Draft #3 August 15, 2024

**Title: Standard Test Method for Measurement of Carbon Dioxide Rebreathing in Infant Products**

**1.0 Scope:**

1.1 This Test Method is intended to quantify rebreathing in bedding materials and infant products. This test method does not include performance specifications, which are left to individual product sub-committees to incorporate into their product-specific standards, with reference to this test method.

**2.0 Terminology**

2.1 Rebreathing, v - inhalation of gases previously exhaled

**3.0 Summary of Test Method**

3.1 Carbon dioxide rebreathing is measured using an infant breathing model illustrated in Figure 1. The model includes a lung that is actuated to simulate an infant breathing at a prescribed rate and tidal volume. Carbon dioxide gas is metered into the lung at a flowrate simulating infant production of $CO_2$ and a small sample is withdrawn from the lung by a pump and sent to a $CO_2$ analyzer. The lung is connected to and breathes through a probe or manikin that is applied to the product being evaluated. Exhaling into and inhaling from the product specimen affects the concentration of $CO_2$ in the lung, which is allowed to accumulate and reach equilibrium. Measurements are performed using a load of 2.4 lbs (10 Newtons), simulating the weight of an infant's head. Units = % $CO_2$ concentration by volume.

3.2 An optional method makes use of a medical instrument called an End Tidal $CO_2$ Monitor. The monitor contains its own sample pump and CO2 analyzer, sampling 50 times

per second. The monitor displays real-time CO2 breath-by-breath and calculates the $etCO_2$ in mm Hg. Figure 2 shows the optional schematic and Figure 3 illustrates the $etCO_2$ Monitor.

The $etCO_2$ sample is withdrawn near the probe. (See Figure 7)

**4.0 Significance and Use**

4.1 In the infant sleep environment, soft items can lead to respiratory hazards if the infant's face becomes engaged in the soft surface. To avoid such hazards, products used with infants should be firm enough to resist conforming to the shape of the infant's face, which helps to minimize the potential for suffocation by airflow resistance or carbon dioxide rebreathing. This test method measures carbon dioxide rebreathing in products used with infants to minimize the risk of respiratory hazards.

4.2 This test method does not measure airflow resistance, which is also a potential suffocation risk in soft surfaces.

4.3 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 and health practices and determine the applicability of regulatory limitations prior to use.

**5.0 Apparatus:**

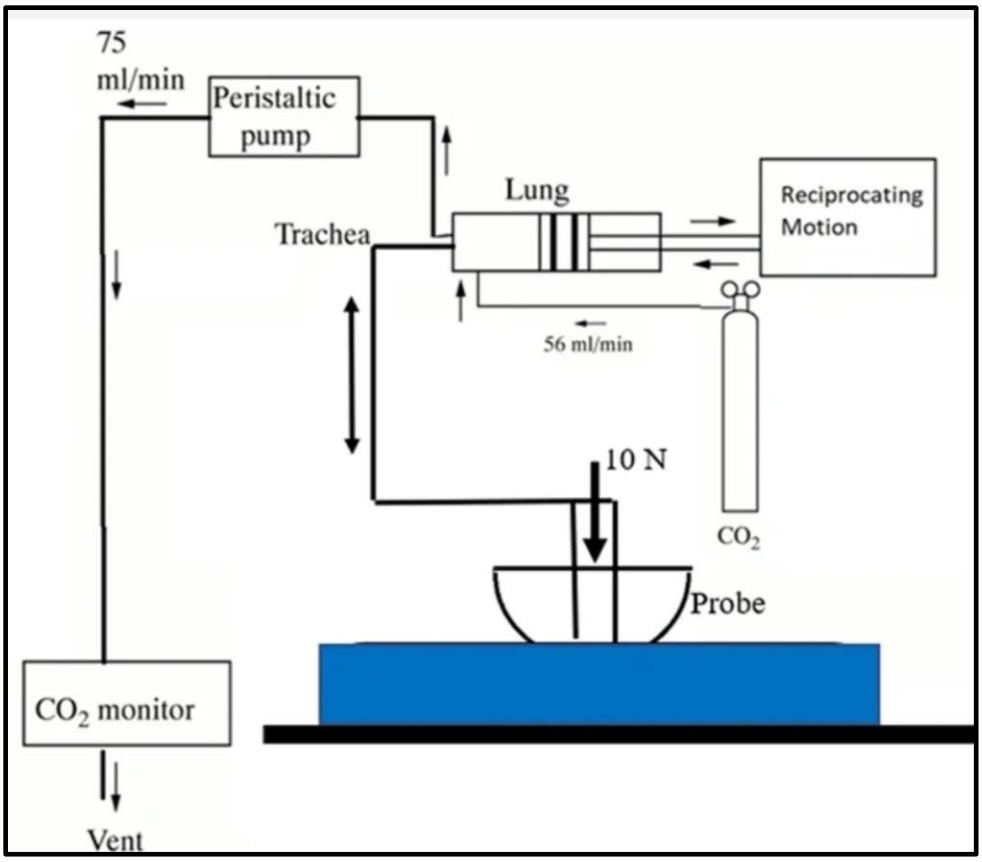


Figure 1 – Infant Breathing Model

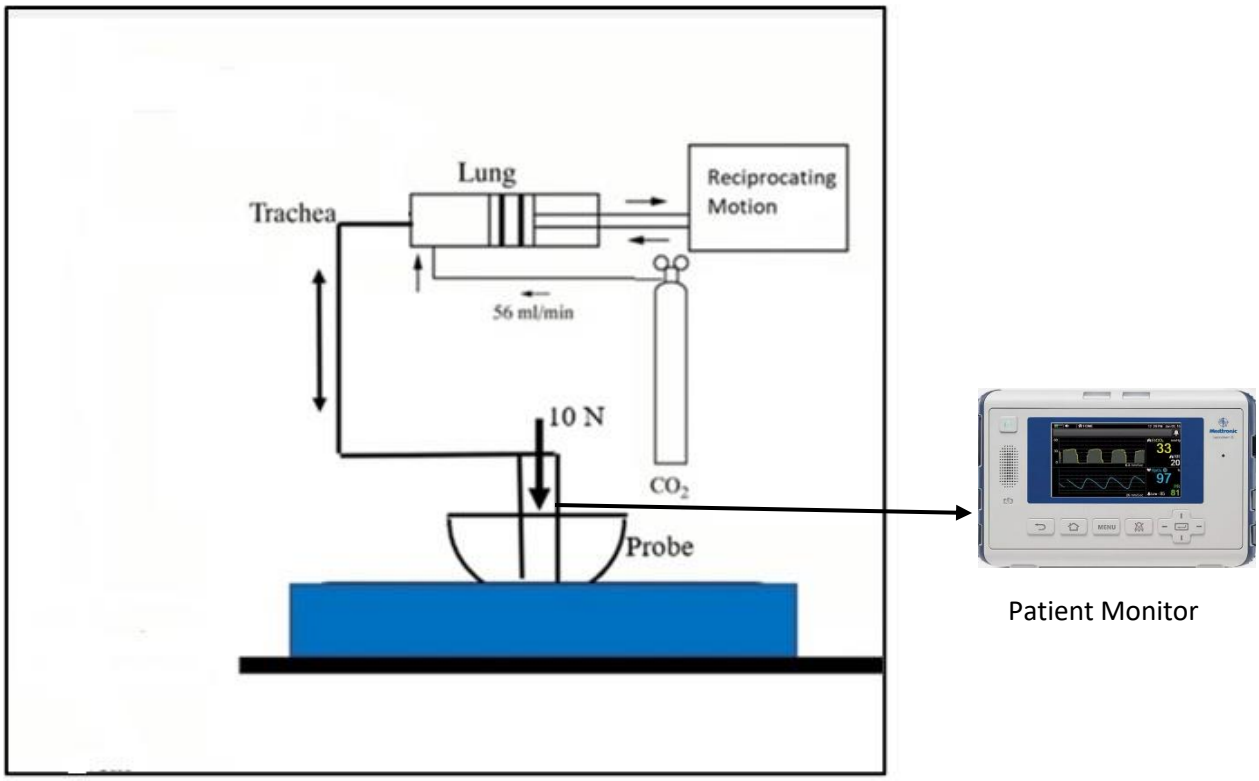


Figure 2 – Optional Schematic


Figure 3 – etCO2 Monitor

5.1 Test shall be performed with the axis of the probe perpendicular to the surface under evaluation.

5.2 Test stand or fixture for application of a measured force along a linear axis, while permitting the model to breathe in and out through the probe.

5.3 Device for applying a measured force such as a force gauge, load cell or fixed weight to apply a load of 2.4 pounds (10 Newtons). Figures 4 and 5 illustrate a fixed weight on the probe.


Figure 4

Figure 5

5.4 Probe – 3 inch (76 mm) diameter, with hemispherical face, 6 x 1 mm stud protruding from center of flat surface. See Figures 4, 5 and 6.

5.4.1 Two breathing holes 1/8 inch (3.175 mm) diameter, spaced ½ inch (12.7 mm) apart, parallel to the hemisphere axis.

5.4.2 Connections to the probe should be made with a minimum inside diameter of 1/8 inch (3.175 mm).

5.4.3 Both connections to the probe are joined using a “tee” fitting with a minimum inside diameter of .150 inches (4 mm).

5.4.4 Flexible tubing connecting the probe to the lung should be made from tubing with a minimum inside diameter of .150 inches (4 mm).

Figure 6

Figure 7

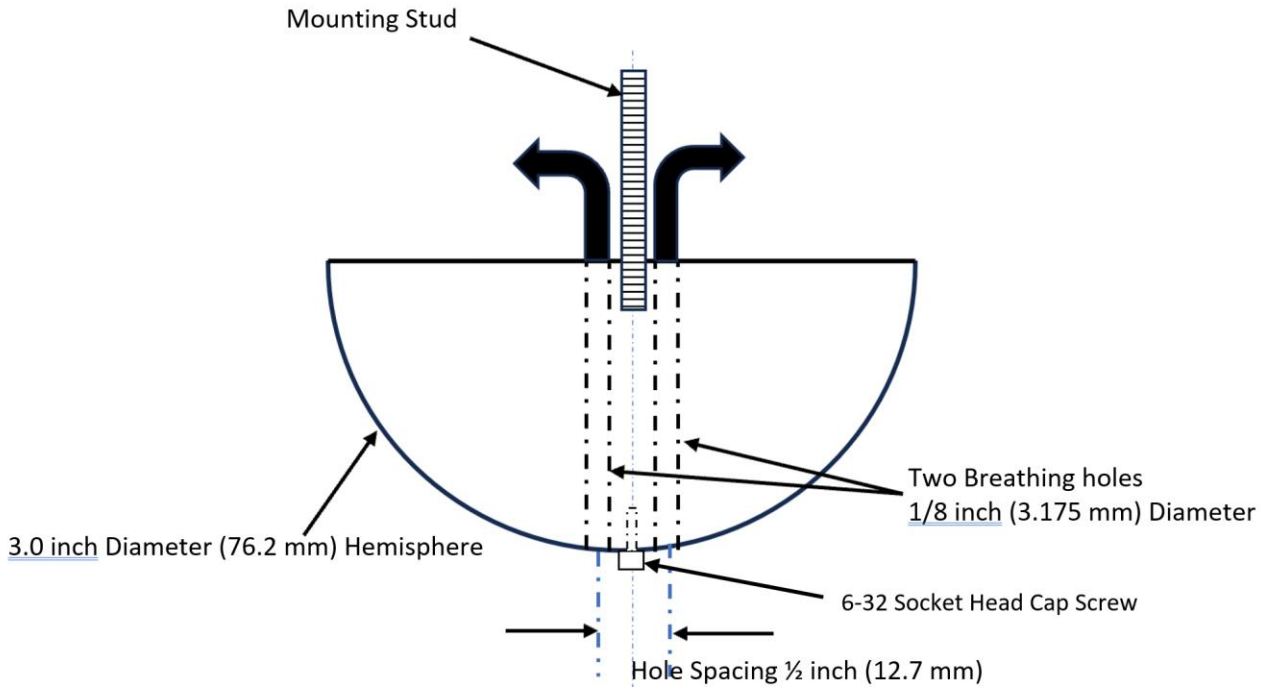


Figure 8 – Hemisphere Probe

5.4.5 As an alternative probe, an infant manikin may be used as a probe as shown in figure 7, configured to breathe through the nares with a geometry similar to the probe in figure 6. The head is weighted to 10 N.

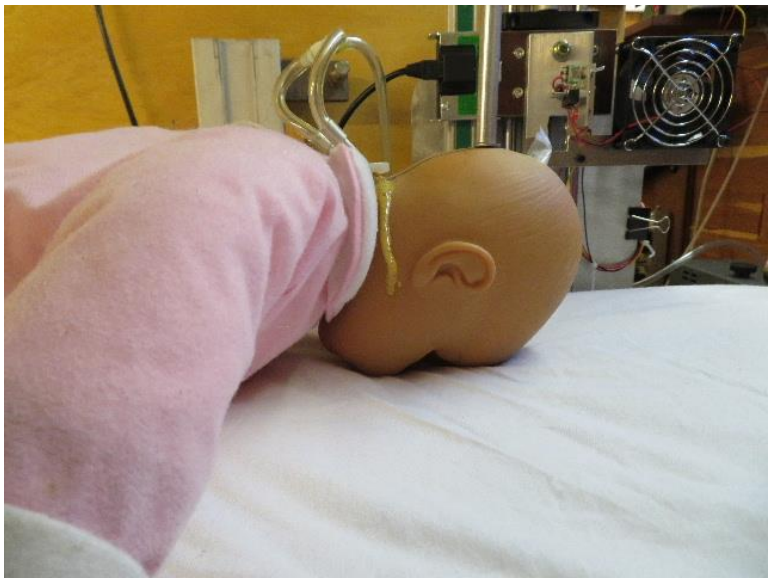

Figure 9 – Manikin Probe

5.5 Mechanical Lung

5.5.1 The lung shall have a total volume of 75 ml when expanded at the end of the inhale stroke and a 40 mL residual volume after the exhale stroke. (Tidal volume = 35 mL)

5.5.2 The breathing rate shall be adjustable in the range of 20 to 50 breaths per minute.

5.5.3 If a biofidelic lung is used it shall have a compliance of 0.1 cubic inch/inch of water (0.7 ml/mbar).

5.5.4 Tubing used to connect the lung and probe or manikin shall have a minimum diameter of .187 inches (5 mm) and a maximum length of 12 inches (30 cm). The volume of this tube has an effect on the $CO_2$ measurement and may need to be adjusted if the baseline measurement is out of the expected range of 3.75% +/- 0.25.

5.6 Sample Pump

5.6.1 A peristaltic pump is recommended for a sample rate of 75 mL/minute, measured by a flowmeter.

5.6.2 If using the optional etCO2 monitor, it has its own sample pump.

5.7 $CO_2$ Delivery

5.7.1 Carbon Dioxide is metered into the lung at a rate of 56 mL/minute, measured by a flowmeter. Beverage grade $CO_2$ is acceptable.

5.7.2 Using a flowmeter calibrated for air, the flow should be set to 81 ml/minute to compensate for the difference in densities between air and $CO_2$.

5.8 Flowmeters

6.8.1 Suggested Flowmeter models for CO2 and the sample are listed in the Appendix.

5.9 $CO_2$ Analyzer

5.9.1 The expected range of measurements is 3% to 40% by volume.

5.9.2 A CO2 analyzer with multiple ranges is recommended.

5.9.3 Optionally, an etCO2 monitor may be used, connected at the probe end.

5.10 Fan

6.10.1 A small fan is suggested to direct a flow of air past the probe to prevent local buildup of $CO_2$, shown in figure 3. A flow of approximately 100 to 200 ft/min (30 to 60 m/min) is sufficient.

**6.0 Test Specimen**

6.1 The test specimen can be either a sample of material, a product component or a finished product.

6.2 When testing a complete product, the product should be oriented in the manufacturer's recommended position. The product may be weighted using a surrogate child of a size and weight appropriate for the product.

6.3 Ideally, the dimensions of the test specimen shall be at least 8 in (203 mm) in length and width. For resilient materials, components, and products that, because of their size or configuration, do not allow for at least this size test specimen, the largest size shall be obtained.

## 7.0 Calibration and Standardization

7.1 Assure that instruments used are within tolerance.

7.2 Check calibration of force at zero and 10 Newtons +/- 0.1N (2.4 pounds)

7.3 Check calibration of CO2 analyzer using reference gas at a concentration in the measurement range. Suggest 5 to 10% CO2 in nitrogen. Use nitrogen for checking zero.

7.4 All testing per this method shall be conducted on the same test specimen.

## 8.0 Procedure

8.1 Choose test locations based on the user's face position in the manufacturer's recommended use orientations. If the product has multiple manufacturer's recommended use orientations, repeat the test for each orientation. If there is no recommended orientation, the product can be placed in what is considered to be its intended use orientation.

8.2 Secure the test specimen so that it cannot move, and in a manner that does not affect the test measurements or test results.

8.3 Test location selection – Select three test locations at least 3 in (76.2mm) apart, if possible, based on potential positions for the child's face on the test specimen. No test location shall be less than 2 in (50.8mm) from the edge of the test specimen. However if, because of its size or configuration, the test specimen is less than 8 in (203mm) in length or width, the distance between each test location can be less than 3 in (76.2mm).

8.4 Record all test locations and note any deviations due to the inability to maintain the 3 in (76.2mm) separation of test locations.

8.5 Align the linear travel of the probe so that the travel of the probe is perpendicular to the specimen surface location to be tested.

8.6 Connect the equipment as shown in Figure 1.

8.7 Start the actuation of the lung at the breathing rate of interest. (Infant range = 30 to 50 breaths per minute).

8.8 Start the flow of $CO_2$ into the lung and adjust to 56 ml/min. (Note flowmeter correction for $CO_2$)

8.9 Start the sample pump and adjust to deliver 75 ml/min to the $CO_2$ analyzer.
8.9.1 If using the optional etCO2 Monitor, no sample pump is needed.

8.10 Start with a baseline measurement, with the probe elevated at least 1 inch above the specimen. The baseline measurement is expected to be approximately 3.75% +/- .25%. The CO2 flow may need to be adjusted at this point to achieve the expected baseline measurement.

8.11 Advance the probe toward the surface of the specimen until the probe applies a load of 2.4 pounds (10 Newtons).

8.12 Allow time for the $CO_2$ analyzer to reach a steady reading. This may take 5 to 10 minutes or more.

Note: For additional guidance on performing steps 8.7 through 8.12, a supplemental video is available at https://youtu.be/CtZAgimnJg8

8.12.1 Perform three repeat measurements at each of three test locations. (Nine measurements) If the test locations must be closer than three inches apart, allow five minutes for the material to recover between tests.

**9.0 Report**

9.1 Report the $CO_2$ concentration data or etCO2 at each measured point.

9.2 Report and justify any deviations from this Test Method.

**10.0 Precision and Bias**

10.1 Products that have a defined shape such as a foam pad with fabric cover can be expected to yield multiple measurements with a standard deviation within 5 percent of the average.

10.2 Products with a more irregular shape may have poorer repeatability, typically with a standard deviation within 20 percent of the average.

**12.0 Keywords**

Infant, bedding, suffocation, rebreathing, carbon dioxide

## 13.0 Appendix

13.1 Test Method rationale – The probe and test conditions are selected to simulate the interaction between a sleeping infant and a surface in the sleep environment.

13.1.1 The probe is designed to simulate the configuration of a small infant's face, which is approximately 3 inches (76.2 mm) across the cheek bones. Breathing holes are designed to simulate an infant upper airway.

13.1.2 A load of 2.25 lbf (10 N) represents the weight of a small infant's head.

13.2 Flowmeters for CO2 and sample – Matheson SEQE13C151E100