National Institute for Occupational Safety and Health National Personal Protective Technology Laboratory P.O. Box 18070 Pittsburgh, PA 15236		
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DETERMINATION OF FACEPIECE CARBON-DIOXIDE AND OXYGEN CONCENTRATION LEVELS OF TIGHT FITTING POWERED AIR-PURIFYING RESPIRATORS WITH THE BLOWER UNIT RUNNING STANDARD TESTING PROCEDURE (STP)

1. PURPOSE

1.1. This special test establishes the procedures for ensuring that tight fitting full facepiece powered air-purifying respirators (PAPR) with a neck seal designed to offer personal protection against particulate and gas/vapor hazards with the blower unit on meets the CO_2 and 0_2 requirements deemed as appropriate under 42 CFR 84.63(c).

While wearing this type of device, the user exhales approximately 5% carbon dioxide into the facepiece. Most of this CO_2 exits through an exhalation valve to the external environment. The residual exhaled portion that remains in the facepiece and is rebreathed during inhalation is the portion of prime concern and is the object of the test requirement and this test procedure. A small amount of CO_2 is physiologically required in order to stimulate respiration; but once concentration levels increase beyond approximately 2% CO_2, there is a sharp rise in a person's respiratory minute-volume and breathing rate. 42 CFR 84 lists the maximum permissible CO_2 concentration levels for open and closed circuit SCBA as a function of the service time of the apparatus; thus, based on the maximum allowable average CO_2 concentration level allowable for SCBA and the maximum allowable levels acceptable under CE standards – the maximum acceptable CO_2concentration level for a PAPR with the blower running will be 1% and the minimum allowable O_2 concentration will be 19.5%.

2. GENERAL

2.1. This procedure describes the "Determination of Facepiece Carbon-Dioxide and Oxygen Concentration Levels of Tight Fitting Powered Air-Purifying Respirators with the Blower Unit Running" in sufficient detail that a person in the appropriate technical field can conduct the test and determine whether or not the product passes testing.

3. EQUIPMENT/MATERIALS

3.1. The list of necessary test equipment and materials follows:

Approvals:	1st Level	2nd Level	3rd Level

3.1.1. Hewlett Packard 7414A four channel thermal tip recording system or equivalent with 8805A carrier preamplifier or equivalent and 8803A low level preamplifier or equivalent.

3.1.2. Beckman LB-1 medical gas analyzer or equivalent.

3.1.3. Scott Aviation mechanical breather with sedentary cam and solenoid valve attached as shown in Figure #1 or equivalent.

3.1.4. Statham Instruments temperature compensated strain sensitive resistance wire type transducer (pressure range $\pm$0.5 psid) or equivalent.

3.1.5. Thin-walled flexible plastic reservoir with a low resistance relief valve (less than 1-inch water gauge).

3.1.6. Beckman 0 -1000 ml/min microcatheter pump or equivalent.

3.1.7. F & P #02-f 1/8-16-5/36 or equivalent CO_2 flowrater tube.

3.1.8. Instrument grade CO_2.

3.1.9. Matheson Gas standard CO_2 - air mixtures (2%, 3%, 5% CO_2) or equivalent.

3.1.10. Low pressure air supply or positive pressure pump.

3.1.11. Two stage regulator with control valve for CO_2 cylinder (first stage gauge with 3000 psig capacity; second stage gauge with 0 - 100 psig capacity).

3.1.12. Beckman medical gas analyzer-OM-11 (oxygen) or equivalent.

4. TESTING REQUIREMENTS AND CONDITIONS

4.1. Test equipment and instruments shall be installed and maintained according to the manufacturer's specifications.

4.2. Test equipment and instruments shall be calibrated at least as frequently as, and according to, the instrument manufacturer's specifications, using calibration standards traceable to those set by the National Institute for Standards and Technology or other nationally recognized standards.

4.3. Normal laboratory safety practices must be observed. This includes safety precautions described in the current ALOSH Facility Laboratory Safety and Hazardous Waste Manuals.

4.3.1. Safety glasses, lab coats, and hard-toe-shoes must be worn at all times.

4.3.2. Work benches must be maintained free of clutter and non-essential test

equipment.

4.3.3 When handling any glass laboratory equipment, lab technicians and personnel must wear special gloves which protect against lacerations or punctures.

5. PROCEDURE

5.1. A calibration curve is prepared using three known CO_2 – air mixtures. The volume percentages of these mixtures should be in the ranges of 2%, 3%, and 5%.

5.1.2. Use the manufacturer's recommended procedure for warm-up, zeroing, and operation of the CO_2 medical gas analyzer.

5.1.3. The lower scale of the 0 to 10 divisions is to be used for a range of 0 - 5% CO_2. Feed the 5% gas mixture through the pick-up lead containing the infrared sensor at a rate of 400 cc/min. Use the gain control for setting the scale reading to double the percent mixture or 9.90 (i.e., on a 0 -10 division scale, a reading of full scale or 10 equals 5% expanded).

5.1.4. Then feed in the 3% and 2% gas mixtures and record the dial readings shown. Also record the upper scale readings which have a 0 - 100 division range.

5.1.5. With linear graph paper, plot the upper scale readings (0 - 100 divisions) on the y-axis and the respective CO_2 % readings on the x-axis. Draw the line which best fits the points plotted for the three mixtures. See Fig.1.

5.1.6. If there is not a noticeable drift upward with the instrument gain control setting over a period of time (i.e., day to day or month to month), it will be necessary to re-run this calibration.

5.2. CO_2 and O_2 concentration levels in the facepiece will be determined for a minimum of three respirators (for example, three of a single-size device or one each of a three size device) as follows:

5.2.1. Assemble the apparatus as shown in Fig. 2. Mount the CO_2 pickup, O_2 pickup and pressure transducer where shock and vibration are minimal. Use exactly 20 inches of 3/4 inch I.D. tubing between the dummy head mouth and the breathing machine "T" (this length is critical since the response time must correlate closely with the pressure measurement for a simultaneous readout). (Tubing has a volume of 145 cc.)

5.2.2. Allow the recorder and analyzer to warm up at least one hour.

5.2.3. Calibrate the pressure transducer by first balancing the carrier preamplifier as instructed in the HP manual. Set the sensitivity control to give a deflection of 2.0 cm at x1 attenuation.

5.2.4. Calibrate the CO_2 analyzer by first balancing the low level preamplifier as

instructed in the HP manual. Set the sample flow rate at 300 - 400 cc/min. The sample flow rate affects the response time of the analyzer. For comparison purposes, all tests must be run at the same sample flow rate. Then zero the analyzer as instructed in the HP manual. Span the analyzer with a reference gas containing slightly less than 5% CO_2, adjusting the gain control so that the meter reads the concentration of the span gas when the full scale deflection is 5% CO_2. The pressure of the reference gas going to the sample cell must not exceed atmospheric. (Use a flow of 500 cc/min of CO_2 or more. Tubing from the CO_2 gas cylinder must be at least three times the diameter of the CO_2 cell inlet port so that it is not necessary to directly connect the two. The excess CO_2 gas will then flow around the inlet port to atmospheric.) Set the low level preamplifier gain to give a corresponding recorder stylus deflection. Remove the span gas to allow the analyzer meter and recorder stylus to return to zero. If this does not occur, re-zero the analyzer and repeat the span procedure as often as necessary until zero is attained.

5.2.5. Adjust the air flow rate to approximately 13.00 M^3/min and the CO_2 flow rate to approximately 0.74 M^3/min. These flow rates will give a 5% CO_2 air mixture at the dummy head during exhalation. The flexible bag will be kept filled with slightly more than 10.5 l/min flow and minimize back pressure in the system. To maintain a 5% mixture, some readjustment of flow rates may be necessary.

5.2.6. Turn on the breathing machine and let it warm-up for one minute. Set the potentiometer for 14.5 rpm on the sedentary cam.
This will give a flow rate of 10.5 lpm.

5.2.7. Run a blank test, operating the equipment to produce the correct CO_2 pattern at the dummy head mouth. Record the CO_2 concentration for three complete respiratory cycles at the mouth of the dummy head. The recommended chart speed of the recorder is 10 mm/sec. Analysis of the tracing provides the average CO_2 concentration contributed by the dummy head. This is a blank value which must be subtracted from the total CO_2 in the inspired air of all facepiece and breathing apparatus tests.

5.2.8. For PAPR tests with the blower running, check the zero point on the analyzer and recorder before each test and correct for zero drift. Mount the facepiece on the dummy head and power up the blower unit. Engage the breathing machine and record both the mask pressure and the CO_2 for at least three complete cycles (See Fig. 3.)

5.2.9. Perform the calibration for the oxygen analyzer by sampling room air and spanning to 21.9%.

5.3. Data is to be analyzed as follows:

5.3.1. The recorder produces two traces, as shown in Fig. 3.: The facepiece resistance, and the CO_2 concentration at the dummy head mouth. The inhalation phase of the breathing cycle (and its duration), as determined from the facepiece resistance

trace, must correspond to the inhalation portion of the CO_2 concentration trace. With a chart speed of 10 mm/sec, the inhalation phase should measure 18 or 19 mm.

5.3.2. The average concentration of inspired CO_2 is determined from the CO_2 curve as follows:

The first point on the inhalation part is the last millimeter of full scale deflection on the exhalation part of the curve. (See Fig. 3.) The shaded area under the inhalation part of the trace is a measure of the inspired CO_2. Representing the time base as the x-axis, measure the deflection in the y-direction for each millimeter increment of the inhalation trace. If the inhalation cycle is 19 mm long, there will be 20 increments on the x-axis. Sum the measured deflections of the inhalation cycle and divide by the number of points (n) measured along the x-axis.

$$\text{Avg. Deflection} = (1/n) * \Sigma\text{Deflections}$$

Determine the average concentration of inspired CO_2 from the analyzer calibration curve.

5.3.3. Record the minimum oxygen reading every minute until the concentration has stabilized at its lowest point.

6. PASS\FAIL CRITERIA

The maximum allowable average carbon dioxide concentration for each sample tested shall not exceed 1.0% and the minimum allowable oxygen concentration is 19.5% with the respirator operating with the blower on with fully charged batteries.

7. RECORDS\TEST SHEETS

7.1. Test data collected will be recorded on the data Test Sheet No. 63 and entered into the RB electronic information system.

7.2. If a strip chart recorder is used to record data, the strip chart record must be attached to the data sheet.

7.3. All videos and photographs of the actual testing being performed, or of the tested equipment shall be maintained in task file as part of the permanent record.

7.4. If the failure occurs to hardware examined under an Off-the-Shelf Audit; the hardware will be examined by a technician and the Team Leader for cause. All equipment failing any portion of this test may be returned to the manufacturer applicant for examination. However, the hardware tested shall be held at the testing laboratory until authorized for release by the Team Leader, or his designee, following the standard operating procedures outlined in RB-SOP-0005-00.

7.5. If the respirator was part of an off-the-shelf audit, it must be returned to NIOSH unchanged after manufacturer examination.

7.6. Notify the manufacturer of the test results.

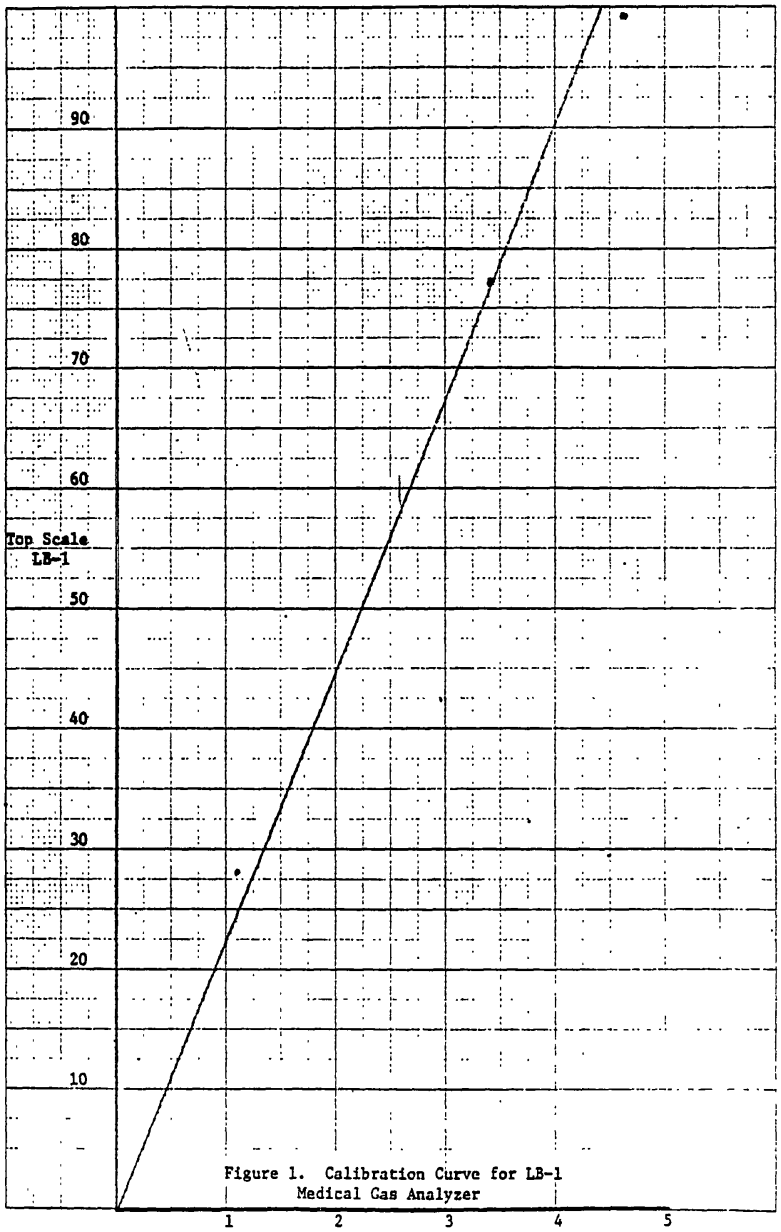

Figure 1. Calibration Curve for LB-1 Medical Gas Analyzer

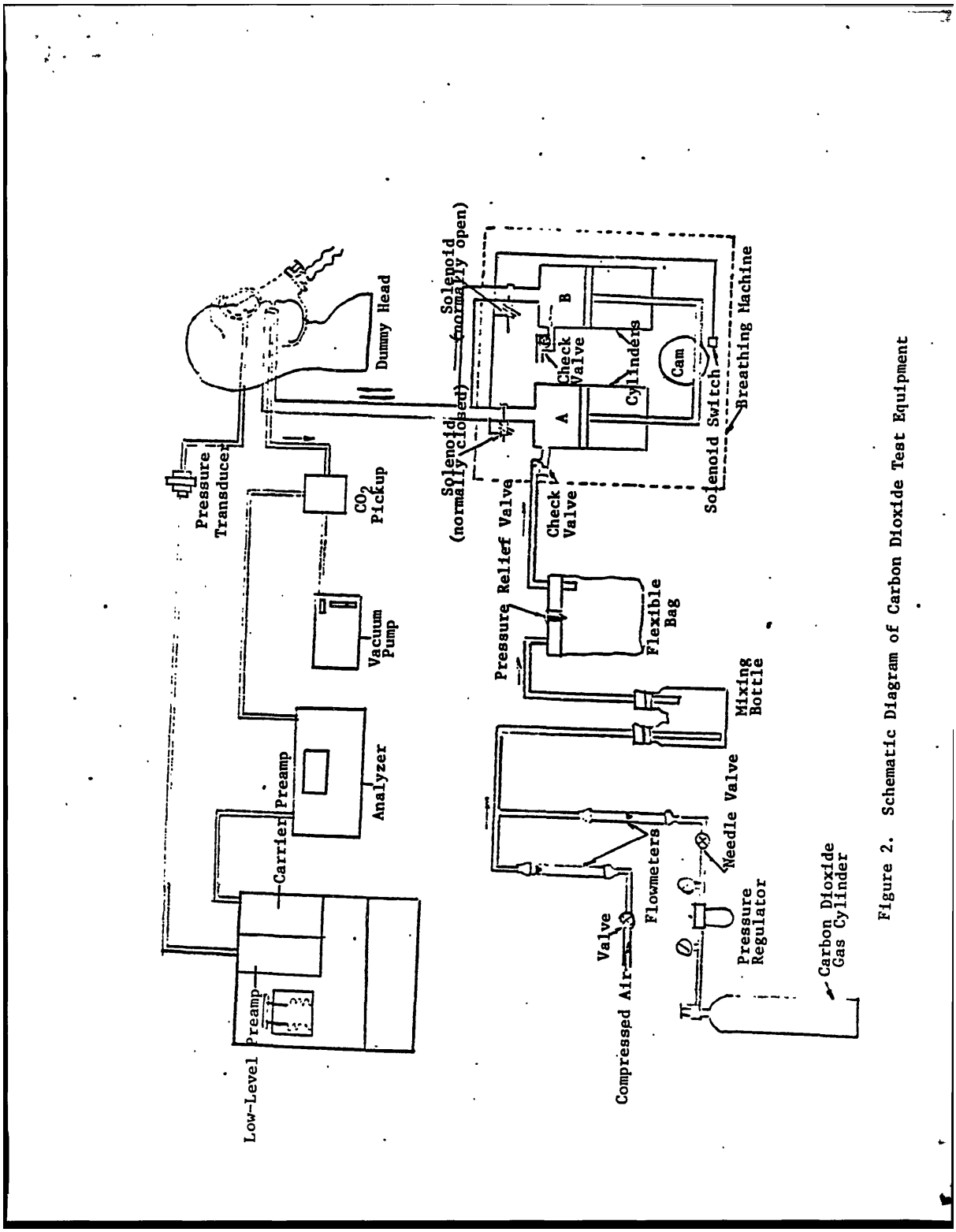

Figure 2. Schematic Diagram of Carbon Dioxide Test Equipment

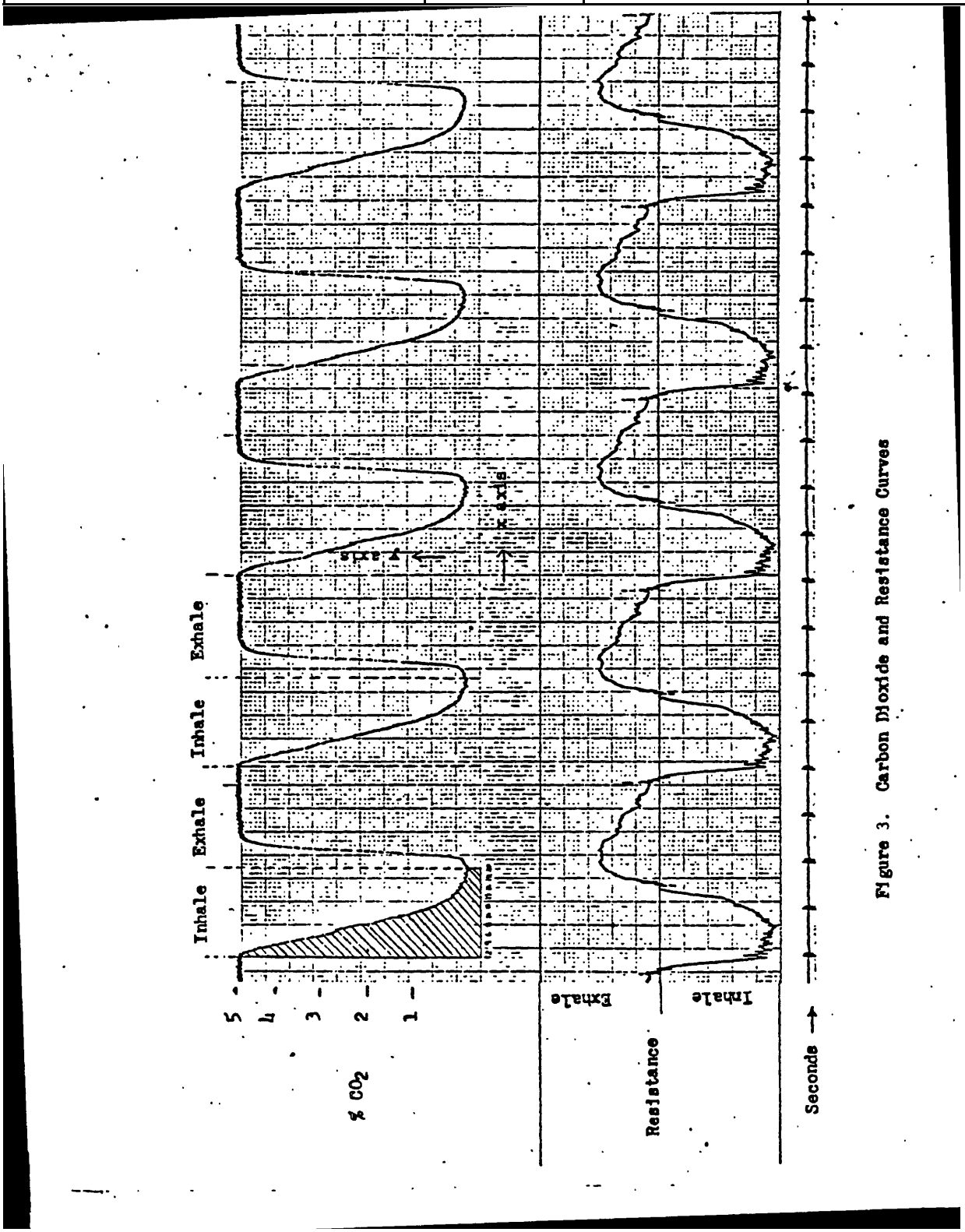

Figure 3. Carbon Dioxide and Resistance Curves

CARBON DIOXIDE AND OXYGEN MACHINE TEST
PAPR BLOWER ON

Test Sheet No. 63

Date:

Project No.:

Company:

Respirator Type:

Requirement: Shall not exceed maximum limits of 1% CO_2 and minimum of 19.5% 0_2.
Results:

Revision History

Revision	Date	Reason for Revision
1.0	6 March 2001	Historic document
1.1	9 September 2005	Update header and format to reflect lab move from Morgantown, WV No changes to method