Respiratory Protection

Objectives

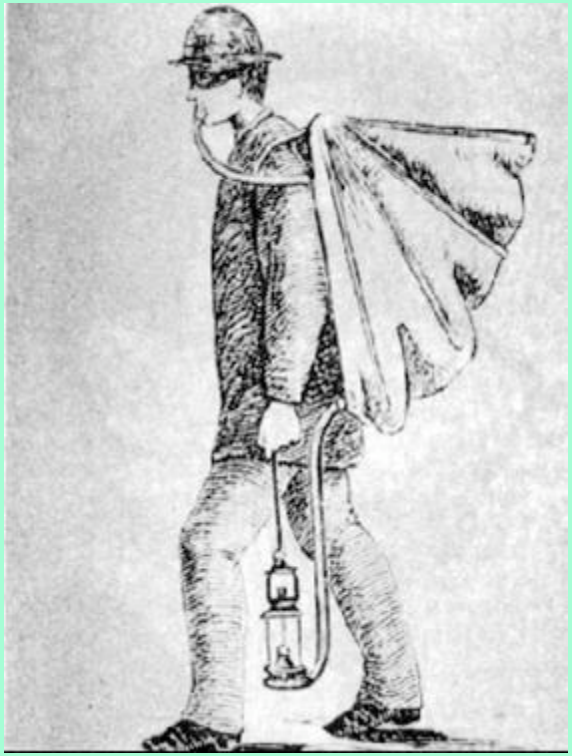
- **Principles of respiratory protection**
  - **History**
  - **Role**
  - **Regulations and guidance**
  - **Equipment**
  - **Fit Testing**
  - **Selection and use**
  - **Programs (WA State)**

History

- **Animal bladders used in Roman mines**
- **Atmosphere-supplying devices in 1700's**
- **Activated charcoal discovered (1854)**
- **World War I “Gas Masks”**

Atmosphere-Supplying Respirators

- **Atmosphere-supplying respirator technology was well developed by the 1700's**



Tyndall and Shaw “Smoke Cap”

Figure 2-2.
Tyndall and Shaw "smoke cap."

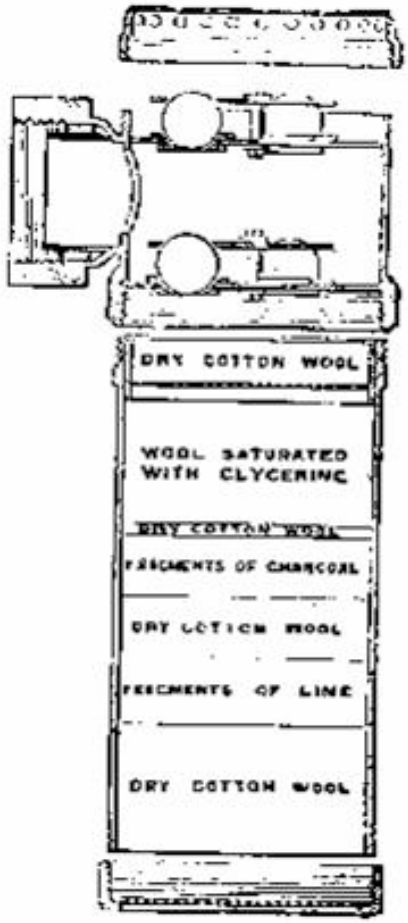


Figure 2-3.
Tyndall and Shaw smoke cap filter

Respiratory protection

OSHA's general policy on respirator use:

- **Where engineering or administrative controls are not feasible or insufficient**
- **During the time when engineering or administrative controls are being implemented**
- **For emergency response situations**

Role in Exposure Control

- **"Hierarchy of Controls"**
  - **PPE is the least desirable method of control**
- **Respirator use involves risk**
  - **Medical use determinations**
- **Administrative procedures**
  - **Written program**
  - **Qualified "program administrator"**
- **Many Limitations of respirators**
  - **Monitoring contaminant levels**
  - **Fit testing**
  - **Cost**
  - **Can leak, wear out, or be the wrong kind**
  - **Can be hot, uncomfortable and make it hard to see or talk**
  - **Can be hard to breathe through**
  - **They are easily removed in contaminated air**

When Are Respirators Needed?

- In an oxygen-deficient atmosphere
- When "Permissible Exposure Limits" are exceeded
- When required by a pesticide label
- When needed for infection control
- When required by company policy

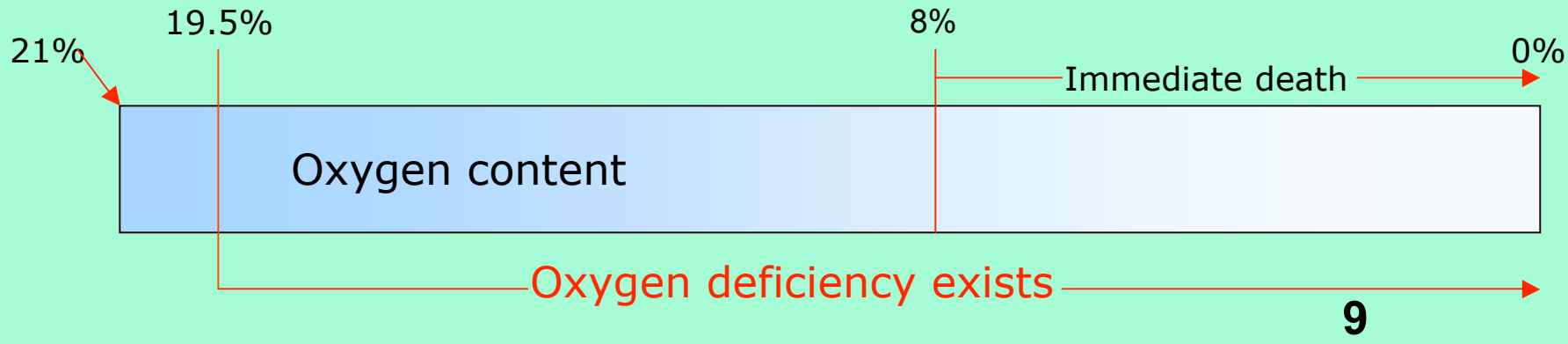
Normally, an oxygen deficiency will only be found in a confined space or a major chemical spill.
There are only a few pesticides that have label requirements for respirators.
Some employers require their employees to wear respirators as a safety precaution even though they may not be required due to a PEL

Oxygen Deficiency

Oxygen deficiency can occur in confined or enclosed spaces, during fires or large chemical releases.

Normal air contains 21% oxygen. An area with oxygen content below 19.5 % is considered "oxygen deficient".

Only a supplied air respirator can protect against the effects of oxygen deficiency.



Regulations and Guidance

- **OSHA**
  - **29 CFR 1910.134, 1974, 1998**
- **NIOSH**
  - **1976, 1987 "Guide to Industrial Respiratory Protection"**
  - **1987 "Respirator Decision Logic"**
  - **1995 "42 CFR 84"**
- **WISHA**
  - **WAC 296-842**
- **ANSI STANDARDS**
  - **Z88.2-1969, 1980, 1992 (Respiratory Protection)**

OSHA's Respiratory Protection Program

1. Written program
2. Selection base on hazards involved
3. Operator training
4. Reserved (?)
5. Cleaning and disinfection of respirators
6. Storage of respirators
7. Inspection and maintenance of respirators
8. Surveillance of worker exposures
9. Regular evaluation of respirator program
10. Medical evaluation of respirator users
11. Use of approved respirators

Updated regulations

- NIOSH changes to respirator equipment approvals
- Substance specific standards sometimes contain unique requirements
- OSHA finalized new 1910.134 standard in 98
  - Consolidates other standards' requirements
  - Assigned Protection Factors (APF) in 2003/04
  - Some changes in medical qualifications (screening)
  - Fit testing (Quant) required for all tight-fitting respirators
  - Cartridge change out to be based on objective data
  - Respirator administrator required
  - TB respirators consolidated in 2003

OSHA Proposes Revised Respiratory Protection Standards

- The Occupational Safety and Health Administration published two proposed rules in the June 6 Federal Register to enhance worker protections from respiratory hazards on the job. OSHA is seeking comments until Sept. 4, 2003, on its proposals to amend the Respiratory Protection Standard to include a new fit testing procedure and incorporate new Assigned Protection Factors (APFs) for respiratory protection programs. The proposed rules are expected to prevent approximately 4,000 injuries and illnesses and prevent about 900 deaths annually from cancer and other chronic diseases.
- In a notice of proposed rulemaking, OSHA proposes to amend the existing Respiratory Protection Standard in order to incorporate Assigned Protection Factors (APFs) as part of a complete respiratory protection program to assist workers and employers in the proper selection of respirators. APFs are numbers that reflect the workplace level of respiratory protection that respirators are expected to provide to employees
- http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER&p_id=13749

OSHA Respirator Standard

- Use engineering controls where feasible
- Employer supplies respirators and establishes a program
- Program must be written with work-site specific procedures and elements for required respirator use
- Program must have an administrator
- Medical evaluations
- Fit testing for tight-fitting respirators

OSHA Respirator Standard

- New procedures where respirator is worn voluntarily (program still required)
- Appropriate selection of respirators - NIOSH certification and within certification limits
- Evaluate exposures - assume IDLH if unable to evaluate
- Selection to include sufficient number…to get a good fit
- Change-out of cartridges – End of Service Life or "objective data"

OSHA Respirator Standard

Medical evaluations:

- **By a “Physician or other licensed health care professional" (PLHCP)**
- **Screening questionnaire**
- **Follow-up examination if any positive answers**
- **Supply PLHCP with respirator info, work conditions, other PPE, duration and frequency or respirator use, copy of written program and OSHA standard**
- **Must supply PAPR if negative pressure respirator is unacceptable**

OSHA Respirator Standard

Additional Medical evaluations required when:

- **Report of related medical signs or symptoms**
- **PLHCP, supervisor or program administrator informs the employer that a reevaluation is needed**
- **Information from program, fit-testing suggest need for reevaluation**
- **Change in workplace increases physiological burden on worker**

OSHA Respirator Standard

Fit testing:

- **Qualitative or quantitative methods used for tight-fitting respirators**
- **Must be re-fitted when respirator changed *and* annually**
- **Qualitative can only be used with fit factors of 100 or less; quantitative required when FF > 100**
- **Must use methods in Appendix A**
- **Atmosphere-supplying respirator must be tested when in negative pressure mode**

OSHA Respirator Standard

Other things …

- No facial hair that can interfere with seal
- User seal test
- Cannot base cartridge change-outs on odor, smell or taste
- Seal check whenever donning respirator
- In IDLH areas, must have standby outside equipped and trained for rescuing
- Structural firefighting: 2 in and 2 out (buddy)

Specific Respiratory Protection Stds.

Abrasive Blasting WAC 296-24-67515
Acrylonitrile WAC 296-62-07336 see section (8)
Agriculture WAC 296-307-11010 , WAC 296-307-13045 see section (3)(l)
Anhydrous Ammonia WAC 296-24-51009 see section (10)
Arsenic (inorganic) WAC 296-62-07347 see section (8)
Asbestos WAC 296-62-07715
Benzene WAC 296-62-07523 see section (7)
Beryllium (welding) WAC 296-24-71515
Butadiene WAC 296-62-07460 see section (8)
Cadmium (construction) WAC 296-155-174 see section (7)
Cadmium (general industry) WAC 296-62-07413
Cadmium (welding, general industry) WAC 296-24-71517
Carcinogens (general) WAC 296-62-07306
Coke Ovens WAC 296-62-20011
Concrete Finishing WAC 296-155-683 see section (4)
Cotton Dust WAC 296-62-14533 see section (6)
DBCP WAC 296-62-07342 see section (8)
Emergency Response WAC 296-824
Ethylene Oxide WAC 296-62-07367
Fire Brigades WAC 296-24-58515
Fire Fighters WAC 296-305-04001 , WAC 296-305-02501 see section (15) , WAC 296-305- 03001 , WAC 396-305-05001 , WAC 296-305-05003
Formaldehyde WAC 296-62-07540 see section (7)
Hazardous Waste Operations WAC 296-62-30220 , WAC 296-62-3170
Lead (construction) WAC 296-155-17613
Lead (general industry) WAC 296-62-07521 see section (7)
Mercury (welding) WAC 296-24-71519
Methylene Chloride WAC 296-62-07470 see section (7)
Methylenedianiline (construction) WAC 296-155-17317
Methylenedianiline (general industry) WAC 296-62-07615
Preservative Coatings (welding) WAC 296-24-722 see section (3)(a)
Thiram WAC 296-62-07519 see sections (3)(c)(vi) & (x)
Tunnels & Shafts WAC 296-155-730 see section (7)
Vinyl Chloride WAC 296-62-07329 see section (7)

This is a list of the most frequently used standards with respiratory protection requirements, but it's not a complete list for all WISHA standards. While these requirements are viewed as being "supplemental" to the requirements specified in the main respiratory protection standard, WAC 296-62 Part E, they may, at times, preempt some of the requirements in the main standard if noted.

Respirator Equipment

Types of Respirators

Air-purifying respirators – filters air through cartridges or filtering facepieces (dust masks)

Powered air-purifying respirators – PARP filters air through cartridges with assistance of a blower.

Airline respirators – provides unlimited clean air from a compressor.

Self-contained breathing apparatus (SCBA) – provides 30- 60 minutes of clean air from a tank.

Escape respirators – provides air for escape only from a small bottle.

Respirator Terminology

- **Respiratory inlet covering**
- **Pressure relative to atmosphere**
- **Mode of operation**

Respiratory Inlet Covering

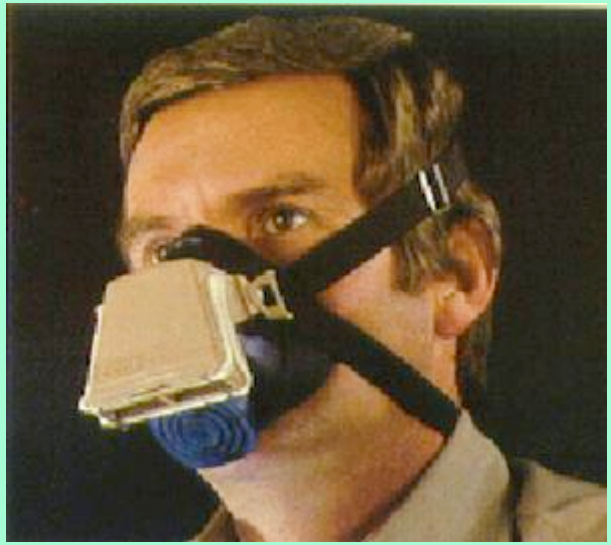
- **Definition**
  - **That portion of a respirator that forms the protective barrier between the user's respiratory tract and an air-purifying device or breathing air source, or both**
  - **ANSI Z88.2-1992**
  - **OSHA 1910.134 (1998)**

Respiratory Inlet Covering

- **Mouthpiece**
  - **Used to escape from a contaminated atmosphere**
  - **Noseclamps prevent inhaling through nostrils**
  - **Acid-gas mouthpiece "escape" respirators (APR)**
  - **"Self rescuer" APR**
    - » **CO catalyst "Hopcalite"**
    - » **Used to escape from mines**
  - **Self-Contained Self Rescuer (SCSR)**
    - » **KO_2 absorbs CO_2 and releases O_2**

Respiratory Inlet Covering

- **Quarter-Face**
  - **Extend bridge of nose to front of chin**
  - **Popular in mining industry**
  - **Replaceable filter element**



Respiratory Inlet Covering

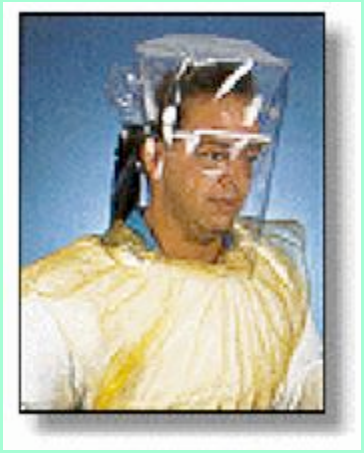
- **Half-Face**
  - **Bridge of nose to bottom of chin**
  - **Variety of sizes**
  - **Usually negative-pressure APR**
  - **Filtering facepiece**
    - » **Avoid using non-NIOSH approved dust masks**

Respiratory Inlet Covering

- **Full Facepiece**
  - **Better "fit" (and protection)**
  - **Variety of sizes**
  - **Eye protection**
  - **Eyeglasses?**
  - **"Dead Air" issues**
    - » **"Nosecup" recommended**

Respiratory Inlet Covering

- **Hood/Helmet**
  - **“Loose fitting”**
  - **Welding**
  - **Abrasive Blasting “Type CE”**



Operating Pressure

- **Negative pressure**
  - **Pressure drops below atmosphere when user inhales**
  - **Less protective due to facepiece leaks**
- **Positive pressure**
  - **Pressure above atmosphere**
- **Pressure Demand**
  - **Elevated pressure at all times**
  - **Most protective - suitable for IDLH**

Mode of Operation

- **Air-Purifying Respirators (APRs)**
  - Contaminants removed from the air
    - » Filters for removing particulates
    - » Cartridges for removing gases or vapors - may have filters, too
    - » Canisters (used with "gas masks" -- large capacity)
    - » Oxygen must be > 19.5%
  - Limited protection
- **Atmosphere-supplying respirators**
  - Not limited by type of atmospheric hazard
  - Suitable for oxygen deficiency or IDLH
  - SCBA's
  - Air line respirators (Type C or CE)
  - Combinations of SCBA's and SAR's

Air Purifying Respirators

- **Respirator Types**
  - **Negative pressure**
    - » **Mouthpiece**
    - » **Quarter-, half-, full-facepiece**
  - **Positive pressure**
    - » **Powered Air Purifying Respirator (PAPR)**
    - » **Less physiological stress,**
    - » **Specified in many OSHA standards**
    - » **Tight- or loose-fitting models**
  - **Specialty respirators**
    - » **Escape (mouthpiece, “gas mask”)**
    - » **Welding**

Some types of Air-purifying Respirators

Filtering facepiece (dust mask)

Half-face cartridge respirator

Full-face cartridge respirator

Powered air-purifying respirator

Aerosol removing respirators

Filters can remove dusts, mists, fumes, others

Cannot protect against gases, vapors, or low O^2

Removal mechanisms:

- **interception**
- **sedimentation**
- **impaction**
- **diffusion**
- **electrostatic attraction**

Nine filter types

- 3 levels of filter efficiency:
  - 95% (called “95”)
  - 99% (called “99”)
  - 99.97% (called “100”)
- 3 categories of resistance to filter efficiency degradation:
  - N (*N*ot resistant to oil)
  - R (*R*esistant to oil)
  - P (oil *P*roof)

Selection of N, R, and P-series filters

- If no oil particles are present in the work environment, use a filter of any series.
- If oil particles are present, use an R- or P-series filter.
- If oil particles are present and the filter is to be used for more than one work shift, use only a P-series filter.
- Selection of filter efficiency depends on how much filter leakage can be accepted.
- Choice of face piece depends on level of protection needed (APF).

Gas and vapor removing respirators

- Use sorbents
- Housed in cartridges or canisters
- Removal mechanisms:
  - adsorption
  - absorption
  - chemisorption
  - catalysis
- Designed for specific contaminants or classes

Gas and vapor removing cartridges

Organic vapor cartridges:

- **currently tested with CCl_4 at 1000 ppm (only)**
- **may or *may not* be very effective for specific vapors**
- **seek guidance from respirator manufacturer including test data on vapor in use**
- **only small amount of charcoal in cartridges**
- **more charcoal in canisters**
- **color code: black**

Service life of cartridges or canisters

Depends on:

- **quality and amount of sorbent**
- **packing uniformity and density**
- **exposure conditions, breathing rate**
- **relative humidity**
- **temperature**
- **contaminant concentration**
- **affinity of the gas or vapor for the sorbent**
- **presence of other gases and vapors**

Acid gas respirators

- Designed for removing acidic gases
- Tested by NIOSH against chlorine, HCl and SO_2 (only)
- Limited to fairly low concentrations
  - Chlorine 10 ppm
  - Hydrogen chloride 50 ppm
  - Sulfur dioxide 50 ppm
- Color code: white

Alkaline gas cartridges

- Contains chemicals for removing alkaline gases such as:
  - ammonia
  - methylamine
- Concentrations limited
  - ammonia 300 ppm
  - methylamine 100 ppm
- Color code: green

Air-purifying respirators additional information

- **Replace cartridges:**
  - **NIOSH: daily or after each use, or even more often if odor, taste, or irritation**
  - **some canisters may have end of service life indicators**
- **Other cartridges available:**
  - **pesticides**
  - **carbon monoxide**
  - **ethylene oxide**
  - **formaldehyde**
  - **hydrogen fluoride**
  - **hydrogen sulfide**
  - **mercury**
  - **phosphine**
  - **vinyl chloride**

Colors for AP elements

• Acid gas	white
• Organic vapors	black
• Ammonia gas	green
• Carbon monoxide	blue
• Acid gases and organic vapors	yellow
• Acid gas, ammonia, and OV	brown
• Acid gas, ammonia, CO, and OV	red
• Other vapors and gases	olive
• Radioactive materials (HEPA)	purple *
• Dusts, fumes, mists (non-radio)	orange *

"Adequate warning properties"

NIOSH permits air purifying respirators only if the contaminant has adequate warning properties:

- ***reliable*** **detection of the contaminant below the PEL by user's sense of smell, taste, or irritation**
- **only applies to gases and vapors -- not particulate**
- **Exception is if AP element has an ESLI.**
- **Remember that odor thresholds vary substantially from one individual to another**

OSHA: respirator cartridge *changeout* based on odors or taste unacceptable (new standard)

Atmosphere-supplying respirators

- **Self-contained breathing apparatus (SCBA)**
- **Supplied Air Respirators or Air-line (called “Type C” or “Type CE”)**
  - **hose can be up to 300 feet**
  - **4 cfm required for tight-fitting mask, 6 cfm for hoods and helmets**
  - **available in demand, pressure demand, and continuous flow arrangements**
- **Combination SCBA and SAR**

Must be supplied with Grade D breathing air, usually from bottles or compressors

Atmosphere-Supplying Respirators

- **Self-Contained Breathing Apparatus (SCBA)**
  - **Pressure-demand, open circuit**
    - » **30 to 60 minute duration**
    - » **2216 or 4500 PSI**
  - **Demand (virtually obsolete)**
  - **Closed circuit "rebreather"**
    - » **Up to 4 hours duration**
    - » **Used for mine rescue, etc.**
    - » **O_2 from cylinder or generator**
    - » **CO_2 is absorbed**

Self-contained breathing apparatus (2)

- Open-circuit type
  - bottled air from 2000 to 4500 psi typically
  - time from 15 min to 60 min typically
  - demand or pressure demand or continuous flow
  - can be combined with supplied air respirator
  - escape-only type available in 5, 7, 10 or 15 minute size
- Closed-circuit type (also called re-breathers)
  - could be either negative or positive pressure type
  - possible to “over breathe”
  - more complicated to maintain
  - requires more training
  - longer use period ... sometimes up to 4 hours

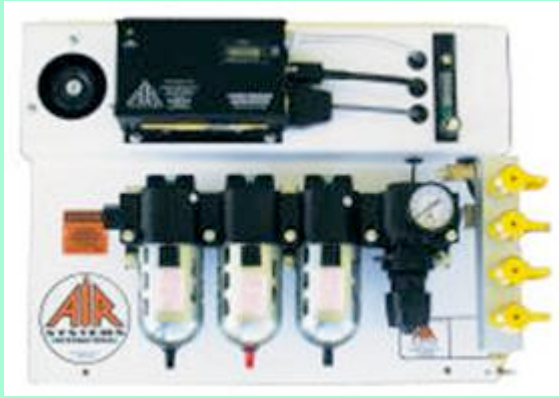
Atmosphere-Supplying Respirators

- **Supplied Air Respirators (SAR)**
  - **Also known as "airline" respirators or "Type C"**
  - **Supplied with compressed air**
    - » **4-6 CFM**
  - **Pressure of operation**
    - » **Pressure demand**
    - » **Demand**
    - » **Continuous flow**
  - **Combination**
    - » **APR**
    - » **SCBA (for IDLH)**

Atmosphere-Supplying Respirators

- **Air Quality “Grade D” minimum (1910.134)**

- **Compressor provisions for air quality**
  - **air intake location**
  - **dew point 10 F below ambient**
  - **sorbent bed and filters maintained**
  - **CO and/or high temperature alarm**
  - **incompatible fittings**



- **Cylinders maintained and tested**
  - **“Certificate of analysis", cylinders marked**
  - **-50 F dewpoint**

Grade D Specifications

CGA G-7.1 Grade "D" (Compressed Gas Association)	
Oxygen	**19.5 - 23.5%**
Carbon Dioxide	**1,000 ppm**
Carbon Monoxide	**10 ppm**
Oil Mist	**5 mg/m_**
Odor	**“no pronounced odor”**

Sources of breathing air

- **Compressors**
  - Subject to failure
  - If oil-lubricated, can overheat changing oil mist into CO
  - Carbon vane type are available and oil-less
  - Can run continuously
  - Can be fitted with CO sensor and/or adsorption units
  - Air intake location is critical
- **Compressed gas cylinders (breathing air)**
  - Can be up to 3500 psi
  - Finite air supply...for limited time spans
  - Do not rely on utility services

Protection Factors

- **BREAK!**

Protection Factors

- **protection factor: $PF = C_o/C_i$**
  - **O for outside the mask, I for inside the mask**
- **Penetration efficiency is inversely related:**
  - Used to average PF values

$$P_e = \frac{1}{PF}$$

- **Fit factor is the PF observed during a quantitative fit test (usually only 5 to 10 min)**
- **Workplace protection factor (WPF)**
  - **time up to 8 hours**
  - **the C_i value is the average contaminant value inside the respirator**

Protection Factors

- **"Protection factors" are related to the amount of contaminant that gets into a respirator**
  - **Generic PF = Conc. outside / conc. inside**
- **Assigned Protection Factor (APF)**
  - **Minimum anticipated protection for a specific type**
  - **Used to established respirator safe use limits**
  - **Recommended by OSHA, 2003 (not addressed by 1910.134 in 1998)**
  - **Established by NIOSH, ANSI**
- **Assigned protection factor APF (also called hazard ratio)**

$$\text{Assigned Protection Factor (APF)} \left[\text{Expected } \frac{C_o}{C_i} \right]$$

$$APF \geq \frac{C_{air}}{TLV}$$

NIOSH Assigned Protection Factor (APF)

Respirator type	APF
Quarter face	**5**
Half-face APR or "demand" supplied air	**10**
Hood or helmet PAPR or continuous flow	**25**
Full-Face APR or "Demand" supplied air, any tight-fitting facepiece PAPR or continuous	**50**
Half-face pressure demand	**1000**
Full-face pressure demand	**2000**
SCBA pressure demand	**10000**

Assigned Protection Factor (APF), from ANSI Z88.2-1992

Respirator type		Inlet covering			
		_ mask, 1/4 mask	full face-piece	Helmet, hood	Loose-fitting facepiece
Air purifying		10	100		
Powered Air Purifying		50	100 or 1000*	1000	25
Atmosphere supplying - Airline	Demand	10	100		
	Continuous flow	50	1000	1000	25
	Pressure-demand	50	1000	* 1000 APF for high-efficiency filters only	
Atmosphere supplying - SCBA	Demand	10	100		
	Pressure-demand		10000		

OSHA proposed Assigned Protection Factors	
Respirator type	**APF**
Quarter face	n.a.
Half-face APR or "demand" supplied air	10
Hood or helmet PAPR or continuous flow	1000
Loose-fitting facepiece PAPR or continuous flow	25
Full-Face APR or "Demand" supplied air	50
Tight-fitting full-facepiece, PAPR or continuous flow	1000
Half-face pressure-demand	1000
Full-face pressure-demand	2000
SCBA pressure-demand	10,000

TABLE V–1.—SUMMARY RESULTS FROM WORKPLACE PROTECTION FACTOR (WPF) STUDIES AND ESTIMATED FREQUENCIES OF RESPIRATOR FAILURE, BASED ON A ONE-FACTOR ANOVA ANALYSIS OF DATA FROM WORKPLACE PROTECTION FACTOR (WPF) STUDIES

Study	Geometric mean WPF (95% C.I.[1])	Geometric standard deviation	Mean WPF	Estimated percent of workers with:			
				Mean WPF ≤10[2]	Mean WPF ≤2[2]	WPF ≤10 at least 5% of the time[3]	WPF ≤2 at least 5% of the time[3]
Studies Reflecting Inadequate Program Elements							
Particulate Exposure							
Toney and Barnhart [1972] (Ex. 64–68)	[4]11.4 (3.2–39.6)	[4]4.12	31.1	76.8	9.0	100	60.4
Harris et al. [1974] (Ex. 27–11)							
Low Estimate	[5]3.6 (1–17.9)	[5]2–93	6.4	99.7	38.8	100	96.4
High Estimate	[5]5.7 (1.6–20.4)	[6]2.93	10.2	97.0	12.5	100	82.3
Weighted Geometric Mean	[6]5.6						
Gas/Vapor Exposure							
Moore and Smith [1976] (Ex. 64–69)							
Respirator A	15.29 (8.3–28.1)	[7]2.36	22.1	36.2	<0.01	98.9	1.9
Respirator B	13.72 (7.7–24.4)	[7]2.15	18.4	41.3	<0.01	99.7	0.5
Respirator C	9.59 (4.8–19.2)	[7]2.16	12.9	83.1	<0.01	100	9.0
Toney and Barnhart [1972] (Ex. 64–68)	[4]3.8 (1.2–11.9)	[4]2.28	5.3	100	14.7	100	95.7
Weighted Geometric Mean	[6]9.4						
Studies Reflecting Good Program Elements							
Particulate Exposure							
Dixon and Nelson [1984][8]	3360 (3101–3640)	1.8	11,498	<0.01	<0.01	<0.01	<0.01
Gabbury and Burd [1989][8]	47 (31–72)	2.5	72	0.2	<0.01	30.1	<0.01
Lenhart and Campbell [1984][8]	166 (120–228)	3.8	405	0.1	<0.01	9.0	0.02
Nelson and Dixon [1985][8]	258 (192–347)	5.2	1004	0.7	<0.01	14.5	0.3
Gosselink et al. [1986][8]	96 (75–123)	2.3	136	<0.01	<0.01	0.1	<0.01
Colton and Mullins [1992][8]	147 (117–185)	2.5	224	<0.01	<0.01	0.1	<0.01
Myers [1990][8]	346 (256–468)	7.2	2,428	2.8	0.1	22.2	1.7
Weighted Geometric Mean	[6]142						
Gas/Vapor Exposure							
Galvin et al. [1990] (Ex. 64–22)	79 (54–115)	3.5	173	1.1	<0.01	31.7	0.2

[1] 95% confidence interval of the geometric mean WPF calculated as follows for simultaneous confidence intervals: $\bar{y} \pm SD/\sqrt{n}\ t_{n-1,1-\alpha_2}$, $\alpha=1-(1-0.05)^{1/N}$

where n is the number of WPF measurements in each study and N is the number of studies being compared (i.e., 10 for particulate studies and 5 for gas/vapor studies).

[2] Calculated from equation 9 as described in the text; $\delta = 0.1$ for WPF = 10, $\delta = 0.5$ for WPF = 2.

[3] Calculated from equation 10 as described in the text; $\kappa = 0.1$ for WPF = 10, $\kappa = 0.5$ for WPF = 2.

[4] Calculated by OSHA from raw data presented by the authors.

[5] Range of WPF values estimated by Popendorf [1985] (Ex. 54–512), from effective protection factor values (EPF) reported by Harris et al. GSDs calculated by OSHA from median and mean EPF values reported by Harris et al.

[6] Calculated as a weighted geometric mean as follows: $\exp[(\sum \ln GM/(\ln GSD)^2)/\sum(1/(\ln GSD)^2)]$.

[7] Calculated by OSHA from median and mean WPF values reported by Moore and Smith.

[8] Studies reviewed by Nelson [1995] (Ex. 64–514).

Protection Factors

- **Fit Factor**
  - **Measured during fit testing procedures**

Quantitative Fit Factor (QNFF) $\left[\frac{C_o}{C_i}\right]$

- **Workplace Protection Factor**
  - **Measured under workplace conditions**

Workplace Protection Factor (WPF) $\left[\frac{C_o}{C_i}\right]$

Protection Factors

- **Effective protection factor**
  - **Includes times when the worker is not wearing the respirator**

$$\text{Effective Protection Factor (EPF)} \left[\frac{C_o}{C_{inhaled}} \right]$$

  - **over unspecified length of time**
  - **supposed to represent total protection afforded worker including times worn and not worn.**
  - **Used in OSHA's lead standard**
- **Program protection factor**
  - **sometimes used with lead aerosols**

Maximum Use Concentration

- **Maximum Use Concentration, MUC**
  - **Not currently defined by OSHA, although many standards incorporate the general principle**
  - **Usually defined as the PEL x APF**
  - **must not be > IDLH or in excess of the cartridge limits**
  - **Based on several factors: APF, IDLH concentrations, and regulatory limits**
  - **Example**
    - » **APF for half mask = 10**
    - » **PEL for lead = 0.05 mg/m^3**
    - » **MUC = 10 x 0.05 mg/ = 0.5 mg/m^3**

RESPIRATOR FIT

- **User "seal checks" (formerly "fit checks")**
  - **Each time the respirator is worn**
  - **Positive- and negative-pressure (OSHA)**
  - **Odorous or irritant agents may be used (ANSI)**
- **Fit Testing**
  - **Formal test, to select respirator sizes and models**
    - » **Involves several "exercises"**
    - » **Initial fit testing, before the respirator is issued**
    - » **Repeated annually**
  - **Subject is exposed to a challenge atmosphere**
    - » **Qualitative tests (taste, odor, irritation)**
    - » **Quantitative tests (instrumentation)**

Fit Testing Requirements

- **Previously, OSHA only required fit testing for negative pressure respirators**
- **Since 1998, all tight-fitting respirators must be fit tested**
  - **Negative pressure respirators**
    - » **Qualitative testing for half-face**
    - » **Quantitative testing for full-face (where 500 FF is desired)**
  - **Positive pressure respirators**
    - » **Must be tested in the negative-pressure mode**
      - **Modify respirator for negative pressure operation, or use a "surrogate" respirator**
    - » **Quantitative or qualitative testing is acceptable**

Fit testing

- **Qualitative fit testing (QLFTs)**
  - isoamyl acetate (IAA)
  - irritant smoke (usually titanium and stannic chloride)
  - saccharin aerosol (taste test)
  - denatonium benzoate (Bitrex)
  - must verify wearer can respond
  - wearer must be truthful
- **Quantitative fit testing (QNFTs)**
  - dioctyl phthalate aerosol (DOP)
  - corn oil
  - sodium chloride
  - DEHS
  - ambient air (with submicron particulate counting)
  - ambient air (pressure differential)

Qualitative Fit Testing

- **OSHA accepts 4 qualitative protocols**
  - **Isoamyl acetate (banana oil)**
  - **Saccharine**
  - **Bitrex**
  - **Irritant smoke**
- **Outcome depends on subject's response**
  - **Strong subject incentive to "pass" the test**
  - **Results may not be reliable**
- **Pass criteria is based on 100 Fit Factor**
  - **This provides a 10x safety factor for APF 10**

Qualitative Fit Testing

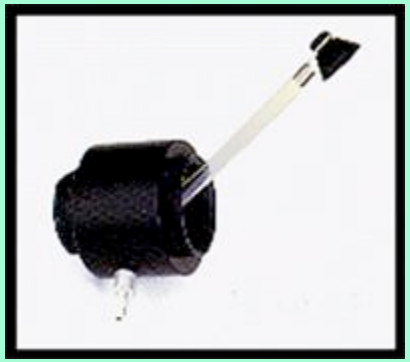
- **Saccharine**
  - **Particulate filter APRs, including dust masks**
  - **Hood**
  - **Sensitivity test**
  - **Challenged with 100 x solution**
- **Bitrex**
  - **Denatonium benzoate**
  - **Same equipment**

Qualitative Fit Testing

- **Isoamyl Acetate (IAA, "banana oil")**
  - **Sensitivity test**
  - **APRs with organic vapor cartridges**
  - **IAA saturated paper towel inside hood**
- **Irritant smoke (stannic chloride)**
  - **Not for persons with asthma!**
  - **No hood or enclosure**
  - **APR with high-efficiency filters**
  - **Safety concerns**

Quantitative Fit Testing

- **Quantitative fit testing uses probed respirators (or adapters) to measure inside the facepiece**
- **"Fit factor" is determined from the leak rate.**
  - **Previously, fit testing was used to determine a "Personal protection factor" (ANSI 1980)**
  - **Now, criteria includes a 10x safety factor (ANSI 1992, OSHA)**
    - » **Measured Fit Factor must be at least 10x the Assigned Protection Factor to accept a facepiece**



Quantitative Fit Testing

- **OSHA accepts 3 quantitative protocols**
  - **Generated aerosol method**
    - » **Old technology**
  - **Condensation Nuclei Counter (CNC)**
    - » **Ambient air challenge atmosphere**
  - **Controlled negative pressure**
    - » **Measures actual leakage**

Quantitative Fit Testing

- **Fit factor calculations**
  - **Fit factors for each exercise are combined**

$$\text{Overall Fit Factor} = \frac{\text{Number of exercises}}{1/ff_1 + 1/ff_2 + 1/ff_3 + 1/ff_4 + 1/ff_5 + 1/ff_7 + 1/ff_8}$$

Where ff_1, ff_2, ff_3, etc. are the fit factors for exercises 1, 2, 3, etc.

Respirator selection

Routine use vs non-routine use

Workplace hazards

Physical characteristics

Physical demands of the work

Respirator capabilities and limitations

Selection: Exposure assessments

- Identify airborne contaminants where possible
- Match up specifications and limitations of respirators
- Consider abnormal conditions that may cause concentrations to rise
- Think in terms of “worst case” exposures
- Apply substance-specific requirements
- Communicate information to employees; discuss signs, symptoms of overexposure
- Keep good records

Determining physical state of airborne contaminant

Listing of contaminant in TLV book is a clue but there are some exceptions

Guidelines for estimating airborne phase have been developed based on:

- identity of the major constituents
- saturated vapor concentrations of constituents
- estimate of total airborne mass concentration

  (the saturated vapor concentration and total airborne concentration can help predict phase)

Selection: Non-routine use of respirators

Three situations require careful consideration:

- entry into confined spaces
- entry into oxygen-deficient atmospheres
- emergencies

IDLH

ANSI: "...any atmosphere that poses an immediate, irreversible debilitating effects on health..." (acute effects vs chronic exposures)

OSHA standard requires atmospheres to be considered IDLH unless shown otherwise

Selection: IDLH, continued

NIOSH: IDLH based on two factors:

- **worker must be able to escape within 30 min without losing life or suffering permanent health damage, and**
- **worker must be able to escape without severe eye or respiratory irritation or other reactions that could inhibit escape**

also, atmospheres > LEL are IDLH

Respirator Selection

Conditions	Type of Respirator
IDLH conditions or oxygen deficiency	**SCBA or airline respirator with escape bottle**
Dust/chemical levels up to 1000 times PEL	**Airline respirator with full facepiece or hood**
Dust/chemical levels up to 100 times PEL	**Air-purifying respirator with full facepiece**
Dust/chemical levels up to 50 times PEL	**Powered air purifying respirator with half facepiece**
Dust/chemical levels up to 10 times PEL	**Air-purifying respirator with half facepiece**

NIOSH respirator decision logic

IDLH atmospheres -- Only 2 types allowed:

- SCBA in pressure-demand mode (≥15 minute air supply)
- Type C airline respirator, pressure-demand or continuous flow mode, with auxiliary escape bottle (minimum service life of 3 minutes)

IDLH atmospheres (low oxygen)

- Can use demand (negative pressure) airline respirator

Respirator Approval

- **Respirators approved by NIOSH**
  - **Previously NIOSH/MSHA (30 CFR part 11)**
  - **NIOSH 42 CFR 84, since 1995**
- **Manufacturers submit respirators to NIOSH**
- **Each respirator configuration is approved**
  - **Includes:**
    - » **Airline hose diameter and length (up to 300 ft.)**
    - » **Air pressure (up to 125 psi)**
    - » **Cartridges**
  - **Any change voids the approval**
- **NIOSH Certified Equipment List**
  - **Previous documents contained useful information**
  - **Current document is little more than a list of manufacturers and approval numbers**
  - **http://www.cdc.gov/niosh/celpamp.html**

NIOSH/MSHA certification

- Testing and certification codes issued (TC #)
- NIOSH personnel do actual testing
- List of approved respirators published

• TC 13F + 2-3 digits	SCBA
• TC 14G + 2-3 digits	AP gas mask
• TC 19C + 2-3 digits	SAR
• TC 21C + 2-3 digits	Particulate AP
• TC 23C + 2-3 digits	Gas or vapor AP

What is required in a respirator program?

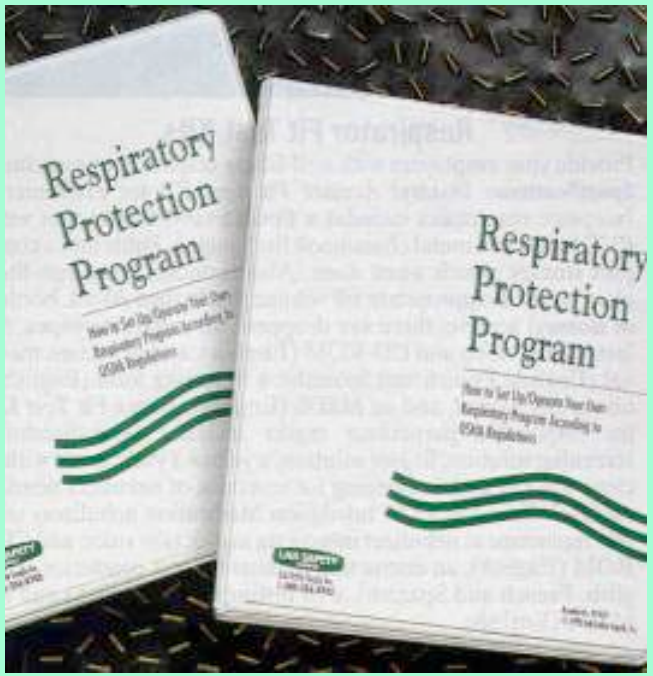
- ✓ Respirator program administrator
- ✓ Written procedures and records
- ✓ Proper respirator selection
- ✓ Medical evaluation of respirator users
- ✓ Fit-testing of respirators to each user
- ✓ Respirator maintenance, repair & storage
- ✓ Assured air quality for supplied-air respirators
- ✓ Employee training

Written Respirator Program

Prepared materials:

- **from manufacturers**
- **From WISHA sample program**
- **Other boiler plate programs**

Must be workplace-specific



Link to sample written respirator program

Much of your written program can be composed of compiled procedures from several sources. But some procedures will need to reflect your specific workplace practices. Be careful of "boiler plate" programs which may not describe your workplace's selection considerations or its specific emergency procedures. The purpose of a written procedure is to get a specific, consistent outcome by giving instructions that can be applied in your actual work area.

Voluntary Respirator Use

If you allow employees to wear respirators:

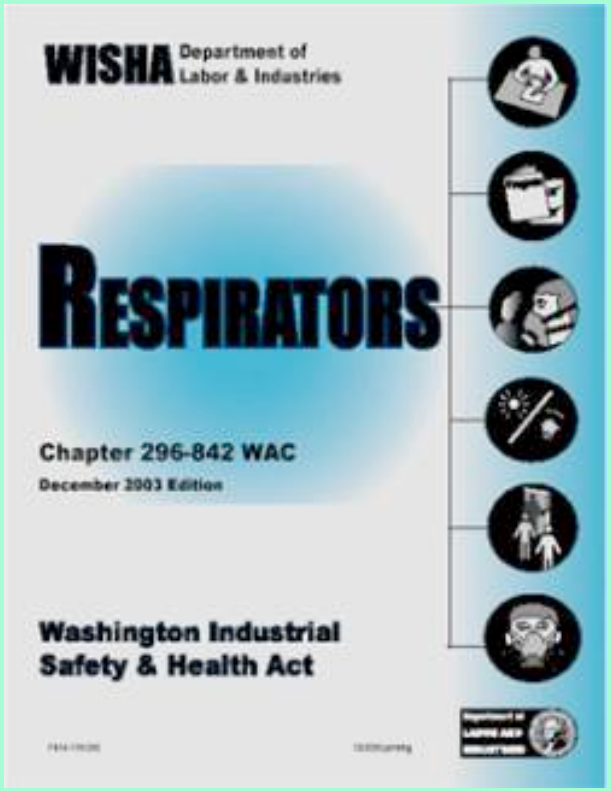
- **Provide the mandatory handout (link below),**
- **ensure safe use,**
- **provide medical evaluations**
- **ensure proper cleaning, storage and maintenance**

http://www.lni.wa.gov/wisha/rules/generaloccupationalhealth/HTML/62E_1.htm#WAC296-62-07117

These requirements apply to voluntary use of all respirators including dust masks. Fit-testing is not required.

WISHA Respirator Regulations

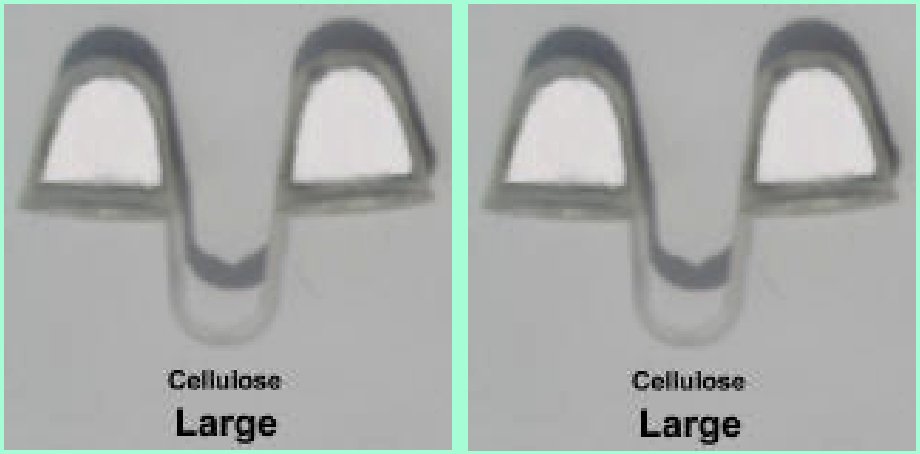
WAC 296-842.

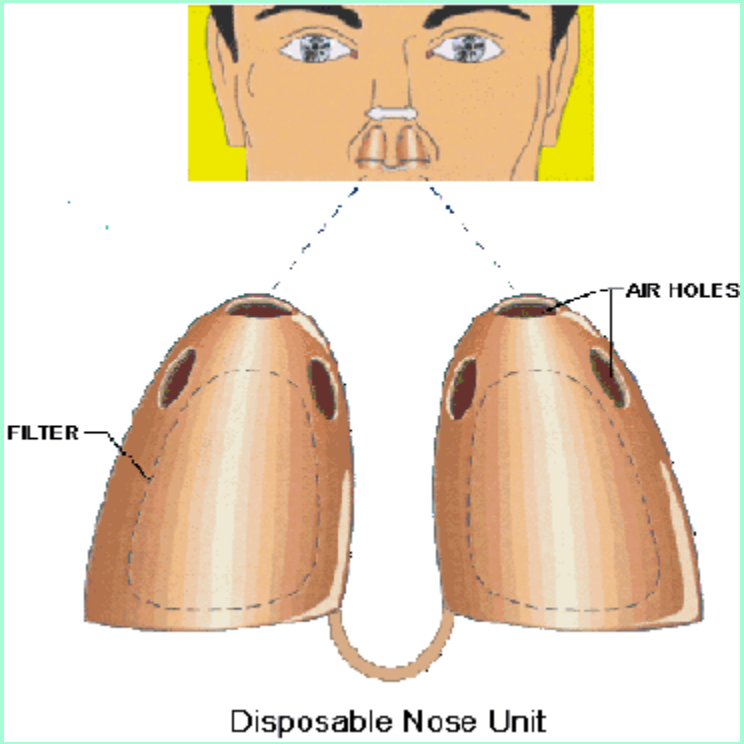


http://www.lni.wa.gov/wisha/Rules/respirators/default.htm

What type of respirator is this?

- **"Nose Filters"**
- **http://nosefilters.com/prod01.htm**





MACBETH'S WITCHES COMPLY TO OSHA STANDARDS