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 SILICA DUST LOADING TEST FOR POWERED AIR-PURIFYING RESPIRATOR FILTERS STANDARD TESTING PROCEDURE (STP)

l. PURPOSE

This test establishes the procedure for ensuring that the level of protection provided by the silica dust test requirements on HEPA (also known as HE) filters designed for powered air-purifying respirators (PAPRs) submitted for Approval, Extension of Approval, or examined during Certified Product Audits, meet the minimum certification standards set forth in 42 CFR 84, Subpart G, Section 84.63(a)(c)(d) and Subpart KK, Section 84.1152; Volume 60, Number 110, June 8, 1995. These filters may be integral components of the PAPR; mounted individually; or used in conjunction with cartridges and canisters.

2. GENERAL

This STP describes the Determination of Silica Dust Loading Test For Powered Air-purifying Respirator Filters test in sufficient detail that a person knowledgeable in the appropriate technical field can select equipment with the necessary resolution, conduct the test, and determine whether or not the product passes the test.

3. EQUIPMENT/MATERIALS

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

3.1.1. Silica Dust Chamber: Tests are conducted in a specially built laminated ½ inch marine grade plywood chamber equipped with a door in the rear and safety glass windows in both front and rear. The chamber floor is 5 feet by 5 feet, and the floor to ceiling distance is 7 feet. An explosion proof light fixture is installed inside the chamber, and a work shelf 24 inches wide extends across the front of the chamber.

A control panel at the left side of the chamber front contains all electrical and air controls for the chamber operation. The following gauges and flow manometers are located on this panel: internal chamber pressure (in. H_2O), sampling vacuum (in. Hg.), air supply pressure (psi), spiral air flow (cfm), venturi diluent (in. H_2O), and concentration sampling flow meters (calibrated at 32 lpm).

Approvals:	1st Level	2nd Level	3rd Level

Dust is fed to the sizing equipment by means of a feed screw which lifts a glass holding tube at a constant rate. The feed tube is driven by an electronically controlled synchronous motor that allows rapid changes in feed rates for maintaining concentration. A step switch selects the feed rate; each step is synchronous and reproducible. Also, a fast forward and fast reverse clutch is installed for quickly setting up the proper conditions in the dust feed tube.

Dust pick up is accomplished by a jet flow pickup tube which dries and disperses dust evenly in the air stream, thereby eliminating clumps of particles due to packing. All components of the dust pickup apparatus (except the tangential jets) are constructed of Pyrex so that operation can be monitored visually at all times.

Sampling ports are located across the front of the chamber to allow the respirator to be connected to the breathing machine outside of the chamber and to allow for hourly concentrations to be taken. A 32 lpm vacuum source is readily available to take chamber concentrations.

The source of negative pressure for the entire sampling system is a rotary carbon vane vacuum pump with a 12 gallon surge tank and vacuum regulator set to maintain a 6 inch of Hg vacuum. All air for the chamber is supplied by house air and is regulated to 14 psi.

The test atmosphere is exhausted from the chamber at equal constant rates from the four vertical corner ports of the chamber through a high efficiency filter. A forge blower provides moving power for the exhaust system and discharges the filtered air back into the laboratory ventilation system. The entire chamber is maintained under negative pressure during operation to prevent laboratory contamination.

A separate resistance measuring assembly is incorporated into the control panel for measuring positive and negative resistance at 85 lpm. Respirator resistance is measured on a slant tube manometer with a 6 in. water column scale. A flow meter calibrated for 85 lpm and valves to adjust flow are incorporated into the resistance assembly.

3.1.2. Analytical balance: A Mettler AK or equivalent balance is used to measure absolute filter weights and should have an accuracy of 10^{-4} gm.

3.1.3. Particle sizing system: A variety of equipment - including laser, optical, and electron microscope systems - is available for particulate size determination.

3.1.4. Absolute filters: Filters used for gravimetric concentrations are MSA 1106B filters or equivalent.

3.1.5. Silica dust: The silica dust must be ground to pass 99+ percent of the test suspension through a 270-mesh sieve. The test suspension will have a geometric mean of 0.4 to 0.6 micrometers with a geometric standard deviation not to exceed

2. The concentration of the test suspension that must be maintained must not be less than 50 mg/m^3 or more than 60 mg/m^3. These parameters are specified in 84.1144.

3.1.6. Breathing machine: A breathing machine at a rate of 24 respirations per minute with a minute volume of 40 liters with a breathing machine cam that provides a work rate of 622 kg-m^2 as specified in 42 CFR 84. 1145.

4. TESTING REQUIREMENTS AND CONDITIONS

4.1. Prior to beginning any testing, all measuring equipment to be used must have been calibrated in accordance with the manufacturer's calibration procedure and schedule. At a minimum, all measuring equipment utilized for this testing must have been calibrated within the preceding 12 months using a method traceable to the National Institute of Standards and Technology (NIST).

4.2. Normal laboratory safety practices must be observed. This includes safety precautions described in the current ALOSH Facility Laboratory Safety Manual.

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

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

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

5. PROCEDURE

Note: Reference Section 3 for equipment, model numbers and manufacturers. For calibration purposes use those described in the manufacturer's operation and maintenance manuals.

5.1. Initial Airflow and Resistance:

Three powered air purifying respirators (PAPRs) shall be tested in accordance with 42 CFR 84.1152. The PAPRs shall be assembled according to the manufacturers instructions. Each unit shall be connected to an airflow measuring system and tested to ensure compliance with minimum airflow requirement as per NIOSH test procedure APRS-0012. Tight fitting respirators shall then be tested for initial resistance to airflow as per APRS -0003 and APRS-0007. The PAPR shall then be placed inside the silica dust chamber and connected to a breathing machine operated at a rate of 24 respirations per minute with a minute volume of 40 liters with a breathing machine cam that provides a work rate of 622 kg-m^2 as specified in 42 CFR 84. 1145.

5.2. Chamber Preparation:

Before starting test, be sure that the door and all ports are closed.

5.3. Dust Tube Filling:

To help maintain repeatability and uniformity in column packing, a known amount of dust (e.g. 200 gm) should be packed to a given column height (e.g. 20") each day. Using a funnel, pour about three or four inches of the preweighed dust into the tube and pack. Repeat filling and packing until all dust is added. Several techniques can be used to pack the tube after each three or four inch addition of silica dust. One technique is to attach a vacuum source to the top of the holding tube. (Note: A filter should be inserted into the vacuum line to prevent dust from entering the vacuum system). By tapping the bottom of the dust holding tube on a rubber pad, the dust bed is packed and any trapped air is removed by the vacuum source.

The top surface of a properly packed column of dust should not bounce up and down more than 1/8 inch when the bottom of the holding tube is tapped on a rubber pad. Excessive bouncing of the top surface is indicative of trapped air.

5.4. Chamber Start-Up:

5.4.1. Place packed dust tube in the hoist carriage, taking care that the hoist carriage is firmly connected to the feed screw attachment.

5.4.2. Turn on main breaker switch.

5.4.3. (a) Turn stepping motor on-off switch to the on position and the up-down directional switch to the up (down if lowering the column) position.

(b) Set high-off-low speed switch, which provides manual control of stepping motor speed, in the high speed position. Tube will rise rapidly. Be sure the spiral tube enters the dust tube properly.

(c) When the top of the silica dust is approximately one inch from the bottom of the spiral tube, switch the motor speed control to off and then to low.

(d) Control low speed with the coarse and fine speed adjustments. Low speed control is important because it directly helps control the chamber concentration of silica dust.

5.5. Turn on Venturi vibrator. This chamber modification was made to prevent excessive accumulations of silica dust within the Venturi body, which would break loose and suddenly alter the chamber concentration of silica dust.

5.6. Turn on the house air supply and adjust to 14 psig with the in-line pressure regulator.

5.7. Turn on the stirrer, exhaust, and inject switches.

5.8. Chamber controls determined by operator should be set and held at their respective values, e.g.:

Air Pressure ..... 14 psig

Chamber Pressure ..... 0.50 $\pm$ 0.02 in H_20*

Cyclone Flow ..... 7.0 $\pm$ 0.5 CFM

Cyclone Pressure ..... 2.1 to 2.2 in H_20

Spiral Flow ..... 2.0 CFM

Venturi Flow ..... 3.0 CFM

Venturi Diluent ..... 1.0 CFM

Venturi Pressure ..... 1.0 to 1.2 in H_2O

Chamber Diluent ..... 0 CFM

* Make certain all ports are tightly closed.

5.9. Check exhaust filter resistance. If the resistance exceeds three inches of water, remove the prefilter and replace with new prefilter.

5.10. Let the chamber run for a minimum of 30 minutes to reach equilibrium.

5.11. Using a psychrometer, measure chamber relative humidity and record.

(a) A battery-operated psychrometer is placed in the chamber for approximately 1 minute to determine relative humidity.

(b) Be sure that the port is tightly closed. Leakage can be checked by observing the chamber pressure reading. If the chamber pressure reading returns to approximately 0.50, no leakage is present.

5.12. Check Chamber Concentration:

(a) Weigh and record initial weight of absolute filter.

(b) Place absolute filter in filter holder.

(c) Remove blank port and install sampling port.

(d) Attach vacuum line to absolute filter holder.

(e) Turn on vacuum switch and timer. Adjust the flow rate to 32 Lpm and the vacuum pressure to 6.2 in.

(f) After 10 minutes, stop vacuum and timer.

(g) Remove sampling port, and replace blank port.

(h) Carefully remove and weigh filter. Record weight.

(i) Calculate chamber concentration (see analysis and recording of data, item # 2).

5.13. If concentration is between 50 and 60 mg/m^3, begin test. If the concentration is not within this range, run an additional concentration test for 10 minutes. If this test is within expected levels, start respirator test. If this test is still outside the acceptable range, adjustments must be made to bring chamber concentrations into proper level. To increase or decrease concentration, increase or decrease the speed of dust hoist drive motor by changing setting on dust hoist speed controls. Wait at least 15 minutes before the next chamber concentration check. Once the test concentration is maintained at the correct level, then a chamber dust concentration is taken once each hour.

5.14. Testing Respirator:

The PAPR face piece is mounted on an anthropometric head which in turn is connected with a ground glass joint that is attached to the silica dust chamber door port. The outside portion of the door port contains the absolute filter holder which is used to collect the leakage sample during the test. The filter holder is connected to the breathing machine with a three foot piece of 2-inch vinyl tubing to the inhale/exhale port of the breathing machine. The machine is operated at a rate of 24 respirations per minute with a minute volume of 40 liters with a breathing machine cam that provides a work rate of 622 kg-m^2 as specified in 42 CFR 84. 1145. The respirator shall be exposed to the test suspension for 4 hours .

5.15. Final Airflow and Resistance:

After the silica dust test, the PAPR shall be connected to an airflow test system and tested to ensure compliance with minimum airflows as per APRS-0012. Final inhalation and exhalation resistance to airflow shall be taken on all tight fitting PAPRs as per APRS-0003 and APRS-0007.

5.16. Final Leakage:

After the silica dust test, the leakage filter sample is weighed to determine the total amount of leakage that was collected during the 4 hour silicca dust loading test.

6. PASS/FAIL CRITERIA

6.1. The criterion for passing this test is set forth in 42 CFR, Part 84, Subpart G, Section 84.63(a)(c)(d) and Subpart KK, Section 84.1152; Volume 60, Number 110, June 8, 1995.

6.2. This test establishes the standard procedure for ensuring that:

84.63. Test requirements; general.

(a) Each respirator and respirator component shall when tested by the applicant and by the Institute, meet the applicable requirements set forth in subparts H through L of this part.

(c) In addition to the minimum requirements set forth in subparts H through L of this part, the Institute reserves the right to require, as a further condition of approval, any additional requirements deemed necessary to establish the quality, effectiveness, and safety of any respirator used as protection against hazardous atmospheres.

(d) Where it is determined after receipt of an application that additional requirements will be required for approval, the Institute will notify the applicant in writing of these additional requirements, and necessary examinations, inspections, or tests, stating generally the reasons for such requirements, examinations, inspections, or tests.

84.1152. Silica dust loading test; respirators designed as protection against dusts, fumes, and mists having an air contamination level less than 0.05 milligram per cubic meter and against radionuclides; minimum requirements.

(a) Three non-powered respirators will be tested in accordance with the provisions of 84.1144, or equivalent, and shall meet the minimum requirements of 84.1144 and 84.1149.

(b) Three powered air-purifying respirators will be tested in accordance with the provisions of 84.1144 except they will be tested for a period of 4 hours each at a flowrate not less than 115 liters per minute to tight-fitting facepieces, and not less than 170 liters per minute to loose-fitting hoods and helmets. The total amount of unretained test suspension in samples taken during testing shall not exceed 14.4 milligrams for a powered air-purifying respirator with tight-fitting facepiece, and 21.3 milligrams for a powered air-purifying respirator with loose-fitting hood or helmet. They shall meet the minimum requirements of 84.1149.

6.3. All tight fitting facepieces must not exceed the following inhalation resistance requirements both before (initial) and after (final) the silica dust test when mounted on a head form at a flow rate of 85 lpm with the blower on and off as per APRS-0007:

Tight fit filter PAPRS with chemical cartridges: Initial: 50 mmH_2O Final: 70 mmH_2O.
Tight fit filter PAPRS without chemical cartridges: Initial: 20 mmH_2O Final: 40mh2o .
Tight fit filter PAPRS with FM or BM canisters: Initial: 70 mmH_2O Final: 85 mmH_2O.
Tight fit filter PAPRS chin style canisters: Initial: 65 mmH_2O Final: 80 mmH_2O.

Note: For those also containing chemical cartridges or canisters, the “Final” criteria should be measured after silica dust testing and all gas and vapor tests.

7. RECORDS/TEST SHEETS

7.1. All test data will be recorded on the DETERMINATION OF SILICA DUST TEST PROCEDURE FOR POWERED AIR-PURIFYING RESPIRATORS test data sheet.

7.2. All videotapes and photographs of the actual test being performed, or of the tested equipment shall be maintained in the task file as part of the permanent record.

7.3. All equipment failing any portion of this test will be handled as follows:

7.3.1. If the failure occurs on a new certification application, or extension of approval application, send a test report to the RCT Leader and prepare the hardware for return to the manufacturer.

7.3.2. If the failure occurs on hardware examined under an Off-the-Shelf Audit the hardware will be examined by a technician and the RCT Leader for cause. All equipment failing any portion of this test may be sent to the manufacturer for examination and then returned to NIOSH. However, the hardware tested shall be held at the testing laboratory until authorized for release by the RCT Leader, or his designee, following the standard operating procedures outlined in Procedure for Scheduling, and Processing Post-Certification Product Audits, RB-SOP-0005-00.

8. LIST OF ABBREVIATIONS

BM – back mounted

cfm – cubic feet per minute

FM – front mounted

Hg – mercury

H_2O – water

in. – inches

lpm – liters per minute

mg/m^3 – milligrams per cubic meter

mm – millimeter

psi – pounds per square inch

National Institute for Occupational Safety and Health
Respirator Branch
Test Data Sheet

NIOSH

Task Number:
Test:
Manufacturer:
Item Tested:

Reference No.:
STP No.:

Mask Type:

AIR FLOW

Sample	Minimum Allowed (Lpm)	Actual (Lpm)	Result
Initial			
Final			
Overall Result:			

RESISTANCE

	Maximum Allowable Resistance (MM of H2O)				Actual Resistance (MM of H2O)				
	Inhalation		Exhalation		Inhalation		Exhalation		
Sample	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Result
Blower Off									
Blower On									
Overall Result:									

LEAKAGE

Sample	Maximum Allowable Leakage (mg.)	Actual Leakage (mg.)	Result
Mask A			
Overall Result:			

Average Silica Dust Concentration:	mg. /cuM
Average Relative Humidity-Room:	%
Average Relative Humidity-Chamber:	%

Signature:

Date: _____

Engineering Technician

Revision History

Revision	Date	Reason for Revision
1.0	11 July 2001	Historic document
1.1	14 June 2005	Update header and format to reflect lab move from Morgantown, WV No changes to method