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Assigned protection factors: A perspective

By Larry Janssen, C.I.H.
Larry Janssen is a Certified Industrial Hygienist with the 3M OH&ESD Laboratory.

The Occupational Safety and Health Administration (OSHA) published its revised respiratory protection regulation, 29 CFR 1910.134, on January 8, 1998.

The regulation did not include a definition of assigned protection factor (APF) or a table of APFs to be used in the respirator selection process. OSHA stated that APFs would be the subject of a separate rulemaking later this year. While awaiting publication of OSHA's proposal, it is worth discussing what APFs really represent and the types of information OSHA may consider in setting these values.

What is an APF?

APFs represent the ratio of air contaminant concentration outside a respirator (Co) to the concentration expected to penetrate into the respirator (Ci). (Co) can be expressed as unity (or 100%) and (Ci) expressed as a fraction (or percentage) of (Co) penetrating into the respirator. Mathematically,

$$APF = \frac{100}{\%\ penetration}$$

It has been stated that "APFs have been determined through rigorous test procedures implemented under 30 CFR 11 by the National Institute for Occupational Safety and Health (NIOSH). Assignment of protection factors is not an arbitrary procedure. . ."[1] In fact, this belief is incorrect. The respirator approval criteria found in 30 CFR 11 (now 42 CFR 84) do not include test procedures for setting APFs. Establishing them is an arbitrary process in the sense that the values are based on a limited amount of data and a significant amount of professional judgement.

The APFs most widely used today are those recommended by two groups, NIOSH[2] and the American National Standards Institute (ANSI).[3] Table 1 lists these APFs and the basis for setting each value. Note that in several instances, different APFs are recommended for the same respirator. This is because different judgements were made regarding the type of data to consider and how it should be interpreted.

It is a commonly held misconception that APFs for tight-fitting respirators represent only faceseal leakage. NIOSH defines APF as the "minimum anticipated protection provided by a properly functioning respirator or class of respirators to a given percentage of properly fitted and trained users."

The ANSI definition differs only slightly: "the expected workplace level of respiratory protection that would be provided by a properly functioning respirator or a class of respirators to properly fitted and trained users." Thus, the term APF is used by both groups as an estimate of **overall** respirator performance in a sound respiratory protection program. **All** sources of contaminant penetration are taken into account by the APF. Examples of these penetration sources include faceseal leakage, filter or cartridge penetration, and "normal" exhalation valve leakage.

It is important to emphasize that APFs are not intended to take poor program performance into account. For example, penetration into the respirator may increase due to defects in a poorly maintained respirator. Similarly, a worker would experience an increase in the amount of contaminant inhaled if a respirator is not worn in the contaminated environment for portions of the work shift. These contributions to exposure are clearly not a result of respirator design and are not to be considered when setting APFs.

Table 1. NIOSH and ANSI assigned protection factors

Type of Respirator	NIOSH Respirator Decision Logic		ANSI Z88.2 - 1992	
	APF	Basis	APF	Basis
Air Purifying (APR) • Quarter-Mask • Half-Mask • Full-Facepiece, D/M or D/F/M • Full-Facepiece, all other media	5 10[1] 10 50	QNFT QNFT; WPF Filter efficiency QNFT	10 10 100 100	Analogy-Half Mask WPF3 QNFT QNFT3

Powered Air Purifying (PAPR)				
• Half-Mask	50	WPF	50	WPF
• Full-Facepiece	50	WPF[2]	1000	Analogy-Airline HH[3]
• Loose-Fitting Facepiece (LFF)	25	WPF	25	WPF, PPF, SWPF
• Hood or Helmet	25	Analogy-LFF PAPR	1000	Analogy-Airline HH[3]
Airline				
• Half-Mask				
- Demand	10	QNFT (PJ)	10	Analogy-APR
- Continuous Flow	50	Analogy-PAPR	50	Analogy-PAPR
- Pressure Demand	1000	QNFT (PJ)	50	Analogy-PAPR&CF Airline
• Full-Facepiece				
- Demand	50	QNFT (PJ)	100	Analogy-APR
- Continuous Flow	50	Analogy-PAPR	1000	Analogy-PAPR
- Pressure Demand	2000	QNFT (PJ)	1000	Analogy-PAPR&CF Airline
• Loose-Fitting Facepiece	25	Analogy-LFF PAPR	25	Analogy-LFF PAPR
• Hood or Helmet	25	Analogy-LFF PAPR	1000	WPF[3]
SCBA				
• Demand	5	QNFT	10	Analogy-APR
• Pressure Demand	10,000	QNFT	10,000[4]	SWPF; Intended Use

1. Includes disposable particulate respirators if quantitative fit testing is used.
2. This value is currently based on a study in which the authors noted leakage due to a defect in the respirator tested. Since defect leakage is not to be included in WPF measurements, ANSI did not use this study.
3. Supported by workplace testing after publication.
4. Definitive APF not listed. For emergency planning where concentrations can be estimated, an APF up to 10,000 should be used.

What is the basis for existing APFs?

As shown in Table 1, most APFs are based on one or more of the following types of information:

- Quantitative fit testing data (QNFT): Measurement of a test aerosol outside and inside a respirator in a controlled laboratory environment while subjects do specific exercises.
- Simulated workplace performance testing (SWPF): Similar to QNFT; more and/or different exercises (simulated work activities) are used.
- Workplace performance testing (WPF): Measurement of workplace contaminants outside and inside a respirator while the respirator is properly worn in the workplace. Test subjects must be trained and fit tested.
- Design analogies: Performance data from one respirator type are used to predict performance of other respirators that have similar designs.

Using each of these approaches involves making judgements and each has its limitations. For example, if QNFT or SWPF data are used to recommend an APF,

a judgement that laboratory performance can predict workplace performance has been made. To date, this relationship has not been shown. If WPF data are used, a judgement has been made that reliable measurements of respirator performance can be made in an uncontrolled workplace environment. An article by Nelson describes the process ANSI used to establish its APFs.[4] ANSI judged WPF studies to be the most appropriate basis for APFs where they were available. Because WPF studies are costly, time consuming and difficult to perform, WPF data were not available for many respirator types. In the absence of WPF data, laboratory studies and design analogies were used to establish the APFs.

When any type of performance measurement is used to recommend an APF, a decision must be made regarding how to use the data. Should the APF be based on the lowest performance result, the average value or a value corresponding to some point in a probability distribution? When WPF data are used, it is common to recommend an APF based on the fifth percentile value of a log-normal distribution. This implies that 95% of WPFs would exceed the recommended value.

Are there better ways to set APFs?

OSHA may consider other ways of deriving APFs from existing data as it develops its proposal. For example, elaborate statistical treatment of existing WPF data has been suggested as an alternate method of estimating APFs.[5] In this case, the quality of both the data and the assumptions used in the analysis are especially critical to any value this approach might have. For example, it would be inappropriate for the analysis to include results from WPF studies in which fit checks (user seal checks) rather than fit tests were used to screen the test subjects prior to data collection. It is also evident from Table 1 that relatively little WPF data exist. As a result, this approach could not be used for most respirator types.

It has been informally suggested that APFs for half-facepieces can be developed based on respirator appearance or design features, such as an elastomeric facepiece (as opposed to a filtering facepiece) or adjustable straps. Available workplace data do not show a difference in the performance of respirators that have or lack these features.[6] This is to be expected, since the same approval criteria and fit testing requirements apply to all respirator designs.

A number of individuals have suggested that it is possible to "synthesize" APFs for half- and full-facepiece respirators with N, R and P series filters. This theoretical approach is outlined as follows:

1. Assume 10% faceseal leakage for half-facepiece respirators or 2% faceseal leakage for full- facepiece respirators. These values correspond to the current APFs of 10 and 50 that NIOSH recommends for half- and full- facepiece respirators.
2. Add filter penetration as indicated by the NIOSH approval for the filter, e.g., 5% for a 95% filter.
3. The "synthetic APFs" for half- and full-facepieces with 95% filters become:

$$\frac{100}{10+5} \quad 6 \qquad \text{and} \qquad \frac{100}{2+5} \quad 14$$

This approach, which would have the effect of lowering APFs for half- and full-facepiece negative pressure respirators, overstates expected penetration (i.e., understates protection) for several reasons:

1. As mentioned earlier, current APFs are based on all expected sources of penetration. Total penetration is estimated at 10% and 2% for half- and full-facepiece respirators, respectively. Faceseal penetration and filter penetration are included in these values. The synthetic approach adds filter penetration to total expected penetration. This amounts to adding filter penetration twice.
2. Expected filter penetration is overstated because basic filtration principles are not taken into account. NIOSH tests N, R and P series filters under worst case conditions. This includes use of the most penetrating particle size and an airflow rate that represents very heavy work. Because these conditions do not exist simultaneously for prolonged periods in any imaginable workplace, filter penetration will be much lower than the NIOSH rating implies. Recent research confirms that it is reasonable to assume no filter penetration for "real world" working conditions.[7]
3. If the synthetic APF approach is used, the contribution of faceseal leakage should be assumed to be 1% for half-facepieces and 0.2% for full-facepieces. These values represent the maximum faceseal leakage permitted by the qualitative and quantitative fit tests that OSHA requires.
4. WPF studies performed on half- facepieces with dust/mist and dust/fume/mist filters approved under 30 CFR 11 support an APF of 10 for those respirators.[6] The criteria for approving these filters were not as severe as those used for N, R and P series filters. It is not logical to expect lesser performance when superior filters are used.

Summary

APFs are estimates of expected respirator performance, not precise measurements. All APFs are based on some degree of assumption and professional judgement. One can assume the performance indicated by the APF only when the respirator is properly maintained, fitted and used. In other words, APFs should not be reduced because respirators are not used correctly. All methods of setting APFs have limitations. However, since respirators are used in the workplace, ANSI's approach, which recommends APFs based on available WPF data, appears to be most sensible. The fifth percentile WPF value is a reasonable and conservative estimate of expected respirator performance.

References

1. Occupational Safety and Health Administration (OSHA): Office of Health Compliance Assistance. Interpretation on Respirator Use Under the Interim Final Rule for Lead in Construction, February 26, 1996.
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3. American National Standards Institute: American National Standard for Respirator Protection (ANSI Z88.2), New York: American National Standards Institute, 1992.
4. Nelson, T.J.: The Assigned Protection Factor According to ANSI, Am. Ind. Hyg. Assoc. J. 57: 735-740 (1996).
5. Nicas, M.: The Analysis of Workplace Protection Factor Data and the Derivation of Assigned Protection Factors. [Report submitted to OSHA Docket H-049 as Exhibit #156.]