



Designation: F2326 – 04 (Reapproved 2021)

# Standard Test Method for Collection and Analysis of Visible Emissions from Candles as They Burn<sup>1</sup>

This standard is issued under the fixed designation F2326; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## INTRODUCTION

During the development of this test method with a specially manufactured “standardized” candle, variability of candle burn behavior was observed that introduced a wide statistical variation in the overall test results from a single design. Variability in testing different types of candle products would introduce even greater variability, that is, a pillar candle comprised of 60 °C (140 °F) melting point wax would not, and would not be expected to, show the same burn behavior as a jar candle comprised of 54.4 °C (130 °F) melting point wax. It is believed that a significant database of candle burn performance, based on each type of candle and formulation format, would be required before one could determine whether a statistical basis could be developed for pass/fail criteria for visible smoke emissions from candles. This method is intended to provide candle manufacturers a standard procedure to use during the development of candle designs and formulations to compare relative smoking/burn behavior. This method neither implies nor sets a standard level for visible smoke emissions for any candle type or formulation.

## 1. Scope

1.1 This test method covers the collection and analysis of visible emissions from indoor use candles as they burn.

1.2 The test is to be used to compare relative smoke/burn behavior during development of candle designs and formulations.

1.3 This test method may not be suitable for multiple wick candles; tapers and candles intended to be burned while floating on water commonly known as “floaters.”

1.4 *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.*

1.5 *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:*<sup>2</sup>

**F1972** Guide for Terminology Relating to Candles and Associated Accessory Items

**PS59** Provisional Specification for Fire Safety for Candles

## 3. Terminology

3.1 See Guide **F1972** for definitions of terms not specified in 3.2.

3.2 *Definitions:*

3.2.1 *burn cycle*—length of time the candle is burned during one test day. For this test, a burn cycle is 4 h (see Provisional Specification **PS59**).

3.2.2 *burn period*—total time the candle is burned over the duration of the test. For this test, the burn period will be 16 h.

3.2.3 *fuel pool establishment period*—time, 15 min or longer, before each burn cycle that a candle must be burned to establish a normal fuel pool and stable flame.

3.2.4 *molten fuel pool*—portion of the wax or fuel pool of a candle that is in the liquid form when the candle is burning.

3.2.5 *optical densitometer*—instrument used for determining the optical density in the transmittance or reflectance mode.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee **F15** on Consumer Products and is the direct responsibility of Subcommittee **F15.45** on Candle Products.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.



3.2.6 *top of the candle*—the upper most part of the candle or container.

3.2.7 *visible emissions*—emissions that can be seen once collected on a substrate.

#### 4. Summary of Test Method

4.1 The visible emissions from a candle are collected on a transparent media over the specified burn period. The emissions can then be assigned a relative value as a function of opacity using a densitometer for a given testing sequence.

#### 5. Significance and Use

5.1 The intent of this test method is to aid the candle manufacturer to optimize candle formulations in the reduction of visible smoke emissions.

5.2 This test method is intended to provide candle manufacturers a standard procedure to use during development of candle designs and formulations to compare relative smoke/burn behavior. For the development of this method, a protocol was established for trimming the wick on specially prepared test candles to 6 mm to 7 mm ( $\frac{1}{4}$  in.) prior to each burn cycle. It is recommended that the manufacturer determine a standardized protocol, that is, either not trimming the wick or trimming the wick to an appropriate length in order for direct comparison of results.

5.3 A relative ranking of candle formulations can be established with the use of a histogram of the data and control charts.

5.4 This test method is not intended to set forth pass/fail criteria for visible smoke emissions from candles, as such, this method sets no standard level for visible smoke emissions.

#### 6. Interferences

6.1 The thickness of the collection material, that is, the glass microscope slide, will create a positive interference and should be corrected for in the set up of the densitometer prior to the analysis of test samples.

6.2 Any material that darkens the microscope slide other than the visible emissions of a candle shall create a positive interference.

#### 7. Apparatus and Materials

7.1 *Glass Microscope Slides*, nominally 76 mm by 25 mm (3 in. by 1 in.) with a writing surface for sample identification) to be placed above the candle to collect visible emissions.

7.2 *Ring Stands and Clamps*.

7.3 *Black and White Optical Densitometer*.

7.4 *Transparent Step Gray Scales*, for the verification of calibration of the densitometer.

7.5 *Number 1.5 Cover Slips*.

7.6 *Transparent Single-sided Tape*.

7.7 *Lint Free Cloth*, or wipe material.

7.8 *Room or Area*, with minimum drafts for burning candles.

7.9 *Noncombustible Surface*, on which to test candles.

7.10 *Ruler*, or similar measuring device capable of measuring to the nearest millimetre.

7.11 *Thermometers or Temperature Monitoring Device*, accurate to  $\pm 1^\circ\text{C}$ .

7.12 *Scissors*, or other device suitable for trimming wicks between burn cycles.

#### 8. Preparation of Apparatus

8.1 Prior to sampling, wipe microscope slides with a suitable lint free wipe to remove dust or fingerprints, or both.

8.2 Attach the microscope slide in a flat horizontal position in a ring stand clamp. The microscope slide should be parallel with the ground and as close to level as possible.

8.3 Place the candle(s) to be tested in a chamber or room with minimal drafts on a level-burning surface. The temperature of the room or chamber shall be maintained to  $25^\circ\text{C} \pm 5^\circ\text{C}$  ( $77^\circ\text{F} \pm 9^\circ\text{F}$ ) throughout the test period.

8.4 Move the microscope slide with ring stand into position such that the center of the microscope slide is above the center of the wick in the candle.

8.5 Position the microscope slide in the ring stand such that it is  $102\text{ mm} \pm 6\text{ mm}$  (4 in.  $\pm 0.25$  in.) above the solid top surface of the candle wax pool. In the event the flame becomes recessed inside the candle either due to a pillar candle maintaining the side walls as it burns or a containerized candle consuming the fuel as it burns, do not position the slide any closer than  $51\text{ mm} \pm 6\text{ mm}$  (2 in.  $\pm 0.25$  in.) from the top of the candle as defined in 3.2.6. If the microscope slide is positioned any closer than  $51\text{ mm} \pm 6\text{ mm}$  (2 in.  $\pm 0.25$  in.) to the top of the candle it may restrict air flow into the candle and effect the performance or behavior of the flame during the test. Once the proper height adjustment has been made prior to the burn cycle, move the slide and holder away from the candle until it is time to collect the sample, that is, after the 15 min or longer required to develop a molten fuel pool and stable flame.

#### 9. Calibration and Standardization

9.1 Place a new, clean microscope slide with a cover slip taped in place in the same manner as the test samples, on the optical portion of the black and white densitometer and zero the instrument. For transparent slides make sure that the densitometer is in the transmittance mode and not the reflectance mode.

9.2 Place another new, clean slide with the cover slip taped in place such that the cover slip is taped only on one side. Place the slide under the optical portion of the black and white densitometer. Slide the step gray scale under the cover slip and into place over the optical portion of the black and white densitometer. Check to verify the instrument is operating properly. The instrument measurement shall be within 5 % of the actual value at a density of 1.0 and within 10 % at a density of 0.40. The instrument is now ready to measure the optical density of actual test samples.



## 10. Conditioning

10.1 The burn test area shall be controlled to  $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$  ( $77\text{ }^{\circ}\text{F} \pm 9\text{ }^{\circ}\text{F}$ ) with 20 % to 70 % relative humidity and an environment that minimizes the disturbance of the flame of the candles under test.

## 11. Test Procedure

11.1 Remove all outer wrapping and remove label material (according to manufacturer's instructions) prior to initiating the burn test.

11.2 Trim the wick in accordance with the manufacturer's instructions. If no information is provided from the manufacturer, do not trim the wick for this test procedure. Place the candle, straight and upright, into the test position. When appropriate, place candles in a holder.

11.3 Light candles taking care not to contaminate them with carbon or debris from the ignition source. Burn for at least 15 min, or longer until a normal fuel pool and stable flame are established and record the time required.

11.4 Place the microscope slide in the manner described and at the height determined in 8.5, such that the center of the slide is over the wick of the candle.

11.5 Burn candles continuously for 4 h ( $\pm 5$  min). Extinguish the candle at the end of the test cycle and allow it to cool. Record the sample collection time, which is determined by subtracting the time required to establish a molten fuel pool and stable flame from the 4 h burn cycle.

11.6 Repeat steps 8.4, 8.5, and 11.2 – 11.5 until the completion of the burn period, that is, 16 h.

11.7 For candles with an expected burn life of less than 16 h, burn candles as described in 11.2 – 11.5 until the end of the candle's useful life. Record the total burn time of the candle for computational purposes.

11.8 If the microscope slide is moved during wick trimming or during candle adjustments or weighing, ensure that the microscope slide is repositioned over the wick such that the wick aligns with the same portion of the slide for each burn cycle. Making a tiny removable or washable dot on the side of the microscope slide not facing the flame may be helpful for alignment of the test slide with the wick. If a washable dot is used in slide positioning remember to remove it prior to analysis of the slide using the densitometer, as this would add a positive bias to the result.

11.9 Do not adjust the slide any closer than  $51\text{ mm} \pm 6\text{ mm}$  ( $2\text{ in.} \pm 0.25\text{ in.}$ ) above the top of the candle as defined in 3.2.6. Once the microscope slide has been positioned such that it is  $51\text{ mm} \pm 6\text{ mm}$  ( $2\text{ in.} \pm 0.25\text{ in.}$ ) above the top of the candle it should not be readjusted throughout the remainder of the burn period unless distance between the top of the candle and the microscope slide changes.

11.10 At the completion of the test period remove the microscope slide from the ring stand and place a cover slip over the visibly darkest area of the microscope slide. Tape the cover glass into place using care not to cover the cover slip with tape. It is best to attach the cover slip to the microscope slide by over lapping 2 to 5 mm of tape onto the cover glass with the majority of the tape on the microscope slide.

11.11 Place label on slide that identifies which candle the slide is from.

11.12 Record the total sample collection time.

## 12. Calculation or Interpretation of Results

12.1 Visually divide the area under the microscope cover slip into four equal quadrants. Place the microscope slide on the densitometer such that the visibly darkest quadrant is over the optical portion of the instrument. Make at least four measurements from the darkest quadrant and average the results.

12.2 Weight the averaged densitometer result for the time required to collect the sample, typically this will be 15 h, however; the time may be shorter depending on the length of time required to establish a molten fuel pool and a stable flame. For example, if the average densitometer result is 3.5 and the total sample collection time (see 11.2) is 15 h, then report the weighted densitometer result as  $3.5/15$  (3.5 divided by 15) or 0.23.

12.3 A standard protocol, especially related to wick trimming, is required for valid comparison of results for candles of a single or similar design.

## 13. Precision and Bias

13.1 The precision and bias for this test method has not yet been determined.

## 14. Keywords

14.1 candles; densitometer; visible emissions



# APPENDIX

## (Nonmandatory Information)

### X1.

X1.1 *Photograph Depicting Sampling Set Up*—See X1.1.

X1.2 *Photograph Depicting Densitometer in Use*—See X1.2.

X1.3 *Initial Research and Non-Commercial Test Candle*—Much of the initial research used to determine the validity of this test method was conducted by testing a non-commercial test candle using 131 °F (55 °C) melting point wax which was compression molded and fitted into a 12.25 oz Status Rock Jar. The wick used was a HTP 41 composite; no fragrance or

colorants were added.<sup>3,4</sup>

X1.4 *Report Information*—Although not a requirement of this test method, it may be in the manufacturer's best interest to maintain detailed records of the candles tested and the test

<sup>3</sup> Information on how to make or purchase this non-commercial test candle to verify a laboratory's in house test procedure can be obtained from Lumi-Lite Candle Company, 102 Sundale Road, Norwich, Ohio 43767.

<sup>4</sup> For information regarding historical data and expected densitometer measurement ranges for this non-commercial test candle contact SEA Ltd., 7349 Worthington-Galena Road, Columbus, Ohio 43085.

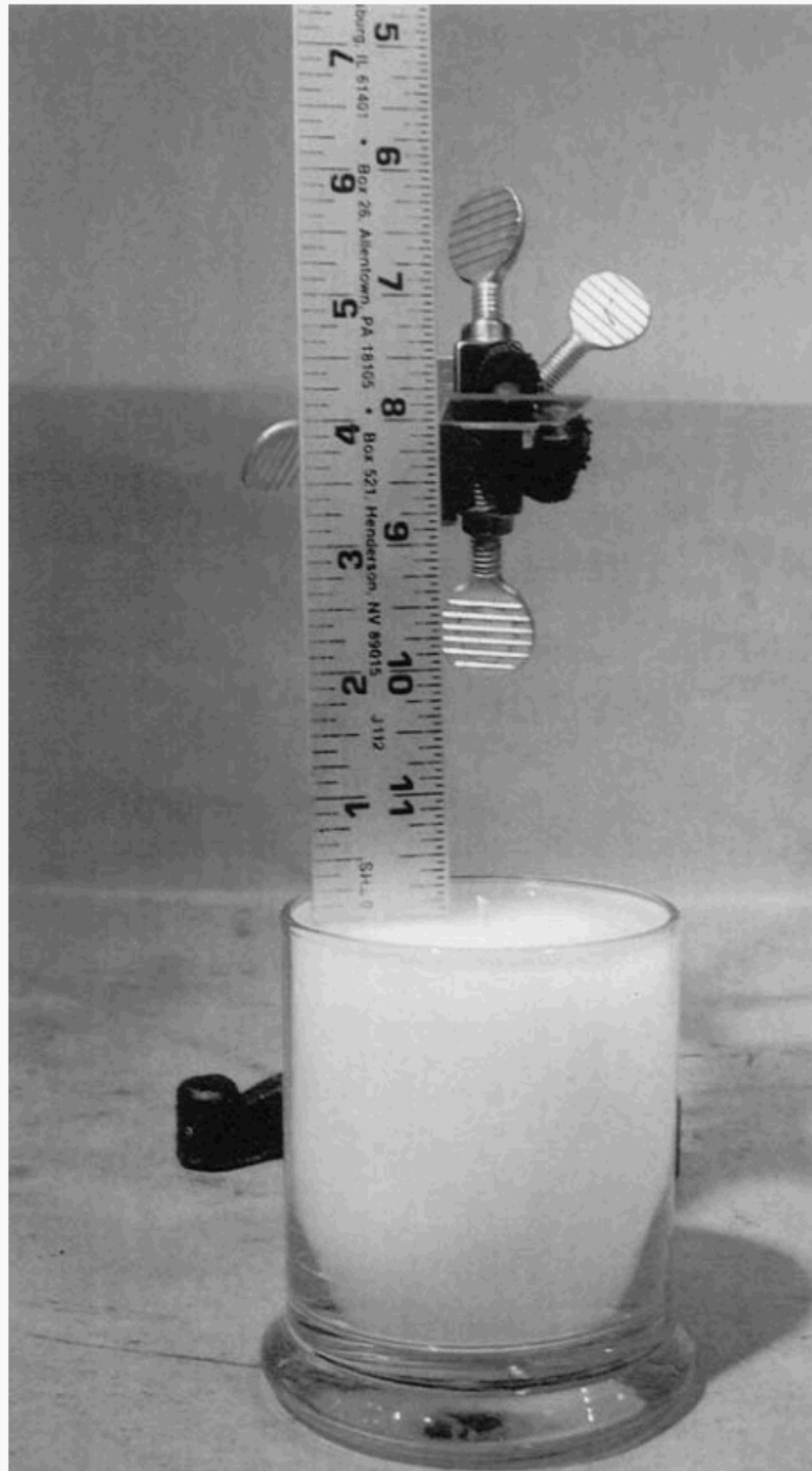
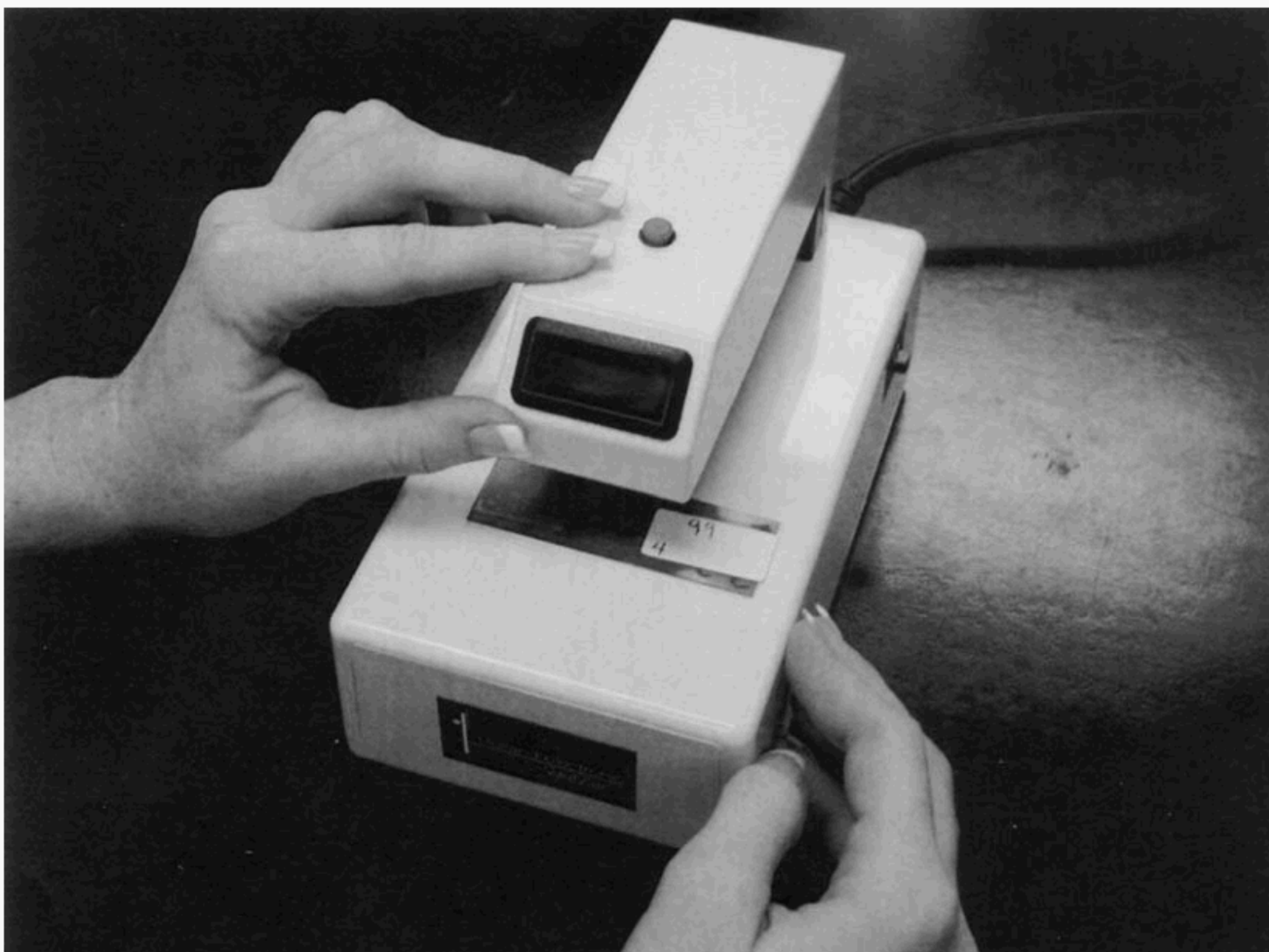


FIG. X1.1 Photograph Depicting Sampling Set Up





**FIG. X1.2 Photograph Depicting Densitometer in Use**

results so that the manufacturer has some basis to evaluate changes in candle formulations. Thus, it may be important to record information about the formulation tested, in addition to the test results so that educated decisions can be made based on

analytical data. It would be expected that any and all report information would be proprietary information of the manufacturer conducting the testing, as these tests would relate to their specific products or research designs.

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