- OUTLINE -

RESPIRATORY PROTECTIVE DEVICES

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I. INTRODUCTION

Although respiratory protective devices are probably the oldest method of controlling occupational diseases, health and safety men are generally less informed about the applications and limitations of these devices than about any other particular field in health and safety. It is emphasized that in the control of occupational diseases caused by airborne contaminants, primary consideration should always be given to preventing the air from becoming contaminated.

There are many situations in which respiratory protective devices are a must either for emergencies or routine use. Personal respiratory protective devices are intended to serve as adjuncts to other control measures not as substitutes for them. However, because a large variety of these devices are available commercially and may be had on short notice and at relatively low cost, such equipment is frequently misused and abused. All too many select and use respiratory protective devices on "faith", without knowing where and where not, when and when not, to use devices or how to select and use them properly.

To know this, it is necessary to understand the nature and extent of the exposure and the degree of protection needed. as well as to be acquainted with the various types of respirator and their uses and limitations. The many new and unusual occupational diseases resulting from industrial processes in the atomic and space age have created a demand for many types of respiratory protective devices with a very high degree of protection; however, the state of development of respiratory protective devices exceeds the state of their selection and use by health and safety personnel. In fact, the state of knowledge of the performance of respiratory devices in relation to the situation of use is better than the use that is made of them. (Brandt - 1947 and Respiratory Manual - 1963)

II. APPROVED DEVICES

A. U. S. BUREAU OF MINES RESPIRATOR TESTING AND APPROVAL

1. Approval schedules in use prior to March 1972

   a. 13E - Self-contained breathing apparatus. (3-31-78)
   b. 14F - Gas masks. (3-31-77)
   c. 19B - Supplied-Air Respirators. (3-31-80)
   d. 21B - Filter-type Dust, Fume and Mist Respirators. (3-31-76)
   e. 23B - Chemical cartridge respirators, including paint spray respirators. (3-31-76)

2. Info Circular 8559 published in 1972 - Approvals as of 5/24/72.

B. NIOSH - MESA APPROVALS: 30 CFR PART II (MARCH 1972).

1. Subpart H - SCBA

   a. TC - 13F-27 (9-73) to 56 (6-75)

   b. 30 devices approved include entry and escape

2. Subpart I - Gas Masks

   a. TC-14G - 82 (5-74) to 91 (6-75)

   b. 9 devices approved include 3 for vinyl chloride

3. Subpart J - Supplied-air respirators

   a. TC-19C - 64 (9-73) to 83 (6-75)

   b. 18 devices approved (No #75 and #64 for 2 mfr)

4. Subpart K - Dust, fume and mist respirators

   a. TC-21C - 132 (5-72) to 167 (6-75)

   b. 36 devices approved

   c. 136 and 136A same 3M PAPR

   d. 2 types FF approved for both 149 and 150

   e. 2 types 1/2 approved for both 160 and 164

5. Subpart L - Chemical cartridge respirator

   a. TC-23C - 40 (10-72) to 99 (6-75)

   b. 60 devices approved

   c. Includes spray paint and pesticide

6. Subpart M - Pesticide respirators

   a. All listed under 23C

   b. TC-23C - 45, 54, 74, 78 (PAPR), 79

7. Subpart E - Quality Control

   a. All mfr. must have QC plan approved

   b. Started buying on market and QC testing 1-75.

C. SOME PROBLEMS AND REVISIONS NEEDED IN PART 11

1. Isoamyl Acetate fit test for all devices
   a. Need quan. fit with test panel
   b. Need performance criteria for all devices
2. Use Time Consuming SiO_2 and Pb Fume Loading Test
   a. UK respirator superior with no loading test
   b. Eliminate loading tests for most respirators
3. No rapid and accurate QC filter test (only DOP)
   a. Use NaCl aerosol test
   b. Need new performance criteria
4. No Use Test for stability
   a. Add wearing 2-3 hrs especially SU and 1/4
   b. Add QC on headbands
5. Electrostatic Felt Filters Degrade
   a. Need test for effect of H_2O, OV, etc.
   b. Seal in impervious bags
6. No test to verify positive pressure devices
   a. Test continuous flow air-line respirators
   b. Test SCBA; closed circuit and self gen.

III. CLASSIFICATION OF RESPIRATORY HAZARDS (Z88,2-1969)

A. OXYGEN DEFICIENCY

B. GAS AND VAPOR CONTAMINANTS

1. Immediately dangerous to life or health
2. Not immediately dangerous to life or health

C. PARTICULATE (DUST, FUME, MIST, FOG, AND SMOKE) CONTAMINANTS

1. Immediately dangerous to life or health
2. Not immediately dangerous to life or health

D. COMBINATION OF GAS, VAPOR AND PARTICULATE CONTAMINANTS

1. Immediately dangerous to life or health
2. Not immediately dangerous to life or health

IV. BASIC CLASSIFICATION OF RESPIRATORS (BASED ON Z88.2-1969)

Respiratory protective devices are grouped broadly according to their mode of operation. The basic classifications are:

A. ATMOSPHERE-SUPPLYING RESPIRATORS

1. Self-contained
2. Hose-mask
3. Air-line
4. Combination self-contained and hose-mask or air-line

B. AIR-PURIFYING RESPIRATORS

1. Gas and vapor (gas mask and chemical cartridge)
2. Particulate (dust, fog, fume, mist, smoke, and sprays)
3. Combination gas, vapor and particulate

C. COMBINATION ATMOSPHERE-SUPPLYING AND AIR-PURIFYING RESPIRATORS

V. DETAILED CLASSIFICATION OF RESPIRATORS

A. ATMOSPHERE SUPPLYING RESPIRATORS

1. S.C.B.A. (13E) and (13F)

a. Closed-Circuit Apparatus:

(1) Compressed oxygen, heavy work, negative pressure
(2) Oxygen generating, heavy work, negative pressure
(3) Liquid oxygen, heavy work, negative pressure

b. Open Circuit (Using Compressed or Liquified Breathing Gas):

(1) Demand, FF, Negative Pressure on inhalation
(2) Pressure-Demand, FF, Positive Pressure, always (?)

c. Combination of a or b + air-line respirator

2. Hose-Mask (19B) and (19C)

a. Hose Mask with blower (Type A) Limitation, 50 lpm, Neg. Pressure
b. Hose Mask without blower (Type B) only MSA 19B-62, Neg. Pressure

3. Air-line Respirator (Type C) (19B or 19C)

a. Continuous flow type

(1) facepiece type, either 1/2 or FF
(2) hoods or helmets; Type C and CE (abrasive)
(3) suits, none approved (only for ERDA by LASL)

V. (continued)

b. Demand type, either 1/2 or FF
c. Pressure-Demand type, FF

4. Combination S.C.B.A. and Air-line respirator (only MSA 13E-23)

B. AIR-PURIFYING RESPIRATORS

1. Gas and Vapor-Removing Respirators

a. Gas masks (full facepiece) - 14F and 14G

(1) Industrial, back or front-mounted type; - Cl_2, NH_3, Acid Gases and organic vapors, SO_2, NO_2, CO
(2) Chin type; SO_2, Cl_2, NO_2, NH_3, CO, organic vapors (14G only
(3) Escape type; SO_2, Cl_2, NO_2, NH_3, CO, organic vapors

b. Chemical cartridge respirator (half-mask facepiece - 23B) + (FF + mouthpiece in 30 CFR 11, 23C)

(1) Only organic vapor approved under 23B
(2) Under Part 11, approve for Amines, NH_3, NH_3, Cl_2, HCl, SO_2, + OV

2. Particulate respirator (dust, fume and mist)

a. Particulates having TLV $\geq$ 0.05 mg/m^3

(1) SU, 1/4, 1/2, FF, Dust respirator (tested against silica dust)
(2) 1/4, 1/2, FF, Fume respirator (tested against lead fume)

b. Particulates having TLV $<$ 0.05 mg/m^3 (Pu, Be, As)

(1) 1/2 for protection to 10 X TLV (21B), No MUC in 21C
(2) FF for protection to 100 X TLV (21B), No MUC in 21C

c. Powered type (PAPR with Hi-Eff. filter, only 3M by 6-75)

3. Combination particulate, gas and vapor removing respirator.

a. Type N gas mask (14F)----- (14G)
b. Fullface - chin canister (Part 11 only, 14G)
c. Spray paint (23B) ---- (23C)
d. Pesticide (23C) 1/4, 1/2, FF

C. COMBINATION ATMOSPHERE-SUPPLYING AND AIR-PURIFYING RESPIRATORS

1. Supplied-air + air-purifying respirator
2. S.C.B.A. + air-purifying respirator

VI. A RESPIRATOR PROGRAM

A. RESPIRATOR MANUAL CHAPTER 1 (1963)

Effective use requires a planned program assigned to trained, experienced person. Following are essentials of program:

1. Selection
2. Instruction
3. Supervision
4. Centralized cleaning station
5. Inspection and Maintenance
6. Storage
7. Medical surveillance

B. ANSI Z88.2-1969 (SECTION 3.5, 3.6, 3.7 and 3.8)

Minimal Acceptable Program

1. Written SOP
2. Selection
3. Training
4. Assigned to Individuals
5. Cleaned and Disinfected
6. Storage
7. Inspection and Maintenance
8. Surveillance for Exposure
9. Evaluation of Program
10. Administration
11. Medical Limitations
12. Use of Approved Devices

C. OSHA, PART 1910.134 (b)

1. "The Eleven Commandments" (per LASL Training Manual) subsection (B), (1) thru (11)

2. Details subsections (c) thru (f)

VIII. SELECTION

A. CANNOT SELECT AND USE BY FAITH

B. THE SELECTION AND USE IS JUSTIFIED ONLY AFTER A CONSIDERATION OF THE FACTORS INVOLVED INDICATES THE DEVICE WILL PROVIDE SATISFACTORY PROTECTION WHEN PROPERLY USED.

1. Chemical, physical and toxicological properties.
2. Processes and conditions relating to dissemination of contaminants.
3. Possible formation of significant secondary products.

a. Welding: TCE-Phosgene

4. Evaluation of actual and potential hazards.

a. Maintenance - Repairing pipes carrying chemicals - Nickel Carbonyl, stripping asbestos insulation.
b. Duct removal - TNT, Pu, etc.

VIII. B (continued)

5. Nature of duties to be performed.

a. To be sure device will not hinder duties.
b. Important also in emergencies

IX. TRAINING AND EDUCATION IN PROPER USE

A. GENERAL

1. Very important, but often neglected

2. Common misconception - training needed only for SCBA

a. The more complicated the device or the more hazardous the atmosphere, the more extensive and intensive the training must be.
b. B of M Mine Rescue Training

3. Examples of improper use of simplest device

4. Training by qualified instructors.

5. Training necessary for supervisors as well as users.

B. ESSENTIALS FOR TRAINING IN USE OF ANY RESPIRATOR

1. Discussion of airborne contaminants

a. Identify contaminants: Odor, Irritant, Skin Absorption, etc.
b. Degree of hazard

2. Reasons for using respirator

a. Provide respirable air during -

(1) Maintenance
(2) Emergency
(3) Unusual Situation - limited egress

3. Description of its construction, operating principles and limitations

a. Air-purifying respirators

(1) Facepiece
(2) Headstraps
(3) Exhalation and inhalation valves - cover
(4) Filter or chemical cartridge - gasket
(5) Type N canister

IX. B. (contined)

b. Atmosphere-supplying respirators

(1) Supplied-air respirator, Type C

Example - "Approved only when the assembly consists of: BM-19B-38 facepiece, BM-19B-34 or BM-19B-34B air flow control valve, and BM-1922 hose".

"This approval applies only when the respirator is supplied with respirable air within the pressure range of 10 to 15 pounds per square inch gage through 15 to 50 feet of hose".

(2) SCBA, requires extensive training for proper use and protection.

(3) Breathing air specs (Grade D, CGS G7.1-1966).

(4) Breathing air compressors

4. Instructions in procedures for assuring that it is in proper working condition.

a. Half-mask respirator

(1) Check facepiece and straps - condition
(2) Check filter and gasket - tightness
(3) Valves, in place, not misshapen, no lint or dust

b. Gas mask

(1) Facepiece, lens (antifog), head-harness
(2) Canister: Proper type, condition, window indicator, harness
(3) Breathing tube

5. Instruction in fitting and checking proper fit.

6. Instruction in proper use and maintenance.

7. Discussion of importance of careful reading of approval labels and manufacturer's instruction.

IX. TESTS AND PROCEDURES FOR FITTING RESPIRATORS

A. PARTICULATE-REMOVING RESPIRATORS, QUAL. FIT TESTS

1. By closing off exhalation valve and exhaling
2. Closing off filter inlet if design permits and inhale
3. Use of irritant fume
4. Coal dust or Talc dust

IX. (continued)

B. GAS- AND VAPOR- REMOVING, QUAL. FIT TESTS

1. Iso-amyl acetate
2. Tear Gas, others
3. Methods of Dispersing Test Vapors

a. Lab. Tests

(1) Chamber
(2) Any room: 17.3 ml./1000 ft.^{3}
(3) Training Hood

b. Field Tests

(1) Few drops of acetate on piece of cotton
(2) Acetate in stencil brush

C. QUANTITATIVE FITTING TESTS

1. Polydisperse DOP aerosol system, 2 Commercial Units
2. NaCl aerosol system, 2 Commercial Units
3. Freon-12
4. Argon

X. CLEANING AND MAINTENANCE

A. STANDARD PROCEDURE

1. Remove filter or cartridge (reuse or discard)
2. Wash in good soap or detergent in warm water (140°F)

a. Methods or washing equipment

3. Rinse completely in clean warm water
4. Air dry the equipment in a clean area
5. Inspect the valves, head straps, and other parts, replace with new parts, if defective.
6. Insert new filters or cartridges, make sure the seal is tight. (?Re-use of filters or cartridges)
7. Place in a plastic or paper bag for storage.

B. COMBINATION CLEANER-SANITIZER

1. Bactericidal agent is generally a quaternary ammonia compound

a. Mfg. recommends cleaning in solution, rinsing in clean, warm (140°F) and air drying.
b. A conc. of 200 PPM quaternary compound in H_2O with less 500 PPM total hardness is generally an effective disinfecting agent.

C. OTHER DISINFECTING METHODS

1. If respirators are used by different men, a good public health

C. (continued)

policy is to disinfect before they are re-issued.

a. A hypochlorite solution (50 PPM of Cl_2), immersion time - 2 min.
b. An alcoholic solution of iodine (50 PPM I_2) immersion time - 2 min.

XI. SPECIAL PROBLEMS IN USE OF RESPIRATORS

A. COMMUNICATIONS

1. Combination exhalation-speaking diaphragm
2. Electronic voice amplifiers
3. Telephones or radio

B. PRESCRIPTION GLASSES WITH FULL FACEPIECE

1. Cannot obtain gas-tight seal with temple bars

C. USE IN TEMPERATURE EXTREMES

1. Lens

a. Antifog - good to 0°F.
b. Nosecup - below 0°F.

2. Exhalation valve - water vapor freezing

a. Thin layer antifog
b. Patented valve - Acme

3. Hot environment

a. A. O. mask
b. Vortex air liner respirator

4. Compressed breathing air in winter use

SAL 000057106

a. Central surface air line system
b. SCBA-moisture in breathing air

D. MULTIPLE CONTAMINANT EXPOSURE

1. NIOSH and/or OSHA - specify only one type respirator

a. Phosphorus (CO fatality)
b. Arsenic (+SO_2 exposure)

E. RECOGNITION OF ATMOSPHERES IMMEDIATELY DANGEROUS TO LIFE

1. Limited Egress (always use SOP)

a. Cleaning sludge tanks - H_2S,
b. Sewage Plant equipment pits - H_2S
c. Silos - CO_2
d. Cleaning tanks - standard solvents

2. Fumigation

a. HCN

3. Emergencies

a. Industrial Fires

XII. CURRENT RESPIRATOR R&D PROGRAMS

A. NIOSH SPONSORED PROJECTS

1. SCBA efficiency - Chicago Firemen, ITI
2. Sorbent life studies - Bendix
3. Test Panel Verification - LASL
4. PAPR Performance Criteria - LASL
5. Aerosol vs Gas Man Test Systems - LASL

B. COAL MINE RESCUE DEVICES - MESA

C. NUCLEAR REGULATORY AGENCY - LASL

D. ERDA - LASL (STUDY ON STRESS)

E. NASA - SCBA (4500 psi)

F. RESPIRATOR MANUFACTURERS

G. MILITARY - EDGEWOOD

XIII. DETERMINATION OF COMPLIANCE OR NON-COMPLIANCE IN FIELD

A. MINIMAL ACCEPTABLE RESPIRATOR PROGRAM IN USE?

1. Major problem, training both OSHA personnel and employer representatives.

a. NIOSH Sponsored Training - REECo
b. LASL Sponsored Training - Industry and OSHA
c. ERDA Sponsored Training - LASL
d. Industry needs consultation by OSHA/NIOSH
e. Some states give special training
f. Respirator Manufacturers - Consult and recommend devices for customers

2. Problem of Availability of Approved Devices with Assured Protection

   a. Amendments to Part 11 moving at snail's pace. (Funds, personnel)
   b. Part 11 should be completely revised and new performance criteria added.
   c. Need approval labels and conditions easily understood.

B. ROUTINE EXPOSURES

1. Requires air sampling to establish need and selection of proper device?

   a. Requires respirator protection factor for MUC, or
   b. Approval performance criteria that specifies MUC.

2. Impossible to routinely sample wearer's BZ inside facepiece or enclosure.

   a. Example: OSHA vs FMC Corp., (Cl_2 1 PPM, citation vacated, must sample Cl_2 breathed through mask.

   b. Example: Sandblasting, sampled under hood, but <u>not</u> in tight fitting facepiece, no violation. Ignored violation of incomplete approved assembly.

3. Work practices requiring respirator use are best for many operations

   a. No air sampling required
   b. Easier to enforce
   c. Currently in some standards

C. MAINTENANCE EXPOSURES

1. Air concentration usually not known and/or impractical to measure. Some automatic samplers.

2. The SOP should specify type of respirator for maintenance, based on potential exposure and duties performed.

   a. Specify areas where respirators must be worn during inspections and/or repair.
   b. For some operations, only exposure from accidental spill or leak, may require escape device.

D. EMERGENCIES (ENTRY INTO UNKNOWN CONCENTRATION)

1. Type of device should be specified in standard and in employer's SOP for entry.
2. Requires periodic (monthly) training and maintenance of devices.

E. EVACUATION OR ESCAPE (UNKNOWN CONCENTRATION)

1. Type of device specified in standard and in employer's SOP for escape.

2. Devices should be readily available.

F. SPECIAL PROBLEMS

1. Requirements in standards often difficult to interpret.

   a. SCP-Ketones (Eye Protection - inconsistent)
   b. When are respirators required?
   c. What type provides adequate protection?
   d. Will citation hold up in hearing?

      (1) coal tar pitch volatiles, what device?
      (2) smelters, are Gas Masks feasible and needed for short time peak excursions?
      (3) high concentration Ag requires FF, is it practical or feasible for Indians making jewelry?

2. No approved air-purifying devices available for some contaminants.

   a. Is supplied-air respirator feasible?
   b. Is SCBA feasible? NO!

3. Employees refuse to wear device, do you cite employer?

   a. Uncomfortable, should try others
   b. Will not wear properly.
   c. Interferes with work.

G. GOAL IS TO PREVENT EXPOSURE

1. Must be feasible, practical, and acceptable to wearer.

2. Respirators should be used to prevent overexposure when needed.

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Dragerwerk AG · Postfach 1339 · D-2400 Lübeck 1

für respirator

RECEIVED
SEP 12 1979

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Ihr Zeichen und Schreiben vom:	Unser Zeichen Hausapparat	Datum
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Re: 1979 American Industrial
Hygiene Conference

Dear Mr. Hall,

thank you for asking me about the paper "Analysis of Compressed Air by Means of Detector Tubes".

I am pleased to send you a copy of this paper.

If you need further information, please let me know.

Sincerely yours,

D R Ä G E R W E R K AG
Development and application technique
detector tubes

Kurt Leichnitz
(Kurt Leichnitz)

Enclosure

SAL 000057110

Analysis of compressed air by means of detector tubes

by Kurt Leichnitz

1 General

Compressed air is used to a large extent for respiratory protective devices and diving apparatus. The user of the apparatus must be able to rely on the air in his breathing air cylinder to be perfect because he will be in a hostile environment when he actually uses the equipment.

The German Standard DIN 3188 requires (1) that the users of breathing apparatus have at their disposal breathing air which is harmless and is not felt to be objectionable. The air used to fill the compressed gas cylinders must be free of harmful gases, vapors and aerosols. According to this Standard, the following purity criteria apply to air which is to be filled in compressed gas cylinders:

a) The carbon monoxide content of the air to be filled must be less than 50 ppm in the expanded state.

b) The carbon dioxide content of the air to be filled must be less than 1000 ppm in the expanded state.

c) The air to be filled must be practically odorless and without taste in the expanded state.

   Air which does not have any odor will not have an objectionable oil concentration either.

d) Even at the highest filling pressure permitted for the compressed gas cylinder, dripping liquid water should not form in the compressed gas cylinder at room temperature. This will be the case if the water content of the compressed air has the following values after expansion to atmospheric pressure:

   At a filling pressure of 200 bar ⟶ water content less than 50 mg/m^3
   At a filling pressure of 300 bar ⟶ water content less than 35 mg/m^3

This standard thus determines the properties of the air used for filling (free of harmful gases, etc.) as well as the limit values (CO, CO_2, oil, H_2O) for the air to be filled in the compressed gas cylinders. Assuming that the filling

is done by means of a compressor, the data of DIN 3188 hold for the drawn-in air and for the air at the compressor outlet.
The purity requirement regarding humidity, carbon monoxide and oil is particularly important with respect to the air at the outlet of the compressor; if the compressor is serviced properly, the set limit values are kept. If these limits are exceeded, this is always almost a consequence of inadequate maintenance of the compressor (exhaustion of the dry filter, exhaustion of the oil filter).

2. Air analysis

2.1 General notes

The air used in respiratory protective devices and diving apparatus is obtained from compressors. The following air analyses must be carried out for comprehensive monitoring.

2.1.1 Analysis of the air ahead of the compressor (drawn-in air)

2.1.2 Analysis of the air at the compressor outlet

2.1.3 Analysis of the air in compressed gas cylinders

2.2 The air ahead of the compressor (drawn-in air) can be measured either by means of short-term measuring systems (Fig. 1 is an illustration of short-term detector tubes and bellows pump) or by long-term measuring systems (Fig. 2 illustrates long-term detector tubes with Polymeter long-term pump). The selection of the measuring system is governed by the task involved. The result of the measurement permits an evaluation of the quality of the air drawn in by the compressor; this evaluation holds for the period of measurement.

Short-term and long-term measuring systems are well known (2) and will therefore not be discussed at this time. In the context of compressed-air analyses, the air analysis at the compressor outlet and analysis of the air in compressed gas cylinders is of particular interest; an obvious solution is to force the air directly through the detector tube. During the measurement, the air then flows through the detector tube at a constant rate of flow.

Since the indicating response of the detector tubes depends on the characteristics of the rate of flow in the air conveyor, tubes specially calibrated to a constant rate of flow must be used for compressed air analyses. This will also meet the (basic) requirement imposed by the standards (3, 4, 5) which states that the detector tubes and air coveyor must be one unit. This new measuring system, which was developed for compressed air analyses, is marketed under the name of Aerotest.

3 Description of the Aerotest

3.1 The Aerotest (Fig. 3) consists of a sampling device, detector tube, and stop watch. The air is routed as follows during the analysis (cf. also Fig. 4):

compressed air system
↓
pressure reducer
↓
needle proportioning valve
↓
flow meter
↓
detector tube

The inner surface of the sampling device was kept as small as possible to avoid sorption processes (adsorption - desorption).

3.2 Execution of the test in brief:

a) Connect the Aerotest to the compressed air system.
b) Flush the air to be sampled through the Aerotest.
c) Set the rate of flow required for the analysis at the flow meter.
d) Insert the detector tube into the tube holder.
e) Determine the total sampling time by means of a stop watch.
f) Remove the detector tube from the tube holder at the end of sample taking.
g) Evaluate the indication of the detector tube.

3.3 Special detector tubes for the Aerotest

3.3.1 Carbon dioxide detector tube 100/a-P

Measuring range: 100 to 3000 ppm CO_2
Relative standard deviation: 15 to 10 %
Volume of air sample: 1 liter

Rate of flow during the measurement: 0.2 liter/min
Total measuring time: 5 min

Description of the tube:

Tube with imprinted calibrated scale • white indicating layer (hydrazine and crystal violet as reagent) • there is a change in color from white to violet during the reaction with CO_2.

Reaction equation:

$$CO_2 + N_2H_4 \xrightarrow{\text{crystal violet as reduction oxydation indicator}} NH_2\ NH\ COOH$$

Interference from other gases and vapors:

With the measuring conditions for compressed air analysis, the indication is specific for CO_2, i.e., no influence from other contaminants.

3.3.2 Detector tube carbon monoxide 5/a-P

Measuring range: 5 to 150 ppm CO (2.5 to 75 ppm CO)
Relative standard deviation: 15 to 10 %
Volume of air sample: 1 liter (2 liters)
Rate of flow during the measurement: 0.2 liter/min
Total measuring time: 5 min (10 min).

Description of the tube:

Tube with imprinted calibrated scale • orange prelayer (chromate - sulphuric acid as reagent) • white indicating layer (iodine pentoxide , selenium dioxide, and fuming sulphuric acid as reagents)
• there is a change in color from white to brownish green during the reaction with CO.

Reaction equation:

$$5\ CO + I_2O_5 + (SeO_2 + H_2S_2O_7) \longrightarrow 5\ CO_2 + I_2$$

Interference from other gases and vapors:

With the measuring conditions for compressed air analysis, the indication is specific for CO; any interfering substances which may be present are retained in the orange prelayer.

3.3.3 Detector tube oil 10/a-P
(the tube measures the sum of oil vapor and oil mist)

Measuring range: 0.1 to 10 mg oil/m^3
Relative standard deviation: 40 %
Volume of air sample: 250 to 10 liters

Rate of flow during the measurement: 2 liters/min
Total measuring time: 125 min to 5 min

Description of the tube:

Tube with enclosed color standard (25 µg; 50 µg, 75 µg, 100 µg oil) ● The tube also contains a built-in ampoule (sulphuric acid and oxydant as reagents) ● white indicating layer (activated silica gel) ● there is a change in color from white to brown during the reaction with oil (vapor and mist).

Reaction principle:

oil + oxydant + $H_2 SO_4$ ⟶ brown reaction product

(Note: The oil is adsorbed at the silica gel. After completion of the collection phase, the reagent ampoule is opened, and the adsorbed oil indicated).

Interference from other gases and vapors:

The reagent system (oxydant + $H_2 SO_4$) is converted (brown indication) with a large number of (higher boiling) organic compounds (e.g., naphthaline, dioctyl phathate).

3.3.4 Detector tube water vapor 5/a-P

Measuring range: 5 to 200 mg H_2O/m^3
(10 to 450 mg H_2O/m^3)
(2 to 80 mg H_2O/m^3)

Relative standard deviation: 20 to 15 %
(30 to 25 %)
(25 to 20 %)

Volume of air sample during the measurement: 50 liters
(25 liters)
(100 liters)

Rate of flow during the measurement: 2 liters/min

Total measuring time: 25 min
(12.5 min)
(50 min)

Description of the tube:

Tube with imprinted calibrated scale ● yellow indicating layer (selenium dioxide/sulphuric acid as reagents) ● there is a change in color from yellow to reddish brown or greenish grey during the reaction with moisture.

Reaction principle:

H_2O + selenium dioxide/sulphuric acid ⟶ reaction product

Interference from other gases and vapors:

Easily oxidized organic compounds (e.g., alcohols, benzene, butadiene) are also indicated.

4 Behavior of gaseous and vaporous air contaminants in pressure systems

If all components (in our example: H_2O, oil, CO_2, CO) are present in the compressed gas cylinder in the gaseous phase, evaluation of the air for the compressed state is possible. However, changes in the concentration (especially in the case of H_2O and oil) may occur in the pressure system as a result of condensation and by evaporation or adsorption as well as desorption at surfaces; chemisorption and direct reactions with the surfaces must be taken into account as well.

Fig. 5 illustrates the change in the H_2O content - measured in expanded air - when a "wet" compressed air cylinder is discharged (before filling, 50 cm^3 of liquid water had been poured into the four-liter cylinder). Although the results permit the conclusion that there is oversaturation by humidity, these results do not show how much water there is actually in the cylinder.

Stability investigations of gases in compressed gas cylinders (6) showed that even far below the saturation state, the humidity content is not always constant. When compressed air was withdrawn from a commercial pressure vessel over a period of nine weeks, the H_2O content in the expanded air rose from about 2 mg/m^3 to more than 7 mg/m^3. The same study on a specially treated pressure vessel yielded a constant H_2O concentration of 2 mg H_2O/m^3 over the same period of nine weeks.

Thus the surface properties may affect the composition of the gaseous phase very considerably. The result of the compressed air analysis thus applies only to the expanded state and to the time of measurement. In order to evaluate the air in the pressure system, time and space differences due to adsorption and desorption processes at surfaces must be taken into consideration. It should also be noted that these processes depend to a great extent on the temperature. This statement applies, by the way, to all analysis processes of compressed air studies, not just to the detector tube method.

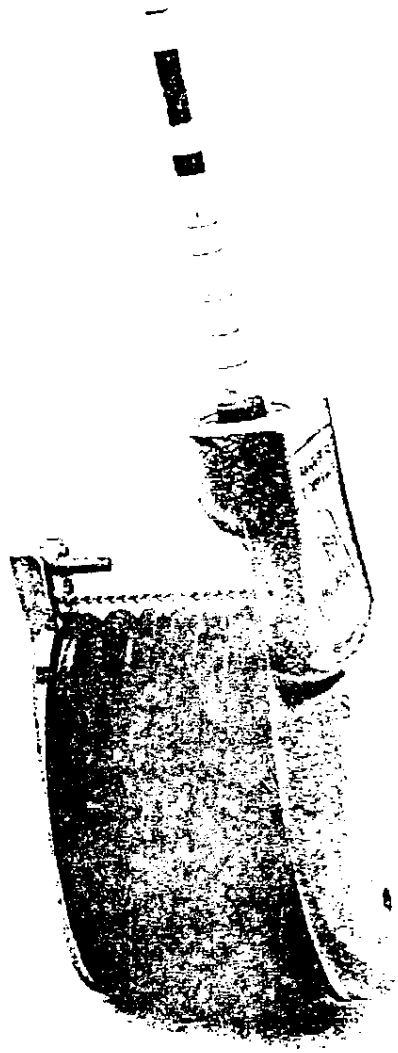

Fig. 1

Bellows pump with gas detector tube for short term tests (result obtained in a few minutes)

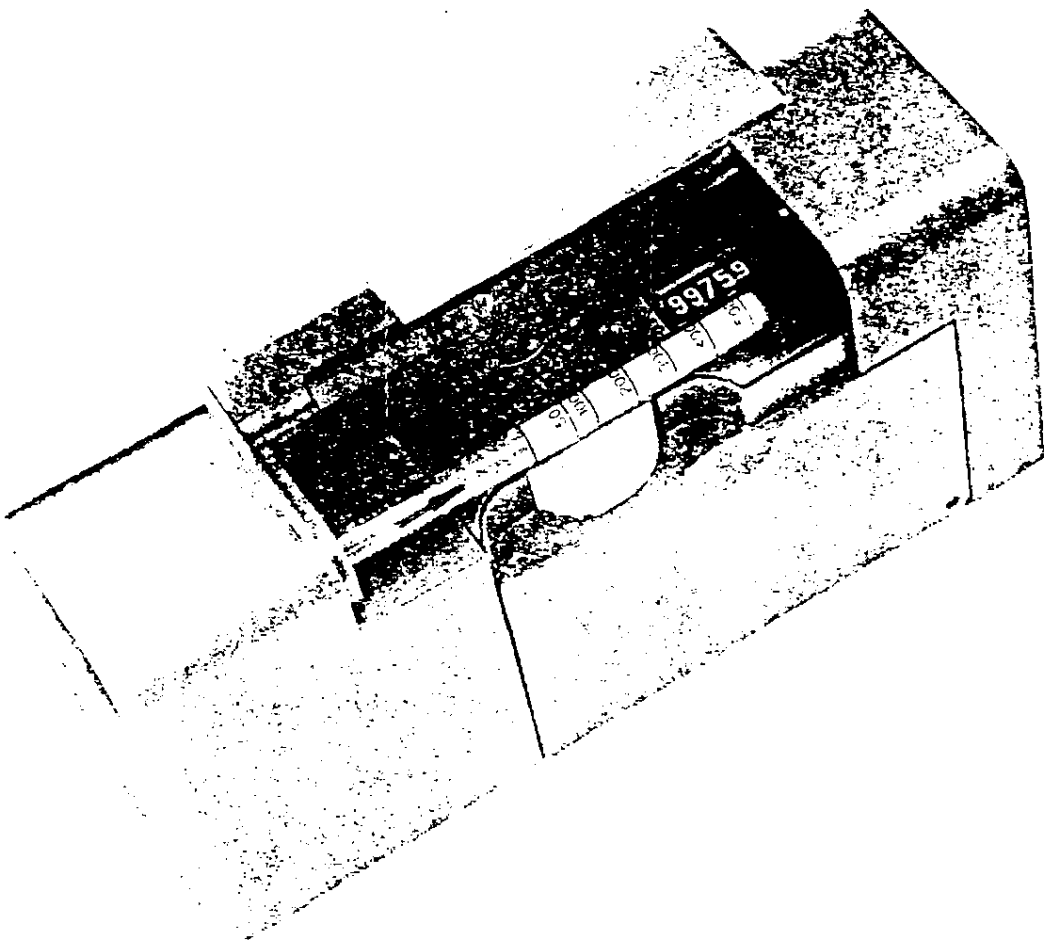

Fig. 2

Long-term measuring system for gases (long-term detector tube and Polymeter-long-term-pump).

By means of this system tests over a time period of several hours can be conducted. The measuring result is the average concentration for the total measuring time.

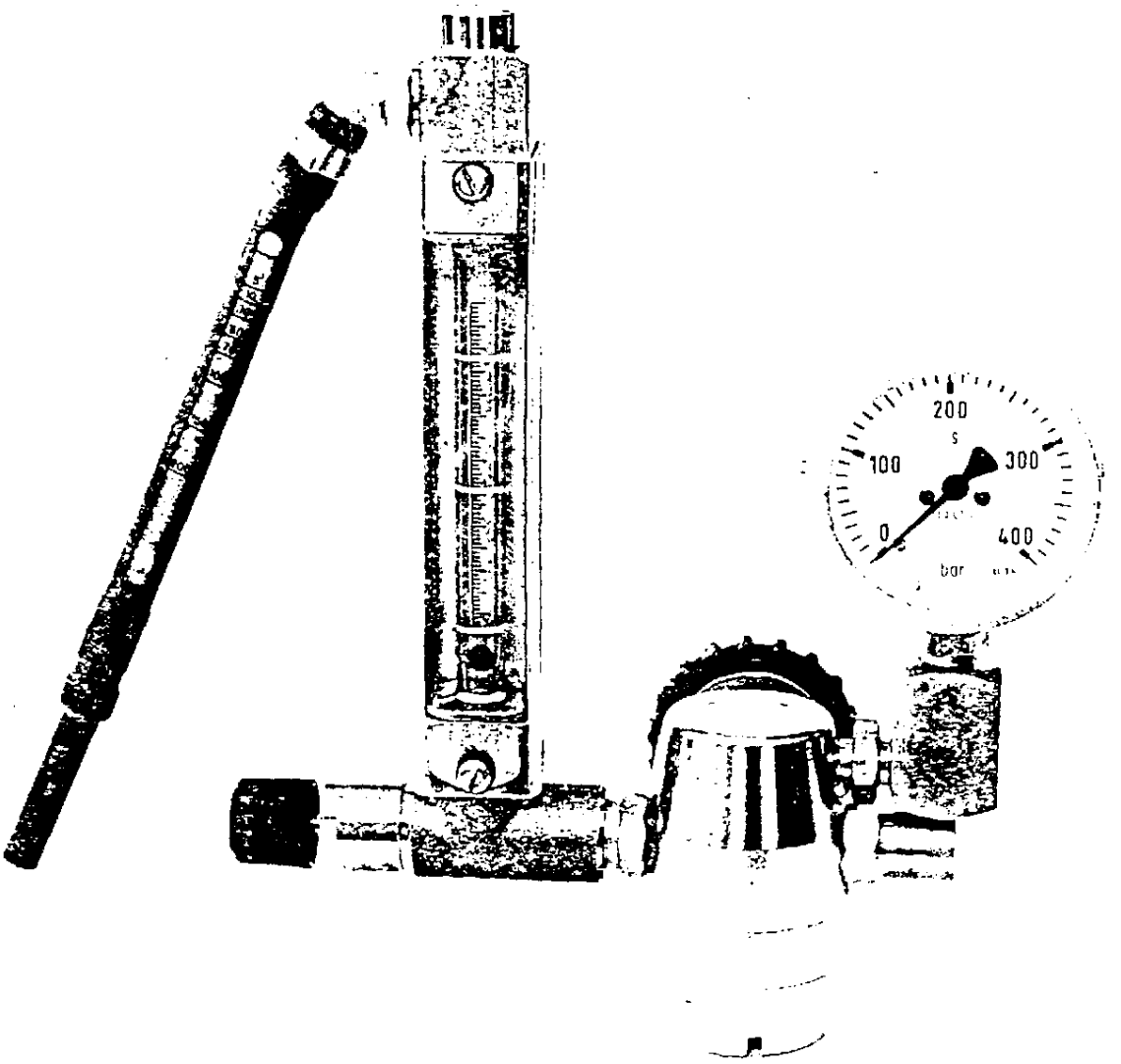

Fig. 3

Aerotest unit for direct testing of compressed air (picture shows sampling device with inserted detector tube).

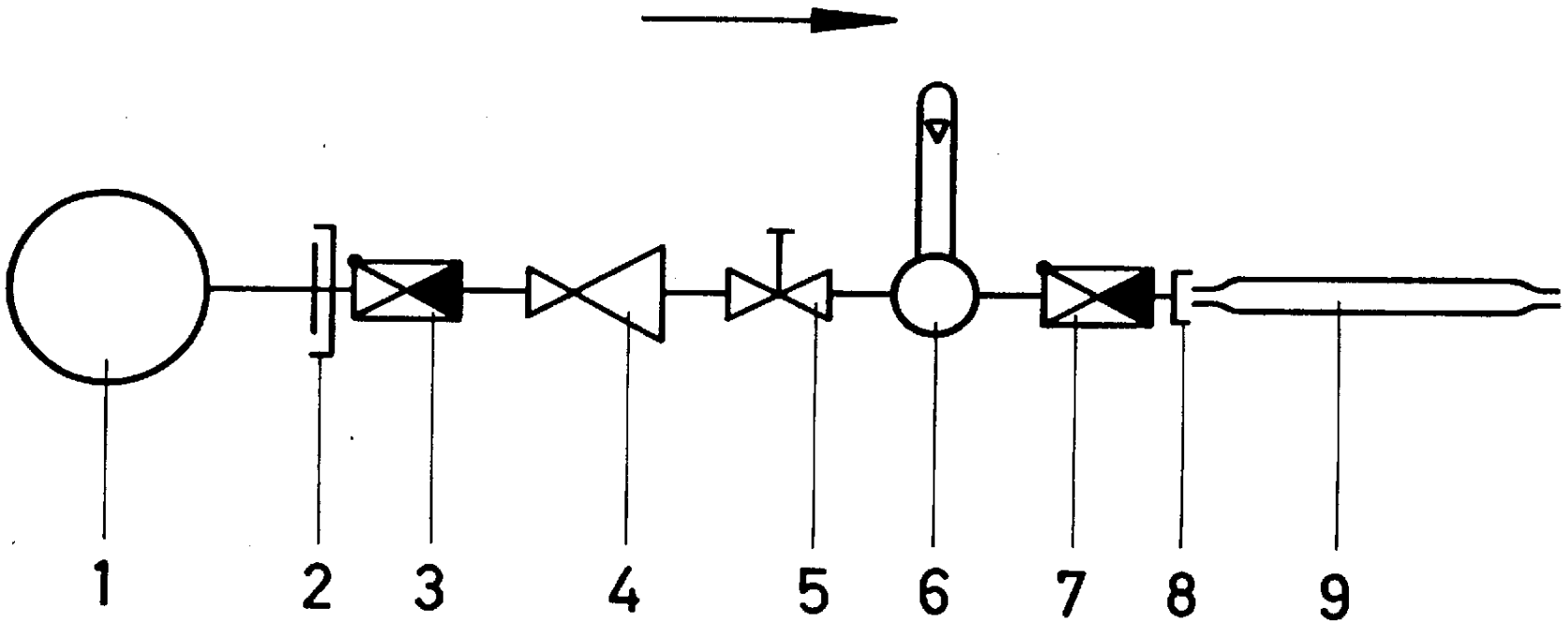

Fig. 4

Principle of Aerotest unit:

1	compressed air system
2	high pressure connection
3	return valve
4	pressure reducer
5	needle proportioning valve
6	flow meter
7	return valve
8	detector tube holder
9	detector tube

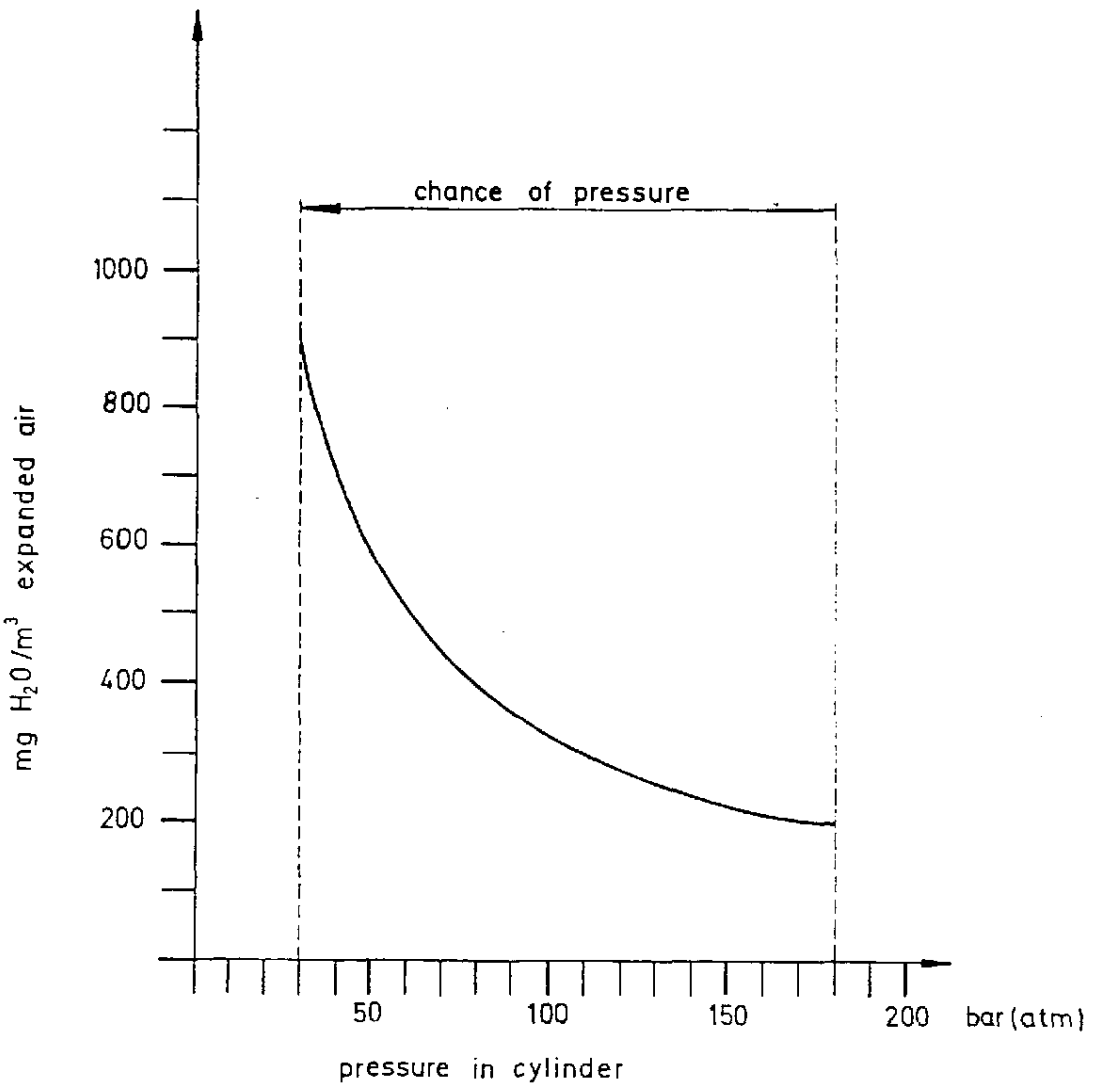

Fig. 5

Change in H_2O content - measured in expanded air - when a "wet" compressed air cylinder was discharged (before filling, 50 cm^3 of liquid water was poured into a four-liter cylinder).

Summary

Compressed air used for breathing purposes must not contain any inadmissibly high concentrations of contaminants; to ensure this the air must be analyzed. In the Federal Republic of Germany, limit values, referred to expanded air, have been established for the gases and vapors listed below: CO 50 ppm, CO_2 1000 ppm, H_2O 50 mg/m^3 (pressure 200 bar, 3000 lbs/sq. in.) H_2O 35 mg/m^3 (pressure 300 bar, 4500 lbs/sq. in.). A new analysis system has been developed to permit direct analysis of compressed air by means of detector tubes. Sampling is handled via a pressure reducer with an incorporated flow meter. The detector tube is connected directly to the nozzle of the flow meter. The properties of the detector tubes have been adjusted to the constant flow rate of the withdrawal system (CO and CO_2 tubes: 0.2 liter/min; H_2O and oil tubes: 2 liter/min). Measuring range of the detector tubes: Model CO 5/a-P from 5 to 150 ppm (1 liter), from 2.5 to 75 ppm (2 liter). CO_2 100/a-P from 100 to 3000 ppm (1 liter). H_2O 5/a-P from 5 to 200 mg/m^3 (50 liter). Oil 10/a-P (mist + vapor is measured) from 0.1 to 10 mg/m^3 (250 to 10 liter). A single relative standard deviation of about 15 % was established as indicating error of the CO and CO_2 tubes. In the H_2O tubes the error is about 20 %. The indication is evaluated in the oil tubes by matching to a color standard; the single relative standard deviation of the results obtained is 40 % max. The pressure reducer has a small internal chamber which allows for unobstructed passage of the air. This design is necessary to prevent adsorption losses (H_2O, oil) at the surface of the parts coming into contact with the test air. With any type of compressed-air analysis, it should be noted that the results of the measurements hold primilary for the contaminants present in the expanded air. Conclusions as to the composition of the compressed air can be drawn only if the physical and chemical behavior of the contaminants in the pressure system is known; this applies particularly to compressed-air cylinders, but may also be relevant as far as compressors are concerned. Changes in the concentration of the contaminants are possible if condensation occurs or sorption effects appear at the surfaces. Analysis of compressed air from a running compressor proved to present few problems; apart from a short startup phase, it can be assumed that the results obtained are representative of the compressed air supplied by the compressor. Conditions in a compressed-air cylinder are different; for instance, representative data on humidity cannot be obtained if liquid water is present in the cylinder.

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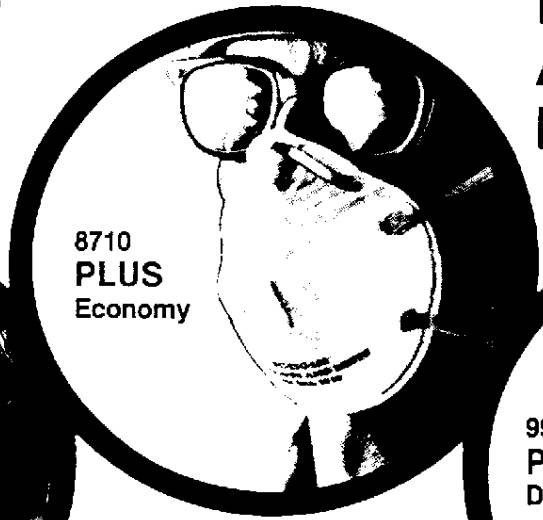
(Improvement of stability of gases in pressure cylinders)

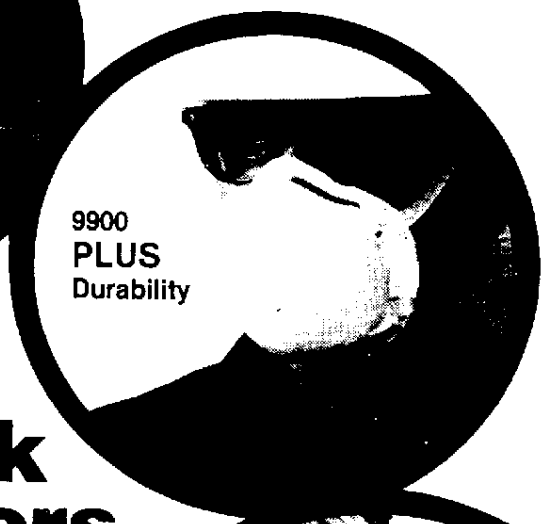
Maintenance Free Economy

Dust/Mist Approval from NIOSH

9913
PLUS
Nuisance
Odor



8710
PLUS
Economy



9900
PLUS
Durability

Half Mask Respirators

Dust/Mist PLUS...

9908
PLUS
Mercury
Vapor

9910
PLUS
Heat
Resistant

9906
PLUS
Hydrogen
Fluoride
Gas

9920
PLUS
Fume

3M

Product Line Features and Standards

		Current					Proposed		
Product	Features	Asbestos	Arsenic	Coke Oven*	Cotton	Lead	Wood	Grain	Welding
8710	*Dust/Mist* Stretch Straps Best Balance (Performance/Cost)	☒	☐	☐*	☒	☒	☒	☒	☐
9900	*Dust* Stretch Straps More Durable; High Heat	☒	☐	☒*	☒	☒	☒	☒	☐
9906	*Dust/Mist* Stapled Elastic Straps Nuisance HF	☐	☐	☒*	☒	☒	☒	☒	☐
9908	*Dust/Mist* Stapled Elastic Straps Mercury/Chlorine	☐	☐	☐*	☒	☒	☒	☒	☐
9910	*Dust/Mist* Four Point Adjustable Buckle More Durable High Heat	☒	☐	☒*	☒	☒	☒	☒	☐
9913	*Dust/Mist* Stapled Elastic Straps Nuisance Odors	☐	☐	☐*	☒	☒	☒	☒	☐
9920	*Dust/Mist/Fume* Four Point Adjustable Buckle More Durable Easy Breathing	☒	☐	☒*	☒	☒	☒	☒	☒

*OSHA regulations specify a NIOSH Approval for Dusts and Mists for coke oven emissions; only 3M Dust/Mist respirators with flame resistant properties are recommended for coke oven uses.

3M Brand Respirators
Product Features

	Approval						
Product	NIOSH Approval Number	Includes Asbestos	Stretch Straps	Adjustable Straps	Durable Outer Shell	Flame Retardant	Specialized Absorbent Capacity
8710	Dust/Mist TC-21C-132	yes	X				
9900	Dust TC-21C-176	yes	X		X	X	
9906	Dust/Mist TC-21C-224	no	X				HF
9908	Dust/Mist TC-21C-233	no	X				Hg. & Cl_2
9910	Dust/Mist TC-21C-190	yes		X	X	X	
9913	Dust/Mist TC-21C-234	no	X				nuisance odor
9920	Dust/Mist/Fume TC-21C-202	yes		X	(Plus exhalation valve) X	X	

Hazard	PEL[1]	NIOSH Approval Required
Dusts		
Arsenic (inorganic)	0.01	High Efficiency[2]
Asbestos	2 fibers/cc	Dust/Asbestos[3]
Beryllium	0.002	High Efficiency
Cadmium	0.2	Dust[4]
Calcium Oxide (Quicklime)	5.0	Dust
Carbon Black	3.5	Dust
Coal	2.0	Dust
Chromium	1.0	Dust
Copper	1.0	Dust
Fiberglass	15.0	Dust
Flouride dust	2.5	Dust - 9906 preferred
Lead	0.05	Dust
Manganese	5.0 Ceiling	Dust
Molybdenum - soluble	5.0	Dust
Molybdenum - insoluble	15.0	Dust
Nickel	1.0	Dust
Silica	—	Dust
Silver	0.01	High efficiency
Tantalum	5.0	Dust
Tin - inorganic	2.0	Dust
Titanium Dioxide	15.0	Dust
Vanadium Pentoxide	0.5 Ceiling	Dust
Mists		
Chromic Acid	0.1 Ceiling	Mist[4]
Oil Mist	5.0	Mist
Phosphoric Acid	1.0	Mist
Picric Acid	0.1	Mist
Sodium Hydroxide	2.0	Mist
Sulfuric Acid	1.0	Mist
Fumes		
Arsenic	0.01	High efficiency
Beryllium	0.002	High efficiency
Cadmium	0.1	Fume[4]
Cobalt	0.1	Fume
Copper	0.1	Fume
Iron Oxide	10.0	Fume
Lead	0.05	Fume
Magnesium Oxide	15.0	Fume
Nickel	1.0	Fume
Vanadium Pentoxide	0.1 Ceiling	Fume
Zinc Oxide	5.0	Fume

Footnotes

1. Permissible exposure level given in milligrams per cubic meter (mg/m^3) based on 8-hour time-weighted average unless otherwise noted.
2. High efficiency denotes a respirator approved for use against dust, fumes, or mist whose PEL is *less* than 0.05 mg/m^3.
3. Respirators for use against asbestos must have specific asbestos approval.
4. Dust, Mist, or Fume denotes a respirator approved for use against dusts, mists, or fumes, respectively, whose PEL is *not* less than 0.05 mg/m^3.

Important Notice to Purchaser

THE FOLLOWING WARRANTY IS MADE IN LIEU OF ALL OTHER WARRANTIES EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PURPOSE: 3M OH&SP products sold will meet the physical standards and properties set forth in the applicable product specification data sheets issued by 3M. 3M's only obligation under this warranty shall be to replace such quantity of 3M OH&SP products proved to be defectively manufactured by failing to meet the aforementioned specification data sheets, and to be responsible for any third party personal injuries directly caused by said defects. Except as provided above, 3M shall not be liable or responsible for any loss, damage, or liability, direct, indirect, incidental, special or consequential, arising out of the sale, use or misuse of, or the inability to use product by the user.

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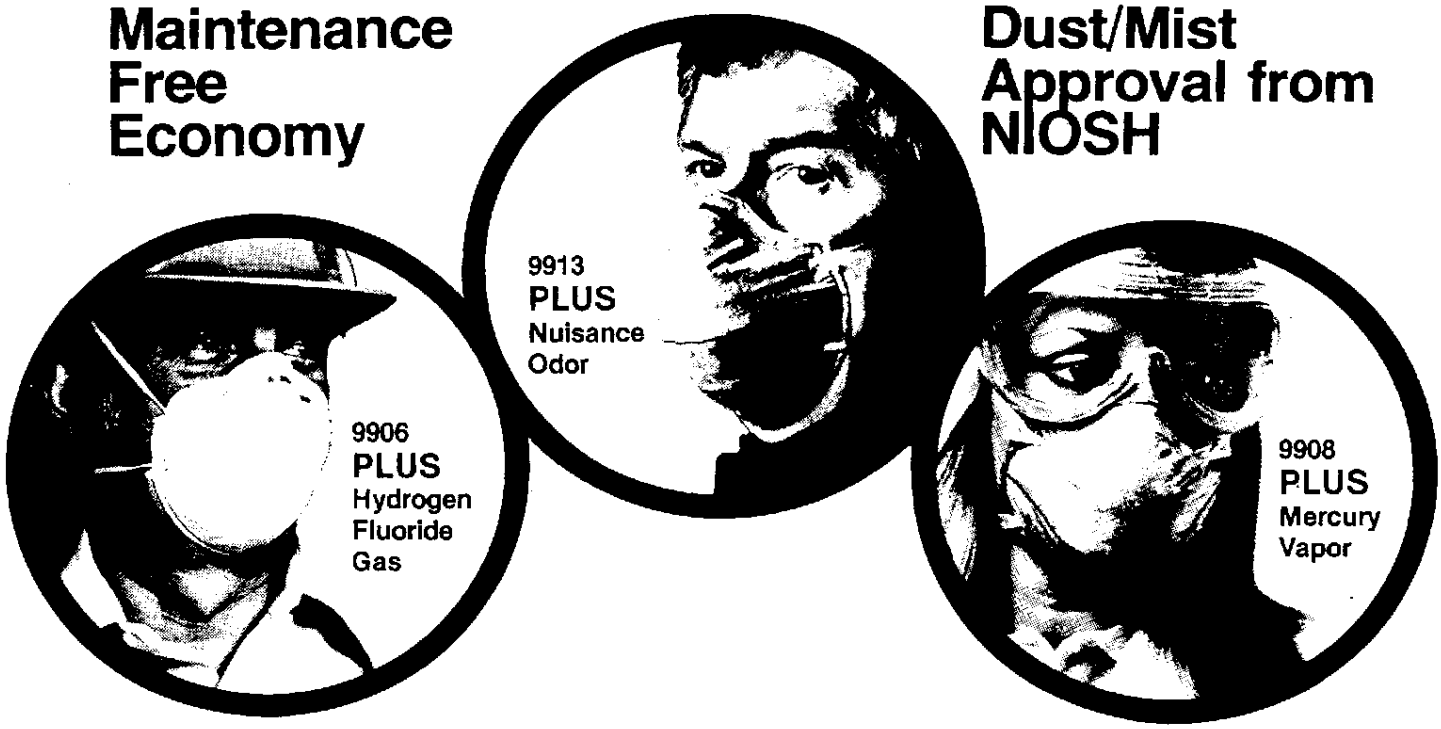
220-7W 3M Center
St. Paul, Minnesota 55144



Facts About 3M Specialty Respirators

Approvals

All three respirators NIOSH/MSHA approved for dusts and mists having a PEL not less than 0.05 milligrams per cubic meter of air. Examples would include dusts resulting from the disintegration of a solid, as in mining, quarrying, etc., and dusts produced during industrial operations such as grinding, crushing, etc. Mists would include mists whose liquid vehicle does not produce harmful levels of gases or vapors.

Product Features

All three respirators feature:

- Half mask design for better fit.
- Durable stapled elastic straps for easy to adjust, secure fit.
- Total filter design for increased filtration efficiency and ease of communication while wearing.
- Disposability for end user convenience and economy.

3M

Plus Added Benefits . . . .

9906 Dust/Mist Approval: TC-21C-224

Plus comfortable relief from low levels of hydrogen fluoride gas.

What protection?

Absorbent removes low levels (below PEL) of hydrogen fluoride gas.

Where needed?

Industries where HF gas represents a potential worker nuisance include:

- Primary aluminum production
- Metal cleaning — cast iron, copper and brass
- Cleaning brick and stone
- Metal casting — removing sand
- Petroleum industry — jet fuel manufacture
- Phosphate mining
- Fertilizer production

9913 Dust/Mist Approval: TC-21C-234

Plus comfortable relief from nuisance odors.

What protection?

Adsorbent removes concentrations of nuisance odors below the PEL.

How do we determine if 9913 can be used.

Easy — just routinely monitor exposure with 3500 Organic Vapor Monitor. If the levels are below the PEL, recommend 9913. If the levels are at or above the PEL — recommend the 8712 Organic Vapor Respirator.

Approval — for organic vapors

No — the 9913 is approved only for dusts and mists.

Where do hazards exist?

Areas where particulates and/or low levels of vapors and odors exist include:

Foundries	Laboratories
Food Processing	Agriculture
	Petrochemicals

9908 Dust/Mist Approval: TC-21C-233

Plus protection against mercury vapor and/or chlorine gas.

What protection?

Absorbent removes mercury vapor up to levels of 0.5 milligrams per cubic meter of air. Additionally, protects workers in combined atmospheres of up to 0.5 mg/m³ mercury and up to 10 ppm chlorine. Test results are available upon written request.

Chlorine only?

No — the 9908 is only recommended for use where mercury and chlorine are found together. For chlorine only, the 8714 Acid Gas Respirator should be used.

What are PEL's?

The PEL for mercury vapor is 0.1 mg/m³. The PEL for chlorine is 1 ppm.

How do we determine if 9908 can be used?

Easy — just routinely monitor exposure. The 3M 3600 Mercury Vapor Monitor or the 3M 3600A Mercury Vapor Monitor (for mercury-chlorine atmospheres).

Mercury or Mercury/ Chlorine approval?

Since NIOSH does not have a test schedule to approve air-purifying respirators for protection against mercury vapor, the 9908 is NIOSH approved for dusts and mists only.

Where needed?

Industries where mercury vapor and/or mercury/vapor chlorine represent a potential hazard include:

SIC:

2812 Alkalies, chlorine
3646 Lighting fixtures, commercial
3691 Batteries, storage
3692 Batteries, primary
3731 Ship building and repairing
3841 Surgical and medical instruments

Important Notice to Purchaser
THE FOLLOWING WARRANTY IS MADE IN LIEU OF ALL OTHER WARRANTIES EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR PURPOSE: 3M OH&SP products sold will meet the physical standards and properties set forth in the applicable product specification data sheets issued by 3M. 3M's only obligation under this warranty shall be to replace quantity of 3M OH&SP products proved to be defectively manufactured by failing to meet the aforementioned specification data sheets. Except as provided above, 3M shall not be liable or responsible for any loss, damage, or liability, direct, indirect, incidental, special or consequential, arising out of the sale, use or misuse, of, or the inability to use products by the user.

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3M

*DEFINITION OF TERMS

1. DUSTS - Solid particles generated by handling, crushing, grinding, rapid impact, detonation, and decrepitation of organic or inorganic materials, such as rock, ore, metal, coal, wood, and grain. Dust may enter the air from various sources. It may be dispersed when a dusty material is handled, such as when lead oxide is dumped into a mixer or a product is dusted with talc. When solid materials are reduced to small sizes in processes such as grinding, crushing, blasting, shaking, and drilling, the mechanical action of the grinding or shaking device supplies a source of energy to disperse the dust formed.

2. FUMES - Solid particles generated by condensation from the gaseous state, generally after volatilization from molten metals. this physical change is often accompanied by a chemical reaction, such as oxidation.

3. SMOKE - Carbon or soot particles less than 0.1 m in size which result from the incomplete combustion or carbonaceous materials such as coal or oil. Smoke generally contains droplets as well as dry particles.

4. MISTS - Suspended liquid droplets generated by condensation from the gaseous to the liquid state or by breaking up a liquid into a dispersed state, such as by splashing, foaming, or atomizing. Mist is formed when a finely divided liquid is suspended in the atmosphere. Examples are the oil mist produced during cutting and grinding operations, acid mists from electroplating, acid or alkali mists from pickling operations, paint spray mist from spraying operations and the condensation of water vapor to form a fog or rain.

5. GASES - Normally formless fluids which occupy the space or enclosure and which can be changed to the liquid or solid state only by the combined effect of increased pressure and decreased temperature. Examples are welding gases internal combustion engine exhaust gases, and air.

6. VAPORS -The gaseous form of substances which are normally in the solid or liquid state (at room temperature and pressure). Evaporation is the process by which a liquid is changed into the vapor state and mixed with the surrounding atmosphere. Solvents with low boiling points will volatilize readily.

*Fundamentals of Industrial Hygiene, Edited by Julian B. Olishifski, P.E., and Frank E. McElroy, P.E., Copyright 1971-National Safety Council.

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Criteria Documents, U. S. Department of Health, Education and Welfare, Public Health Service, National Institute for Occupational Safety and Health, Division of Laboratories and Criteria Development, Cincinnati, Ohio 45202. Available from the Superintendent of Documents. Criteria Documents are available for a number of compounds including important solvents.

RESPIRATOR PROTECTION FACTORS[1]

TYPE RESPIRATOR	FACEPIECE[2] PRESSURE	PROTECTION FACTOR
I. AIR-PURIFYING		
A. PARTICULATE[3] REMOVING		
SINGLE-USE,[4] DUST[5]	-	5
QUARTER-MASK, DUST[6]	-	5
HALF-MASK, DUST[6]	-	10
HALF-OR QUARTER-MASK, FUME[7]	-	10
HALF-OR QUARTER-MASK, HIGH-EFFICIENCY[8]	-	10
FULL FACEPIECE, HIGH-EFFICIENCY	-	50
POWERED, HIGH-EFFICIENCY, ALL ENCLOSURES	+	1000
POWERED, DUST OR FUME, ALL ENCLOSURES	+	X[9]
B. GAS AND VAPOR-REMOVING[10]		
HALF-MASK	-	10
FULL FACEPIECE	-	50
II. ATMOSPHERE-SUPPLYING		
A. SUPPLIED-AIR		
DEMAND, HALF-MASK	-	10
DEMAND, FULL FACEPIECE	-	50
HOSE MASK WITHOUT BLOWER, FULL FACEPIECE	-	50
PRESSURE-DEMAND, HALF-MASK[11]	+	1000
PRESSURE-DEMAND, FULL FACEPIECE[12]	+	2000
HOSE MASK WITH BLOWER, FULL FACEPIECE	-	50
CONTINUOUS FLOW, HALF-MASK[11]	+	1000
CONTINUOUS FLOW, FULL FACEPIECE[12]	+	2000
CONTINUOUS FLOW, HOOD, HELMET, OR SUIT[13]	+	2000
B. SELF-CONTAINED BREATHING APPARATUS (SCBA)		
OPEN-CIRCUIT, DEMAND, FULL FACEPIECE	-	50
OPEN-CIRCUIT, PRESSURE-DEMAND FULL FACEPIECE	+	10,000[14]
CLOSED-CIRCUIT, OXYGEN TANK-TYPE, FULL FACEPIECE	-	50
III. COMBINATION RESPIRATOR		
A. ANY COMBINATION OF AIR-PURIFYING AND ATMOSPHERE-SUPPLYING RESPIRATOR.	USE MINIMUM PROTECTION FACTOR LISTED ABOVE FOR TYPE OF MODE OF OPERATION	
B. ANY COMBINATION OF SUPPLIED-AIR RESPIRATOR AND AN SCBA		

EXCEPTION: COMBINATION SUPPLIED-AIR RESPIRATORS, IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE, WITH AN AUXILIARY SELF-CONTAINED AIR SUPPLY, AND A FULL FACEPIECE, SHOULD USE THE PF FOR PRESSURE-DEMAND SCBA.

USE OF TABLE REQUIRES ACCOMPANYING FOOTNOTES.

COURTESY OF LAS ALAMOS SCIENTIFIC LABORATORIES

[1]THE OVERALL PROTECTION AFFORDED BY A GIVEN RESPIRATOR DESIGN (AND MODE OF OPERATION) MAY BE DEFINED IN TERMS OF ITS PROTECTION FACTOR (PF). THE PF IS A MEASURE OF THE DEGREE OF PROTECTION AFFORDED BY A RESPIRATOR, DEFINED AS THE RATIO OF THE CONCENTRATION OF CONTAMINANT IN THE AMBIENT ATMOSPHERE TO THAT INSIDE THE ENCLOSURE (USUALLY INSIDE THE FACEPIECE) UNDER CONDITIONS OF USE. RESPIRATORS SHOULD BE SELECTED SO THAT THE CONCENTRATION INHALED BY THE WEARER WILL NOT EXCEED THE APPROPRIATE LIMIT. THE RECOMMENDED RESPIRATOR PF'S ARE SELECTION AND USE GUIDES, AND SHOULD ONLY BE USED WHEN THE EMPLOYER HAS ESTABLISHED A MINIMAL ACCEPTABLE RESPIRATOR PROGRAM AS DEFINED IN SECTION 3 OF THE ANSI Z88.2-1969 STANDARD.

[2]IN ADDITION TO FACEPIECES, THIS INCLUDES ANY TYPE OF ENCLOSURE OR COVERING OF THE WEARER'S BREATHING ZONE, SUCH AS SUPPLIED-AIR HOODS HELMETS, OR SUITS.

[3]INCLUDES DUSTS, MISTS, AND FUMES ONLY. DOES NOT APPLY WHEN GASES OR VAPORS ARE ABSORBED ON PARTICULATES AND MAY BE VOLATILIZED OR FOR PARTICULATES VOLATILE AT ROOM TEMPERATURE. EXAMPLE: COKE OVEN EMISSIONS.

[4]ANY SINGLE-USE DUST RESPIRATOR (WITH OR WITHOUT VALVE) NOT SPECIFICALLY TESTED AGAINST A SPECIFIED CONTAMINANT.

[5]SINGLE-USE DUST RESPIRATORS HAVE BEEN TESTED AGAINST ASBESTOS AND COTTON DUST AND COULD BE ASSIGNED A PF OF 10 FOR THESE PARTICULATES.

[6]DUST FILTER REFERS TO A DUST RESPIRATOR APPROVED BY THE SILICA DUST TEST, AND INCLUDES ALL TYPES OF MEDIA, THAT IS, BOTH NONDEGRADABLE MECHANICAL TYPE MEDIA AND DEGRADABLE RESIN-IMPREGNATED WOOL FELT OR COMBINATION WOOL-SYNETHETIC FELT MEDIA.

[7]FUME FILTER REFERS TO A FUME RESPIRATOR APPROVED BY THE LEAD FUME TEST. ALL TYPES OF MEDIA ARE INCLUDED.

[8]HIGH-EFFICIENCY FILTER REFERS TO A HIGH-EFFICIENCY PARTICULATE RESPIRATOR. THE FILTER MUST BE AT LEAST 99.97% EFFICIENT AGAINST 0.3 μm DOP TO BE APPROVED.

[9]TO BE ASSIGNED, BASED ON DUST OR FUME FILTER EFFICIENCY FOR SPECIFIC CONTAMINANT.

[10]FOR GASES AND VAPORS, A PF SHOULD ONLY BE ASSIGNED WHEN PUBLISHED TEST DATA INDICATE THE CARTRIDGE OR CANISTER HAS ADEQUATE SORBENT EFFICIENCY AND SERVICE LIFE FOR A SPECIFIC GAS OR VAPOR. IN ADDITION, THE PF SHOULD NOT BE APPLIED IN GAS OR VAPOR CONCENTRATIONS THAT ARE: 1) IMMEDIATELY DANGEROUS TO LIFE, 2) ABOVE THE LOWER EXPLOSIVE LIMIT, AND 3) CAUSE EYE IRRITATION WHEN USING A HALF-MASK.

[11]A POSITIVE PRESSURE SUPPLIED-AIR RESPIRATOR EQUIPPED WITH A HALF-MASK FACEPIECE MAY NOT BE AS STABLE ON THE FACE AS A FULL FACEPIECE. THEREFORE, THE PF RECOMMENDED IS HALF THAT FOR A SIMILAR DEVICE EQUIPPED WITH A FULL FACEPIECE.

[12]A POSITIVE PRESSURE SUPPLIED-AIR RESPIRATOR EQUIPPED WITH A FULL FACEPIECE PROVIDES EYE PROTECTION BUT IS NOT APPROVED FOR USE IN ATMOSPHERES IMMEDIATELY DANGEROUS TO LIFE. IT IS RECOGNIZED THAT THE FACEPIECE LEAKAGE, WHEN A POSITIVE PRESSURE IS MAINTAINED, SHOULD BE THE SAME AS AN SCBA OPERATED IN THE POSITIVE PRESSURE MODE. HOWEVER, TO EMPHASIZE THAT IT BASICALLY IS NOT FOR EMERGENCY USE, THE PF IS LIMITED TO 2,000.

[13]THE DESIGN OF THE SUPPLIED-AIR HOOD, SUIT, OR HELMET (WITH A MINIMUM OF 6 CFM OF AIR) MAY DETERMINE ITS OVERALL EFFICIENCY AND PROTECTION. FOR EXAMPLE, WHEN WORKING WITH THE ARMS OVER THE HEAD, SOME HOODS DRAW THE CONTAMINANT INTO THE HOOD BREATHING ZONE. THIS MAY BE OVERCOME BY WEARING A SHORT HOOD UNDER A COAT OR OVERALLS. OTHER LIMITATIONS SPECIFIED BY THE APPROVAL AGENCY MUST BE CONSIDERED BEFORE USING IN CERTAIN TYPES OF ATMOSPHERE.

[14]THE SCBA OPERATED IN THE POSITIVE PRESSURE MODE HAS BEEN TESTED ON A SELECTED 31-MAN PANEL AND THE FACEPIECE LEAKAGE RECORDED AS LESS THAN 0.01% PENETRATION. THEREFORE, A PF OF 10,000+ IS RECOMMENDED. AT THIS TIME, THE LOWER LIMIT OF DETECTION 0.01% DOES NOT WARRANT LISTING A HIGHER NUMBER. A POSITIVE PRESSURE SCBA FOR AN UNKNOWN CONCENTRATION IS RECOMMENDED. THIS IS CONSISTENT WITH THE 10,000+ THAT IS LISTED. IT IS ESSENTIAL TO HAVE AN EMERGENCY DEVICE FOR USE IN UNKNOWN CONCENTRATIONS. A COMBINATION SUPPLIED-AIR RESPIRATOR IN PRESSURE-DEMAND OR OTHER POSITIVE PRESSURE MODE, WITH AUXILIARY SELF-CONTAINED AIR SUPPLY IS ALSO RECOMMENDED FOR USE IN UNKNOWN CONCENTRATIONS OF CONTAMINANTS IMMEDIATELY DANGEROUS TO LIFE. OTHER LIMITATIONS, SUCH AS SKIN ABSORPTION OF HCN OR TRITIUM, MUST BE CONSIDERED.

RDL → Part of SCP and is ∴ statement of policy @ this time - see. sect. IV H

JOINT NIOSH/OSHA STANDARDS COMPLETION PROGRAM

RESPIRATOR DECISION LOGIC

18 AUGUST 1975

I. INTRODUCTION

The purpose of the respirator decision logic is to assure technical accuracy and uniformity between substances in the selection of respirators and to provide necessary criteria to support this selection, the decision logic is a step-by-step elimination of inappropriate respirators until only those which are acceptable remain. Judgement by persons knowledgeable of inhalation hazards and respiratory protection equipment is essential to ensure appropriate selection of respirators.

The primary technical criteria for what constitutes a permissible respirator is based on the technical requirements of 30 CFR Part 11 (Department of the Interior, Bureau of Mines, Respiratory Protective Devices and Tests for Permissibility). The proposed substance health standards will allow only respirators approved by the Bureau of Mines (or Mining Enforcement and Safety Administration (MESA)) and NIOSH under 30 CFR 11.

Protection factors are criteria used in determining what limiting concentrations are to be permitted for each respirator type that will afford adequate protection to the wearer. The referenced subparts of 30 CFR 11 give technical descriptions concerning each type or class of respirators referenced in the decision logic. 30 CFR 11 should be use with the decision logic in order to properly understand the criteria for the specification of allowable respirators.

II. GENERAL DECISION LOGIC FLOW CHART

Step 1 - Assemble Information on Substance

Assemble necessary toxicological safety, and research information for the particular contaminant. Typically the following are required:

1. Permissible exposure limits specified in 29 CFR 1910.1000 (Tables Z-1, Z-2, and Z-3). These are the former 29 CFR 1910.93 Tables.

2. Warning properties if the substance is a gas or a vapor. Refer to part IV (8) of this logic.

3. Eye irritation potential of the substance. Refer to part IV (D) of this logic.

4. LFL (Lower Flammable Limit) for the substance. Refer to part IV (F) of this logic.

5. IDLH concentration for the substance. Refer to Part IV (E) of this logic.

6. Possibility of poor sorbent efficiency at IDLH concentration and below. Refer to part IV (C) of this logic.

7. Any evidence of possible systemic injury or death resulting from absorbance of the substance (as a gas or vapor) through the skin. Refer to part IV (A) of this logic.

8. The vapor pressure of the substance (and equivalent PPM).

Step 2 - Determine Physical State of Substance

Determine the physical state(s) of the substance as it is likely to be encountered in the occupational environment. It will be either:

A. Gas or vapor.
B. Particulate (dust, fume or mist), or
C. Combination of (A) and (B).

Step 3 - Assemble a Table of Permissible Respiratory Protection for Substance

This is done using the material from step 1 and the appropriate specific decision logic chart from part III of this logic and the respirator protection factors in Appendix I.

III. A. Specific Decision Logic Chart for Respiratory Protection Against Gases or Vapors

CONDITION	SELECTION SEQUENCE
Routine use	a. Consider skin sorption - (See IV A).
	b. Poor warning properties - eliminate all air purifying respirators (see IV B).
	c. Eye irritation - eliminate or restrict use of half mask respirator (see IV D).
	d. IDLH or LFL - above this concentration eliminate all but positive pressure self-contained breathing apparatus and combination positive pressure self-contained breathing apparatus (see IV E and F).
	e. List all allowed respirators by condition of use and type.

Entry and escape from unknown concentrations	Use positive pressure self-contained breathing apparatus or combination positive pressure supplied air respirator with positive pressure self-contained breathing apparatus.
Firefighting	Use positive pressure self-contained breathing apparatus.
Escape	Gas mask or escape self-contained breathing apparatus (see IV C).

III. B. Specific Decision Logic Chart for Respiratory Protection Against Particulates

CONDITION	SELECTION SEQUENCE
Routine use	a. Consider skin sorption - (see IV A), b. Eye irritation - eliminate or restrict use of half mask respirator (see IV D), c. Systemic poison - eliminate single-use respirator, d. For permissible exposure less than 0.05 MG/CU,M, - eliminate DFM respirators except with high efficiency particulate filter, e. IDLH or LFL - above this concentration eliminate all but positive pressure self-contained breathing apparatus and combination positive pressure self-contained breathing apparatus (see IV E), f. List all allowed respirators by condition of use and type.
Entry and escape from unknown concentration	Use positive pressure self-contained breathing apparatus or combination positive pressure supplied air respirator with positive pressure self-contained breathing apparatus,
Firefighting	Use positive pressure self-contained breathing apparatus (see IV F).

III. C. Specific Decision Logic Chart For Respiratory Protection Against Combination of Gas or Vapor and Particulates

CONDITION	SELECTION SEQUENCE
Routine use	a. Consider skin sorption - (see IV A), b. Poor warning properties or inadequate sorbent efficiency - eliminate all air purifying respirators (see IV B & C), c. Eliminate all respirators except with combination sorbent/particulate filter, d. Eye irritation - eliminate or restrict use of half mask respirator (see IV D), e. For permissible exposures less than 0.05 MG/CU, M, - eliminate all respirators except with sorbent/high efficiency particulate filter, f. IDLH or LFL - above this concentration eliminate all but positive pressure self-contained breathing apparatus and combination positive pressure self-contained breathing apparatus (see IV E), g. List all allowed respirators by condition of use and type,
Entry and escape from unknown concentration	Use positive pressure self-contained breathing apparatus or combination positive pressure supplied air respirator with positive pressure self-contained breathing apparatus,
Firefighting	Use positive pressure self-contained breathing apparatus (see IV F),
Escape	Gas mask or escape self-contained breathing apparatus (see IV C).

IV. A. Skin Absorption

Personal protection requirements for protection against exposure to substances which may cause injury by absorption through the skin from materials splashed or spilled on the skin are covered in section (F) of each substance standard. Respirator selection criteria are based primarily on the inhalation hazard of the substance. A supplied-air suit may provide both skin and respiratory protection for extremely toxic substances which may be absorbed through the skin.

Supplied-air suits are not covered in 30 CFR 11. Data are not available upon which to make recommendations for supplied-air-suits for all types of exposures.

Where information is available indicating systemic injury or death resulting from absorbance of a gas or vapor through the skin, the following statement is included in Appendix B, Section (V) of the substance standard:

> "Use of supplied-air suits or other impervious coverings may be necessary to prevent skin contact with * when the concentration of * is unknown or greater than ** (IDLH). Supplied-air suits should be selected, used, and maintained under the immediate supervision of persons knowledgeable in the limitations and potential life endangering characteristics of supplied-air suits."
>
> A sentence is added to the respirator table in the entry and escape from unknown concentrations section as shown below:
>
> Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand mode or other positive pressure mode. (Supplied-air suits may be necessary.)

IV. B. Poor Warning Properties

It is important to realize that 30 CFR 11 NIOSH/MESA approvals for air-purifying (organic vapor) devices prohibit use against organic vapors with poor warning properties. Specifically, 30 CFR 11.90 (B) (Note 4) covers gas masks (canister respirators) and 30 CFR 11.150 (note 7) covers chemical cartridge respirators. Thus these approvals are only for those organic vapors with adequate warning properties and not all organic vapors.

Warning properties relying upon human senses are not foolproof. However, they provide some indication to the employee of possible sorbent exhaustion or of poor facepiece fit or other respirator malfunction. Warning properties include odor, eye irritation, and respiratory irritation.

Adequate warning properties can be assumed when the substance odor, taste, or irritation effects are detectable and persistent at concentrations "at" or "below" the permissible exposure limit.

If the odor or irritation threshold of a substance is many times greater than the permissible exposure limit, this substance should be considered to have poor warning properties. If the substance odor or irritation threshold is somewhat above the permissible exposure limit (not in excess of three times the limit) and there is no ceiling limit, consideration is given as to whether or not undetected exposure in this concentration range could cause serious or irreversible health effects. If not, the substance is considered to have adequate warning properties.

It is expected that environmental concentrations will vary considerably and, therefore, warning of a respirator failure would soon be perceived at contaminant concentrations somewhat above the permissible exposure limit.

IV. C. Sorbent Efficiencies

Where supporting evidence exists on immediate (less than three minutes) breakthrough time at the IDLH concentration and below for a cartridge or canister sorbent. Air-purifying devices shall not be allowed for any use, escape or otherwise.

IV. D. Eye Irritation

For routine work operations, any perceptible eye irritation is considered unacceptable. Therefore, only full facepiece respirators are permissible in contaminant concentrations which produce eye irritation. Note that 30 CFR 11.90 (B) (Note 6) specifies that eye protection may be required in certain concentrations of acid gases and organic vapors. For escape, some eye irritation is permissible if it is determined that such irritation would not inhibit escape and such irritation is reversible.

Where quantitative eye irritation data cannot be found in literature references, and theoretical considerations indicate the substance should not be an eye irritant, half facepiece respirators are allowed.

IV. E. IDLH

The definition of IDLH provided in 30 CFR 11.3 (T) is as follows:

> "Immediately dangerous to life or health" means conditions that pose an immediate threat to life or health or conditions that pose an immediate threat of severe exposure to contaminants, such as radioactive materials, which are likely to have adverse cumulative or delayed effects on health.

The purpose of establishing an IDLH exposure concentration is to insure that the worker can escape without injury or irreversible health effects from an IDLH concentration in the event of failure of the respiratory protective equipment. The IDLH is considered a maximum concentration above which only highly reliable breathing apparatus providing maximum worker protection is permitted. Since IDLH values are conservatively set, any approved respirator may be used up to its maximum use concentration below the IDLH.

In establishing the IDLH concentration the following factors are considered:

1. Escape without loss of life or irreversible health effects. Thirty minutes is considered the maximum permissible exposure time for escape.

2. Severe eye or respiratory irritation or other reactions which would inhibit escape without injury.

IDLH should be determined from the following sources:

1. Specific IDLH provided in the literature such as the AIHA hygienic guides.

2. Human exposure data.

3. Acute animal exposure data.

4. Where such data are lacking toxicological data from analogous substances, and chronic animal exposure data may be considered.

The following guidelines should be used to interpret toxicological data reported in the literature for animal species:

1. Where acute exposure animal data are available (30 minutes to 4-hour exposures), the lowest exposure concentration causing death or irreversible health effects in any species is determined to be the IDLH concentration.

2. Where only chronic exposure data are available and these data do not reveal any exposure concentration which would result in irreversible health effects, then these data have no relevance and should not be used in determining the IDLH concentration.

Where there is evidence of an IDLH concentration above that allowed on the basis of a protection factor, respirators should be selected on the basis of the protection factor afforded by each device within the limitations of the device.

IV. F. Lower Flammable Limit and Firefighting

Contaminant concentrations in excess of the LFL are considered to be immediately dangerous to life or health, at or above the LFL, the use of respirators is limited to those devices which provide the maximum protection, i.e., positive-pressure SCBA, and combination positive-pressure supplied-air respirator with positive pressure SCBA.

Firefighting is defined by ANSI Z88,5-1971 as being immediately dangerous to life. For firefighting, the only device providing adequate protection is the positive pressure self-contained breathing apparatus.

IV. G. Protection Factors

Protection factors are a measure of the overall effectiveness of a respirator. Filtering efficiency is a part of the protection factor and becomes a significant consideration for less efficient air purifying respirators.

The protection factors used in the preparation of the standards are based on quantitative fit tests performed at Los Alamos and elsewhere, and in some instances on professional judgment. In Appendix I, the protection factors for each class of respirators listed in the checklists

are shown. The entries in each list are for an entire class of respirators, and are assigned the protection factor of the lowest performing device within each class.

IV. H. Variations with 30 CFR 11

1. The type A supplied-air respirator is allowed in 30 CFR 11 for use in immediately dangerous to life and health atmospheres. However, air supply requirements of 50 L/Min. is insufficient to maintain a positive pressure in the facepiece under all working conditions. Therefore, this device should have the same protection factor as applied to other air-purifying and atmosphere supplying respirators having a negative pressure in the facepiece (see Appendix I). 30 CFR 11 will require a revision to eliminate approval of type A for IDLH atmospheres.

2. An amendment to 30 CFR 11 is being processed which will delete use of gas masks for entry and use in IDLH atmospheres. Therefore, in this decision logic gas masks are not allowed in concentrations greater than the IDLH or entry and escape from unknown concentrations.

3. In the same amendment described above, maximum use concentrations (MUC) for gas masks are being deleted. This decision logic is consistent with this amendment. However, canisters approved prior to this amendment will have the MUC specified on the label which will be inconsistent with the substance standards for most substances.

4. 30 CFR 11 does not contain protection factor requirements. Protection factors are used in the decision logic. An amendment to 30 CFR 11 is planned to include protection factor requirements for DFM respirators. Future amendments are comtemplated for other types of respirators.

5. 30 CFR 11 does not permit the use of an escape gas mask against acid gases or organic vapors with poor warning properties. A change to 30 CFR 11 is necessary to permit the use of an escape gas mask against substances with poor warning properties.

IV. I. Escape

Where escape respirators are provided they shall be selected from the escape category in Table 2. The employer shall provide and ensure employees carry an escape respirator where exposure may occur to extremely toxic substances (an extremely toxic substance is defined as a gas or vapor having a rat exposure mortality LC50 of less than 10 PPM.

The following statement is added to the introduction to the respirator table for these substances:

> Employers shall provide each employee working in areas where **name** may be released into the workplace air with an approved escape respirator as specified in Table 2. The employer shall ensure that each employee carry the escape respirator in the area where **name** may be released into the workplace.

IV. J. "Entry Into Tanks or Closed Vessels, or . . ."

Item (D) (4) (IV) is a variable provision in the introductory statements to the respirator tables which lists the specific operations where a respirator is considered to be an acceptable means of control. Examples of where this may occur are for operations which require occassional entry into tanks or other closed vessels.

APPENDIX I

A. Protection Factors for Particulate Filter Respirators

Protection Factor (minimal)	Permissible respiratory protection.
5x	Any dust and mist respirator (30 CFR 11.130)
5x	Any dust and mist respirator, except single use (30 CFR 11.130).
10x	Any dust and mist respirator, except single-use or quarter-mask respirator (30 CFR 11.130).
10x	Any fume respirator or high efficiency particulate filter respirator (30 CFR 11.130).
10x	Any high efficiency particulate filter respirator (30 CFR 11.130).
50x	A high efficiency particulate filter respirator with a full facepiece (30 CFR 11.130).
1000x	A powered air-purifying respirator with a high efficiency particulate filter (30 CFR 11.130).

B. Protection Factors for Chemical Cartridges and Gas Masks

Protection Factor (minimal)	Permissible respiratory protection
10x	Any chemical cartridge respirator with an ** name** cartridge(s) (30 CFR 11.150).
50x	A chemical cartridge respirator with full facepiece and **name** cartridge(s) (30 CFR 11.150).

50x	A gas mask with a chin-style **name** canister (30 CFR 11.90 (A)).
50x	A gas mask with a front or back-mounted **name** canister (30 CFR 11.90 (A)).
1000x	A powered air-purifying chemical cartridge respirator with a **name** cartridge (unlisted device).
Escape	Any gas mask providing protection against **name** vapors (30 CFR 11.90).

NOTE: The approval **name** may consist of acid gases or organic vapors as a class or specific acid gases, ammonia, or organic vapors. It may also consist of combinations of acid gases, organic vapors, and other gases and vapors.

C. Protection Factors for Combination Chemical Cartridges and Particulate Filters and Gas Masks and Particulate Filters

Protection Factors (minimal)	Permissible respiratory protection.
10x	Any chemical cartridge respirator with **name** cartridge(s) and **name** filter(s) (30 CFR 11.150 and 11.130).
50x	A chemical cartridge respirator with a full facepiece, **name** cartridge(s), and **type** filter (30 CFR 11.90 (A) and 11.130).
50x	A gas mask with a chin-style **name** canister and **type** filter (30 CFR 11.90 (A) and 11.130).
50x	A gas mask with a front or back mounted **name** canister and **type** filter (30 CFR 11.90 (A) and 11.130).
1000x	A powered air purifying chemical cartridge respirator with a **name** cartridge and high efficiency particulate filter.
Escape	Any gas mask providing protection against **name** and particulates (30 CFR 11.90 and 11.130).

name refers to any acid gas, akaline gas, organic vapor, or other specific gas or vapor.
type refers to dust and mist, fume, or high efficiency particulate.

D. Protection Factors for Supplied-Air Respirators

Protection Factor (minimal)	Permissible Respiratory protection.
10x	Any supplied air-respirator (30 CFR 11.110 (A)).
50x	Any supplied-air respirator with a full facepiece, helmet, or hood. (30 CFR 11.110 (A)).
1000x	*A type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous flow mode (30 CFR 11.110 (A)).
2000x	A type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, hood, or helmet operated in continuous flow mode (30 CFR 11.110 (A)).

*This category is not fully covered by preceding category.

E. Protection Factors for Self-Contained Breathing Apparatus

Protection Factor (minimal)	Permissible respiratory protection
10x	Any self-contained breathing apparatus (30 CFR 11.70 (A)).
50x	Any self-contained breathing apparatus with a full facepiece (30 CFR 11.70 (A)).
10,000+x or fire-fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode (30 CFR 11.70 (A)).
10,000+x	A combination respirator which includes a type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or positive pressure mode (30 CFR 11.70 (B)).
Escape	Any escape self-contained breathing apparatus (30 CFR 11.70 (A)).