor detector which interacts with (senses) vapor and generates a signal.

4. REQUIREMENTS

4.1 Minimum Performance

The portable vapor detector shall meet or exceed the performance requirements listed in this standard.

4.2 User Information

The manufacturer or distributor shall supply an instruction manual with the vapor detector. The following information shall be supplied:

- a) Assembly and set-up instructions; schematic diagram and parts list.
- b) Preoperation and adjustment instructions.
- c) A statement of principle and theory of operation.

- d) The calibration and operation procedures, and a description of the controls and their function.
- e) The vapor or gas used for calibration.
- f) The sensitivity to and measurement range of vapor concentrations.
- g) The detector's response to vapors of compounds in at least three chemical classifications, excluding the calibrating vapor or gas; e.g., aromatic and aliphatic hydrocarbons, alkenes, alcohols, esters.
- h) Interfering substances and their effect on the response of the detector's sensor and damage to it, if any.
- i) Response time and recovery time after full-scale response.
- j) Description of batteries including their nominal voltage, type and model, rated in-use capacity, and recharge rate (if rechargeable).
- k) The maximum period of time the vapor detector will remain ready for use in a standby state, if one is available.
- l) The maximum period of time for reliable continuous operation.
- m) The care required during an inoperative period or one of intermittent use to maintain the detector in a ready-to-use state.
- n) The environmental extremes, including temperature and relative humidity (if applicable), which affect reliable measurement of vapors.

4.3 Portability

4.3.1 Design

The design of the vapor detector shall allow operation and vapor measurement while it is being carried. The weight or dimensions of the operating vapor detector shall not induce excessive strain or exhaustion in the operator when it is carried for a 15-min period [1]¹.

4.3.2 Transporting Devices

The instrument shall be equipped with handles, straps, or other grips that permit transportation and operation by one person.

4.4 Precision

When tested in accordance with section 5.5, the device shall measure concentrations of isooctane (2,2,4 trimethyl pentane) and toluene vapor in air within the range 10 to 50 parts per million (ppm), with a standard deviation of no more than ± 10 percent from the mean value.

4.5 Accuracy

The calibrated detector shall measure the hydrocarbon content of vapor standards at concentrations of 10 to 50 ppm, with an accuracy of ± 20 percent, when tested in accordance with section 5.5.

4.6 Sensitivity

4.6.1 Known-Chemical Sensitivity

The response of the detector to changes in concentration of the vapor of hydrocarbons such as toluene or isooctane in air shall be readable to 2 ppm or less.

4.6.2 Relative Sensitivity to Simulated Fire Debris

The response of the detector to the vapor of simulated arson fire debris containing gasoline residues shall be significantly greater than the response to accelerant-free fire debris. When tested in accordance with section 5.5.2.3, the ratio of signals from accelerated and control samples shall be greater than 3.

¹ Numbers in brackets refer to references in appendix A.

4.7 Temperature and Humidity Requirements

4.7.1 Temperature

The vapor detector shall meet the requirement for sensitivity (sec. 4.6), when operated at temperatures from 0 °C (32 °F) or that stated by the manufacturer, whichever is lower, to 40 °C (104 °F) or that stated by the manufacturer, whichever is higher, in accordance with the test in section 5.6.

4.7.2 Relative Humidity

The vapor detector shall meet the requirement for sensitivity (sec. 4.6), when operated in an atmosphere with a relative humidity up to 90 percent, or higher if so specified by the manufacturer, in accordance with the test in section 5.7.

4.8 Battery Power Requirement

Fully-charged batteries shall have sufficient power to operate the detector accurately (see sec. 4.5) for at least four consecutive hours, when tested in accordance with section 5.8.

4.8.1 Battery Power Alarm

The detector shall have a visual or audio indicator which warns of low internal battery power during operation, and a meter to indicate degree of charge for other than nickel-cadmium batteries.

4.8.2 Battery Charger

A device with rechargeable batteries shall be provided with a battery charger which operates from 110 V at 60 Hz.

4.9 Ruggedness

When shock tested in accordance with section 5.9, the fixed parts of the vapor detector shall not become dislodged nor shall the detector fail to function normally.

4.10 Safety

The vapor detector shall be certified by the manufacturer or distributor to be intrinsically safe to operate in environments containing combustible vapors and flammable materials; i.e., for use in Division 1 Hazardous Locations. (See National Fire Codes, Vol. 4, 1983, National Fire Protection Association, Quincy, MA 02269.)

5. TEST METHODS

5.1 Test Conditions

Unless otherwise specified, all tests shall be performed with the unit operated in a normal laboratory environment. Tests shall be performed with the unit powered by its internal power source (batteries), and the device shall be operated in accordance with the manufacturer's instructions. Instrument readings (vapor concentrations) shall be recorded to the nearest scale-division mark.

5.2 Sampling

One or more vapor detectors of a given model shall be selected at random for testing. Each instrument shall have fully-charged batteries, an appropriate sampling probe, and a battery-charger, if required.

5.3 Test Equipment

5.3.1 Dynamic Vapor Standards Generator

Use any method to generate the specified organic vapors of the required concentrations in air (sec. 4.5), provided the vapor concentrations are known with an accuracy of 10 percent or better. The known vapor-

air mixtures shall be generated at atmospheric pressure and at a rate which is greater by 25 percent or more than the sampling rate of the vapor detector.

5.3.2 Optional Vapor Standards Generator

Vapor-air standards meeting the specifications in section 5.3.1 may be prepared using a commercial apparatus, e.g., the Analytical Instrument Development, Inc. Model 350² vapor standards generator [2]. By use of this type of generator a constant flow of vapor is obtained from a pure liquid contained in a diffusion cell and maintained at constant temperature ($\pm 0.1^\circ\text{C}$) and pressure (of one atmosphere). Under these conditions, the rate of vapor generation depends only on the length and cross-sectional area of a capillary tube through which the vapor diffuses from the liquid into a controlled flow of air [2,3]. Diagrams of the generator's flow system and a cross-sectional view of the diffusion cell are shown in figures 1 and 2, respectively.

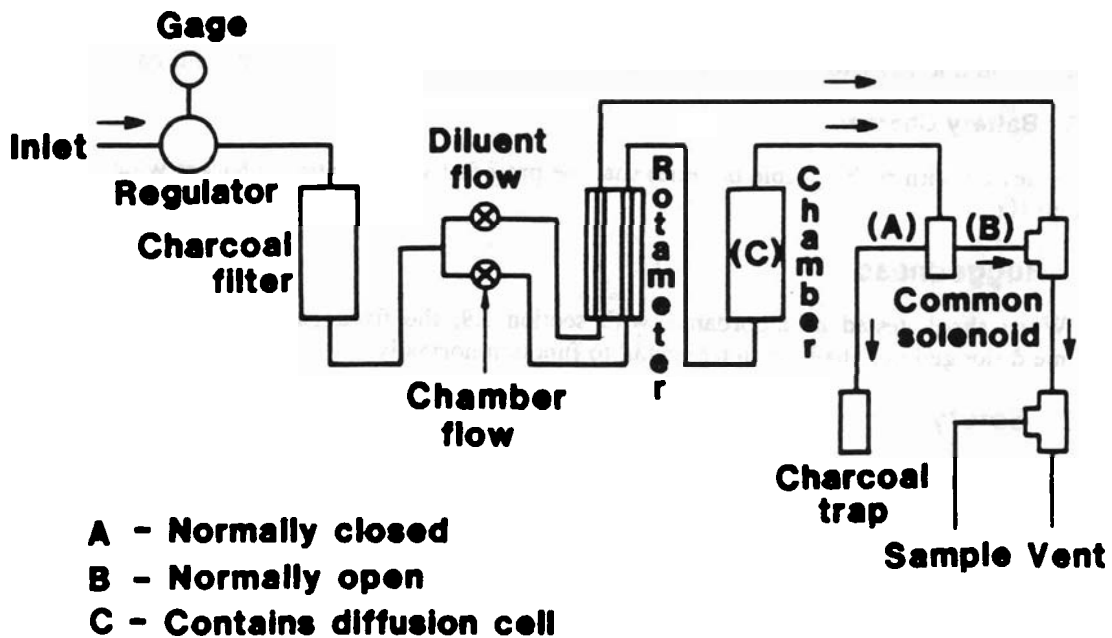


FIGURE 1. Diagram of a vapor standards generator's air and vapor flow system.

² Certain commercial instruments are identified in this standard in order to adequately specify the experimental procedure. In no case does such identification or suggested use imply recommendations or endorsement by the National Bureau of Standards or the Department of Justice, nor does it imply that the equipment identified is necessarily the best available for the purpose.

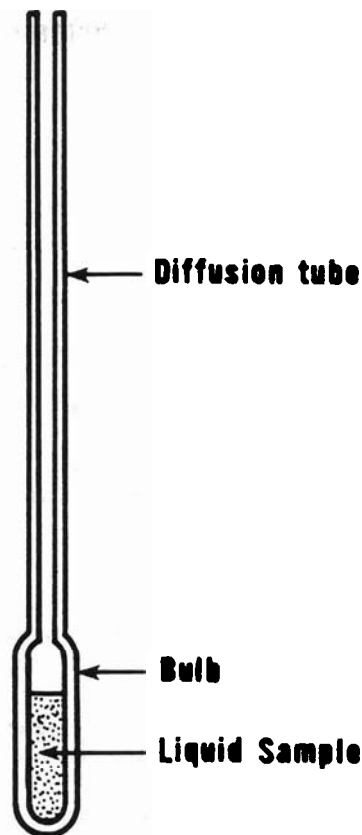


FIGURE 2. Cross-sectional diagram of a diffusion cell.

5.3.3 Optional Diffusion Tubes

If the vapor standards generator (sec. 5.3.2) is used, obtain at least two cells with diffusion tube diameters measuring 0.5 cm i.d. and lengths of 3.4 and 3.8 cm, respectively.

5.4 Optional Preparation of Vapor Standards

If calibrated diffusion cells (sec. 5.3.2) are available, the subsequent section, 5.4.1, may be omitted.

5.4.1 Calibration of Diffusion Tubes

Obtain a clean dry diffusion cell having a 0.5-cm i.d. diffusion tube which has been cut to a length of 3.8 cm. Transfer about 4 mL of toluene (reagent grade or equivalent) to the cell reservoir. A hypodermic syringe may be used for this purpose. The liquid shall not contact the inside walls of the diffusion tube during the transfer or at any time during the calibrating process. Avoid getting fingerprints or other matter on the outside of the diffusion cell. Repeat the above procedure using a diffusion cell with a 0.5-cm i.d. diffusion tube, 3.4 cm long, and filled with isooctane (reagent grade or equivalent).

Place the filled diffusion cells in the temperature-controlled cell chamber and secure the chamber cover in place. Set air flow through the chamber at 100 mL/min and the temperature control to 50 °C. After temperature equilibrium is established in the diffusion cell chamber, in 3 to 4 h, remove the filled diffusion cells and record their weight (M_0) to the nearest 0.1 mg. Immediately return the filled diffusion cells to the thermostated cell chamber and record the time as t_0 . Keep the diffusion cells in the chamber for at least 24 h (since longer periods yield greater accuracy of subsequent weight-loss determinations).

After this interval during which there is diffusion of vapor from the cells, remove the cells with the remaining liquid from the thermostated chamber and weigh them to the nearest 0.1 mg. Record the weights as M_1 and the time as t_1 . Immediately return the diffusion cells containing the liquid hydrocarbons to the thermostated chamber. Continue to the next weighing at least 24 h later. Record the weight as M_2 and the removal time as t_2 .

Compute the weight loss (grams) and the time interval (minutes) for each diffusion period as follows:

$$\Delta t_1(\text{min}) = t_1 - t_0 \quad (1)$$

$$\Delta M_1(\text{g}) = M_0 - M_1 \quad (2)$$

$$\Delta t_2(\text{min}) = t_2 - t_1 \quad (3)$$

$$\Delta M_2(\text{g}) = M_1 - M_2 \quad (4)$$

Compute the diffusion rates of the hydrocarbon vapor as follows:

$$v_1 = \text{Rate}_{(1)} (\mu\text{g}/\text{min}) = (\Delta M_1 / \Delta t_1) \times 10^6 \quad (5)$$

$$v_2 = \text{Rate}_{(2)} (\mu\text{g}/\text{min}) = (\Delta M_2 / \Delta t_2) \times 10^6 \quad (6)$$

$$v = \text{Average Rate } (\mu\text{g}/\text{min}) = (v_1 + v_2) / 2 \quad (7)$$

If diffusion rates determined by eqs (5) and (6) differ by more than 2 percent from the average determined by eq (7), redetermine the diffusion rate using diffusion times which are not less than 48 h.

5.4.2 Vapor Concentration Computation

Secure a calibrated diffusion cell containing about 4 mL of the selected hydrocarbon (isooctane or toluene) in the vapor-generator cell chamber. Set the air flow through the chamber at about 100 mL/min and allow thermal equilibrium of the diffusion cell to be established at 50 °C, as prescribed in section 5.4.1.

Set diluent flow of air so that the total flow of vapor and air from the vapor generator is about 2 L/min. The total flow from the vapor generator shall be greater by 25 percent or more than the sampling rate of the vapor detector under test. The uncertainty of the total flow from the vapor generator shall not be greater than 10 percent.

Compute concentration of the vapor in air as ppm (v/v) as follows:

$$\text{Vapor concentration (ppm)} = \frac{v}{\rho K} \quad (8)$$

where v = Diffusion rate of vapor, $\mu\text{g}/\text{min}$,

ρ = Vapor density of hydrocarbon at 25 °C, $\mu\text{g}/\mu\text{L}$,

K = Total flow (air + vapor) from the vapor generator, L/min.

5.5 Test for Sensitivity

These tests shall be performed in an environment essentially free of hydrocarbon vapor (containing 3 ppm or less).

The batteries, rechargeable or not, shall be fully charged before proceeding with the test. Test the battery with the "battery check" function switch. Set the detector's amplifier gain switch, if so equipped, and all other function switches for determination of vapor concentration in accordance with the manufacturer's instrument calibration. Move the appropriate function switches to the positions for operation of the vapor detector. Allow the instrument to stabilize, and then adjust the meter to zero in accordance with the prescribed procedure of the operator's manual.

5.5.1 Known-Chemical Sensitivity

Use isooctane to generate the vapor standard, and repeat the procedure using toluene.

Insert the sampling probe of the detector into the vapor-air mixture flowing from the standards generator (i.e., flow at 2 L/min), and record the indicated vapor concentration. Remove the sampling probe from the vapor standard and reset the meter null-position while the probe is in hydrocarbon-free air. Make at least three measurements on the vapor standard. Calculate the average of the measurements.

Set the flow of the vapor standard to half the previous rate (i.e., 1 L/min) and repeat the measurement of the vapor standard as described above. Make corrections, if necessary, for the vapor content of the test atmosphere. For each set of measurements made in accordance with the above procedures, calculate the average and the standard deviation. Also calculate the accuracy of the set of measurements from the average and the concentration of the vapor standard.

5.5.2 Test for Debris Vapor Sensitivity

5.5.2.1 Materials

The materials used for the preparation of simulated fire debris shall include:

- a) Methenamine tablets.
- b) Regular gasoline.
- c) Industrial or domestic carpet, treated to be fire retardant (20×20 cm).
- d) Plywood, 20×20 cm×1 to 2 cm

5.5.2.2 Preparation of Fire Debris

This method is used for the preparation of debris specimens without accelerant residue, and specimens containing residues of an accelerant.

Select two specimens of the same material for the preparation of simulated incendiary and nonincendiary fire debris. Add 10 mL of gasoline to the center area of one of the specimens. Place both specimens in a horizontal position on a mineral fiber board or stone-like surface in the area provided for the specimen burn. The separation between the specimens should be sufficient to prevent specimen-to-specimen accelerant transfer and flame spread during the subsequent burn.

Place three methenamine tablets in the center area of each specimen, about 2.5 cm apart. Ignite the tablets, and consequently, the specimen surface and accelerant, by using a small flame. Natural gas flowing through a metal tube (about 2 mm i.d. and 60 cm long) may be used to provide a suitable pilot flame about 1 cm in height. Allow the methenamine tablets to burn to completion (about 1.5 min). If a test specimen continues to burn after 4 min, extinguish the fire with a spray of water.

5.5.2.3 Detector Response to Debris Generated Vapor

(Note: See reference [5] for sensitivity evaluation of several detectors.)

Prepare the vapor detector for the measurement of organic vapor as prescribed by the operator's manual (sec. 5.5.1). Adjust the amplifier, if available, for maximum sensitivity using the appropriate function switch.

Obtain two specimens of plywood debris (incendiary and nonincendiary), prepared in accordance with section 5.5.2.2 and allow to cool at least 30 min. Sample the atmosphere at all surfaces of the accelerant-free debris using the detector's most sensitive measurement range. Record maximum vapor concentration (ppm) as C_n . Repeat the vapor measurement procedure on the debris of the gasoline-treated specimens and record vapor level (ppm) as C_a .

Compute the relative response of the vapor detector, DS, as:

$$DS = C_a / C_n \quad (9)$$

Repeat the measurement and computational procedures on two specimens of carpet fire debris, with and without the accelerant treatment.

Compute the average of the relative response determinations.

5.6 Temperature Tests

Place the detector and its probe in an environmental chamber at a temperature of 40 ± 2 °C (104 ± 3.6 °F) and a relative humidity of 50 ± 10 percent. Allow it to remain at that temperature for at least 6 h. Remove the device from the environmental chamber and perform the test in accordance with section 5.5.1.

Repeat with the environmental chamber at 0 °C (32 °F) and relative humidity of less than 50 percent.

If the manufacturer's specifications allow operation at more extreme temperatures, use those temperatures in these tests.

5.7 Humidity Test

Place the detector and its probe in an environmental chamber at nominal room temperature, 20 ± 2 °C (68 ± 3.6 °F) and 90 ± 5 percent relative humidity. Allow it to remain at that temperature for at least 6 h. Remove the device from the environmental chamber and perform the test in accordance with section 5.5.1.

If the manufacturer's specifications allow operation at a relative humidity above 90 percent, then perform the test at that humidity.

5.8 Test for Battery Power

The vapor detector used in this test shall have its batteries fully charged (if rechargeable); if replaceable batteries are used, unused batteries shall supply power.

Operate the detector as prescribed in section 5.5.1. With the instrument in a stable operating condition, make at least three replicate measurements of the vapor content of any suitable vapor standard which meets the specifications prescribed in section 5.3.1. These are to be made at intervals of at least 1 h, with the last measurement made 4 h after the device was turned on. Null the vapor detector or reset its zero scale position before each measurement. Examine the results for a time-dependent effect on the accuracy of the vapor measurement indicative of insufficient battery power; i.e., note whether the results are within the manufacturer's specification for continuous operation.

5.9 Test for Ruggedness

Place the detector on a bench with a wooden top. Lift one edge of the detector 10 cm or until the base forms an angle of 30° with the bench top, whichever is less. Release the detector and allow it to fall freely to the bench surface. Repeat the procedure lifting the other practical edges while using the opposite edge as pivot.

Operate the detector and make a vapor measurement of a vapor-air reference as prescribed in section 5.5.1.

APPENDIX A—REFERENCES

- [1] Kramer, J. J.; Meguire, P. G. Consumer product portability as related to warranty rulemaking. Natl. Bur. Stand. (U.S.) NBSIR 76-1092. Available from National Technical Information Service, Springfield, VA 22161.
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