

Protection Factor Research

Conducted on Continuous Flow Airline Respirators

Manufactured by Bullard

Updated Spring 2002



Introduction

How do respirators really perform in the workplace? For decades, this question has puzzled industrial hygienists, safety professionals and respirator users throughout the U.S. Although some testing has been conducted over the years, many questions still exist about how respirators really perform.

NIOSH and OSHA have set performance levels for classes of respirators based on limited research, conducted in both workplace and laboratory settings. These performance levels affect the selection and use of respirators in the workplace.

Testing performed by Bullard during the development of its respiratory protection products gives the company confidence that, when used and maintained in accordance with the manufacturer's instructions, its respirators offer the level of protection required for their intended use. However, in order to respond to federal regulatory initiatives, Bullard has participated in several additional research studies on the performance levels of its hood and helmet style respirators within recent years. Some tests were performed in the workplace, and others were performed in the laboratory under simulated workplace conditions. In all tests, Bullard respirators were proven capable of providing a level of protection far higher than NIOSH Assigned Protection Factors would allow for these classes of respirators.

Notwithstanding the higher levels of protection, no respirator should be used in concentrations which exceed the assigned protection factors established for the class of respirators to which it belongs. Doing so may constitute an OSHA violation.

The purpose of this summary is to inform industrial hygienists and safety professionals of the protective capabilities of Bullard continuous flow airline respirators. This document defines protection factors, explains the protection factor recommendations of ANSI, OSHA and NIOSH, and provides an overview of five studies in which Bullard respirators have achieved protection factors well in excess of 1,000.

Bullard's Background in Respiratory Protection

Bullard, based in Cynthiana, Kentucky, is a manufacturer of continuous flow airline, pressure demand and powered air-purifying respirators. Bullard's first respirators, introduced in the 1930s, were designed to protect abrasive blasters during their work activities. Today, Bullard respirators are used to protect workers in a broad range of industries, from abrasive blasting and painting to pharmaceutical

and chemical manufacturing. With more than 60 years of experience with industrial respirators, Bullard remains a leader in the airline segment of the respiratory protection market.

Protection Factor Definitions

The term "protection factor" has been associated with a number of different meanings over the years. This term can be used in at least three different ways to describe the degree of protection that a respirator or class of respirators is expected to provide. First, it can apply broadly to an entire class of respirators. Second, it can apply to a given make and model of respirator. And third, the term "protection factor" can apply to the level of protection that a specific wearer may achieve when wearing a given respirator.

To clarify specific methods of measuring and using protection factors, it is now correct to refer to Fit Factors (FF), Assigned Protection Factors (APF) and Workplace Protection Factors (WPF). FF, APF and WPF are all expressed as the ratio of the level of contaminant or test agent measured outside the respirator to the level measured inside the facepiece or head covering during operation. For example, a protection factor of 100 means that the concentration outside the respirator was 100 times greater than the concentration inside during testing.

Fit Factor

Fit Factor (FF) is defined, under the conditions of quantitative fit testing, as the test agent concentration in the environment divided by the concentration inside the respirator facepiece due to leakage. Fit testing is not normally performed for continuous flow airline respirators. A quantitative fit factor is a number that applies only to the respirator/wearer combination tested and is not necessarily an expression of the protection the respirator will afford during actual working conditions.

As the term fit factor implies, quantitative fit testing is utilized by employers to determine the fit of a respirator and whether it is adequate for protecting the worker. Pass/fail criteria are available for evaluating the fit factors obtained. If the respirator tested does not achieve the minimum required fit factor, then another size, model or style of respirator must be considered. Another method of fit testing is the qualitative fit test, which does not involve measuring actual fit factors.

Assigned Protection Factor

Assigned Protection Factor (APF) is defined as the minimum expected workplace level of respiratory protection that would be provided by a properly

functioning respirator or class of respirators, to a stated percentage of properly fitted and trained users. A respirator's APF is based on workplace protection factor studies, when available, or on laboratory simulated workplace studies, or, as a least desirable alternative, laboratory fit factor tests. This number applies to all respirators of a given class. A respirator's maximum use concentration is generally determined by multiplying a contaminant's exposure limit by the Assigned Protection Factor for that class of respirator.

Workplace Protection Factor

Workplace Protection Factor (WPF) is defined as a measure of the protection provided in the workplace, under the conditions of that workplace, by a specific, properly selected, fit tested and functioning respirator when correctly worn and used. WPF equals the ratio of the workplace contaminant concentration which the user would inhale if he were not wearing the respirator, divided by the workplace contaminant concentration inside the respirator facepiece or head covering. Simulated Workplace Protection Factors (SWPFs) are similar to WPFs, but are measured in a simulated environment. The primary advantage of simulated tests is that they are conducted in a lab, so all variables are controlled.

The Difference Between APFs and WPFs

The protective capability of a respirator is determined by its functional capabilities and performance limitations, and the ability of each respirator wearer to obtain a satisfactory fit with a given respirator. It is important to recognize that the APF is not the actual WPF that a wearer will obtain during use. The APF is a number assigned to an entire class of respirators, and it is a minimum level of expected protection that almost all wearers will obtain. A WPF number is the actual performance achieved with the respirator tested, under a specific set of work conditions.

Assigned Protection Factors According to OSHA, NIOSH and ANSI

The National Institute for Occupational Safety and Health (NIOSH) began assigning protection factors to classes of respirators in the mid-1970s. The first American National Standards Institute (ANSI) standard that refers to protection factors was the 1980 edition. OSHA, although not assigning protection factors to respirators in the original 1970 regulations for general industry, incorporated the early NIOSH Assigned Protection Factor recommendations in the field operations manuals

used by their inspectors. During the 1980s and 1990s, OSHA incorporated Assigned Protection Factors in their substance-specific standards, such as the standards for asbestos and lead.

NIOSH

In 1987, NIOSH revised APFs from their original numbers when the organization published the NIOSH Respirator Decision Logic. In this revision, APFs for powered air purifying respirators (PAPRs) with hoods and helmets were related from 1,000 to 25. At the same time, APFs for hood and helmet style airline respirators were restated from 2,000 to 25.

ANSI

The latest Assigned Protection Factor information can be found in the ANSI Z88.2-1992 American National Standard for Respiratory Protection, published in 1992. This standard contains a table of APFs in which continuous flow airline or powered air purifying hoods and helmets have an APF of 1,000. In the 1992 standard, ANSI created a new category of respirator facepiece called "loose-fitting facepiece." The loose-fitting facepiece is defined as a facepiece that is designed to form a partial seal with the face and does not cover the neck and shoulders. In the APF table, loose-fitting facepieces are rated with an APF of 25, both in powered air purifying and airline modes.

This new respirator category was created by ANSI because the studies that NIOSH relied on to restate all continuous flow hoods and helmets, including PAPRs, involved the loose-fitting facepiece style devices. In establishing APFs, the ANSI committee performed an exhaustive evaluation of all known research to date. During the process of revising the standard, the ANSI committee decision was guided by several research studies that supported an APF of 1,000 for continuous flow hoods and helmets designed to seal at the wearer's neck.

OSHA Revises 29 CFR 1910.134

In January of 1998, OSHA published a major revision to the 25 year old federal standard on respiratory protection. APFs were not addressed in this revision, and OSHA intends to address this issue in a subsequent phase of rule making. Ongoing, OSHA continues to defer to the APFs listed in the NIOSH RDL, in cases where OSHA has not already made a different determination on protection factors in a substance-specific standard. This new regulation is the first time we know of that OSHA has verified NIOSH as their source of APF guidance.

However, the preamble to the updated regulation includes a phrase that would seem to provide some relief from NIOSH APFs. This phrase is, "In the interim, OSHA expects employers to take the best available information into account in selecting respirators." This would seem to allow the use of other guidance such as ANSI Z88.2-1992, which lists an APF of 1,000 for continuous flow hoods and helmets. Bullard's special ruling from OSHA for Lead in Construction, in which the model 88 abrasive blasting respirators was given an Assigned Protection Factor of 1,000, is still in effect.

Bullard Contracts IH Firm to Conduct Protection Factor Tests

To further investigate the level of protection afforded by Bullard airline hood and helmet style respirators, Bullard enlisted the services of an industrial hygiene firm to conduct a Simulated Workplace Protection Factor study. **Results of this study concluded that all models yielded 5th percentile protection factors greater than 1,000.** For a summary of study objectives, methods, results and conclusions, see [Study 1](#), page 8.

Bullard generally views the ANSI Z88.2-1992 Assigned Protection Factors as the best numbers to use at this time. The APFs in ANSI Z88.2 are based on the latest scientific data and represent the "state of the art" in Assigned Protection Factors. For a summary of Assigned Protection Factors according to OSHA, NIOSH and ANSI, see [Attachment 1](#), page 14.

OSHA Reduces Assigned Protection Factors in Lead Environments

In its 1993 Interim Final Rule for Lead Exposure in Construction, OSHA adopted the NIOSH-recommended Assigned Protection Factor of 25 for loose-fitting hood/helmet style continuous flow respirators, when used in lead environments. Under the new rules of the Interim Standard, safety professionals were left without a completely satisfactory alternative for protecting blasters working in lead environments.

Bullard's Response

Bullard responded to this difficult situation on two parallel fronts. First, the company designed and manufactured the Lancer® respirator to meet the requirements of the Interim Standard. The Lancer® respirator incorporates a tight-fitting half-mask under a conventional abrasive blasting helmet.

At the same time, Bullard took exception to the way in which the standard was promulgated by OSHA, and began a two year-long appeal to OSHA for relief from

the Interim Standard. After several meetings, OSHA proposed that Bullard submit its respirators to Lawrence Livermore National Laboratory in Livermore, California, a respected research institution that has been evaluating the performance of respirators since 1963, for testing in accordance with a strict protocol approved by OSHA. Bullard's CC20TIC was surveyed to be the number one airline respirator used in the pharmaceutical industry.

In tests at Lawrence Livermore National Laboratory, **Bullard's Model 77 and 88 abrasive blasting respirators achieved protection factors in excess of 40,000, while maintaining positive pressure throughout the testing.** For summary of study objectives, methods, results and conclusions, see [Study 2](#), page 9.

OSHA Recognizes New APF for Bullard Abrasive Blasting Respirators

Based upon this simulated workplace evidence, OSHA formally acknowledged an APF of 1,000 for Bullard's 88 hood/helmet-style respirator in an OSHA Standards Interpretation and compliance letter dated August 30, 1995. Other manufacturers of Type CE continuous-flow abrasive blasting respirators have been offered the same relief.

While Bullard's 88 respirators were being tested at Lawrence Livermore, Bullard conducted a study on the newly-introduced Lancer® respirator. The purpose of conducting this study was to verify that the Lancer® achieves a WPF greater than the APF of 1,000. For purposes of this study, respirators were tested in actual workplace conditions. **Workplace Protection Factors were significantly higher than 1,000, supporting an APF of 1,000 for the Lancer®.** For summary of study objectives, methods, results and conclusions, see [Study 3](#), page 10.

CC20 Ranks at Top in Independent Study of Supplied Air (Airline) Hoods

ORC Coordinates Hood-Style Respirator Study

In 1996, Bullard became involved with a study of hood-style respirators coordinated by Organization Resources Counselors (ORC), a management consulting firm based in Washington, D.C., that provides a link between member companies and the appropriate government agencies, such as OSHA and NIOSH. ORC sponsors an Occupational Health and Safety Group which is comprised of more than 120 companies from a wide range of industries, including many members from the pharmaceutical industry.

In response to the low assigned protection factor of 25 in NIOSH's Respirator Decision Logic, a group of ORC member companies from the pharmaceutical industry initiated a study to persuade OSHA, through research, that these respirators are capable of providing protection far higher than the 25 assigned by NIOSH. This low APF would restrict the use of these devices in the pharmaceutical industry where high protection may be required to protect workers handling biologically active compounds. Another objective of the study was to provide solid documentation on the performance level of the equipment used by industry participants.

SWPF Study Conducted at LLNL

Participating pharmaceutical companies asked ORC to work in cooperation with the industry to design and perform a Simulated Workplace Protection Factor study of hood-style supplied air respirators (SARs) and hood-style powered air purifying respirators (PAPRs). The ORC respirator task force chose to use a simulated workplace environment because essentially all variables can be controlled, study conditions can be reproduced and the test results should be repeatable.

Respirators were selected for the ORC study following a survey of members from the pharmaceutical industry. Respondents were asked to list the respirators most frequently used by their companies. ***Bullard's CC20TIC was surveyed to be the number one airline respirator used in the pharmaceutical industry.*** Other respirator manufacturers with respirators in the study included 3M, MSA, North, and Racal. Respirators tested included six SARs, four PAPRs with hoods/helmets, and one loose fitting PAPR. The study was conducted at Lawrence Livermore National Laboratory.

Results

Six supplied air respirators (SARs) were tested, and five tested with SWPFs $\geq 250,000$, with the exception of one SAR that achieved a lower fifth percentile of less than 20 and a study APF of less than 2. Of the 720 SWPFs recorded with these five respirators, only 35 were less than 250,000. For a summary of SWPF results from the ORC study, see [Attachment 4](#) on page 17.

The Bullard CC20 was the highest testing SAR with a soft or disposable hood. Of 144 SWPFs recorded for the CC20, there was only one measurement below 250,000, and this SWPF was 160,000. Taking into account the differences between normal respirator use and those exercises performed in the study, and for interpersonal variability among subjects, a safety factor of 25 was used to come up with the study APFs. For a complete summary of study objectives, methods, results and conclusions, see [Study 5](#), pages 12 and 13.

For More Information

For a complete copy of a particular study or for more information contact Bullard's Sales Support Team at 877-BULLARD (285-5273).

Graphical Summary of Results

For a graphical summary of protection factor research conducted on Bullard airline respirators, see [Attachments 2 and 3](#) on pages 15 and 16. Attachment 2 shows the protection factors found in all five studies. Attachment 3 is a log-normal statistical plot of the protection factors found in [Studies 3 and 4](#) on pages 10 and 11.

STUDY 1

Laboratory Protection Factor Tests of Bullard Supplied Air Respirators¹

By J.H. King* and H.D. Caldwell** Fall, 1994

Objectives: The purpose of this study was to document the performance of Bullard's continuous flow supplied air respirators. Such a study was undertaken in light of the controversy which exists between the 1987 NIOSH Respirator Decision Logic, which lists an assigned protection factor (APF) of 25 for all loose fitting devices, and ANSI Z88.2-1992, which lists an APF of 1,000 for hoods and helmets.

Methods: Researchers tested seven models of Bullard supplied air respirators that are still being manufactured. The models included two abrasive blasting helmets, two Tyvek airline hoods, one nylon airline hood, a containment suit consisting of a hood and suit, and a model incorporating a full facepiece with a head covering and cape for abrasive blasting. The 12-subject test panel essentially conformed to the Los Alamos Fit Test Panel for Full Facepieces.

Testing was carried out using a quantitative fit testing apparatus, the ATI TDA-50. This system has a test chamber, an aerosol generator and a forward light scattering photometer detection system. The aerosol used was mineral oil with a mass median aerodynamic diameter of 0.7 micrometer with a range of 0.3 to 3.0 micrometers. The concentration range inside the chamber was 10 to 100 micrograms/liter. Protection factors can be measured up to 100,000. The output of the generator was sufficient to prevent dilution of the aerosol concentration by incoming air to the respirators.

The exercises performed were normal breathing, deep breathing, moving the head from side to side, touching the toes, jogging in place and normal breathing. Each exercise was performed for four minutes. Two airflow rates were used: minimum flow (115 lpm for tight fitting facepieces and 170 lpm for hoods and helmets) and normal flow (170 lpm for tight fitting facepieces and 225 lpm for hoods and helmets). Minimum flow is the established NIOSH respirator certification requirement in this case. Both peak and average penetrations were measured and were used to calculate protection factors.

Results: The mean laboratory time weighted average protection factors at the minimum flow rate ranged from 38,168 to 58,653 for the seven different models worn by 12 different people. The fifth percentiles ranged from 14,886 to 46,626. The highest protection factors were provided by the Model 88 abrasive blasting respirator and the PC/CS90 containment suit. The fifth percentile obtained in laboratory tests is often reduced by a factor of 10 to account for the usually lower protection factors found in workplace studies. One tenth of the fifth percentiles of the seven different models all well exceed the APF of 1,000 assigned by ANSI Z88.2-1992 to these types of respirators, supporting the use of an APF of 1,000 rather than the 25 recommended in the NIOSH RDL.

STUDY 2

A Simulated Workplace Protection Factor Study of the Bullard Model 77 and Model 88 Abrasive-Blasting Supplied-Air Respirators

By K.L. Foote*, J.S. Johnson*, R.A. daRoza* and J.H. King** May, 1995

Objectives: The purpose of this study was to verify that the Bullard Models 77 and 88 abrasive blasting respirators are capable of providing a protection factor of at least 1,000 during simulated sandblasting exercises. At the request of OSHA, Bullard engaged Lawrence Livermore National Laboratory to evaluate two of its most popular abrasive blasting helmet-style respirators in terms of their respiratory protective capabilities.

Methods: Respirators were tested at the Lawrence Livermore respirator test chamber, which measures 8 ft. by 10 ft. by 8.5 ft. high. The aerosol used was polyethylene glycol 400 with an average concentration of 20 mg/m³, and mass median aerodynamic diameter of 0.78 micrometer with a g.s.d. of 1.5. The once through chamber flow rate was 100 cfm. Aerosol measurements were made using a Phoenix JM-7000 forward light scattering photometer. Due to equipment sensitivity, background noise and instrument drift, protection factors greater than 40,000 were not reported.

The exercise protocol used by LLNL was designed to simulate abrasive blasting activities. Three different samples of each model were tested by four subjects who performed 12 exercises per test with two minutes per exercise. Respirators were tested with the minimum design air flow, which means that the combination of airline pressure, air hoses, and fittings used were selected to provide the minimum possible approved air flow to the respirators. The pressure inside the respirator helmets was continuously monitored and recorded.

Results: Both models tested achieved protection factors of at least 40,000, the highest protection factor detectable on the equipment that was used.

The average protection factors for all four subjects wearing all six tested respirators exceeded 40,000, and the pressure inside the respirator helmets remained positive.

Conclusions: Both models were found to be comfortable to wear. Both helmets achieved protection factors greater than 10,000, which supports an Assigned Protection Factor of 1,000 for these models of respirators, as the measured protection factors were greater than 10 times the APF of 1,000.

STUDY 3 Workplace Protection Factor Study of the Bullard Lancer® Supplied Airline Respirator

By S.D. Ecoff* and K.E. Crump** Spring, 1996

Objectives: In response to the OSHA Interim Final Standard for Lead in Construction (29 CFR 1926.62), E.D. Bullard Company designed a new airline respirator, the Lancer®, for use in abrasive blasting operations involving lead. Lancer® represents a new category of abrasive blasting respirator since it incorporates a tight-fitting half mask under a conventional abrasive blasting helmet. The NIOSH Assigned Protection Factor for this class of respirator is 1,000. The purpose of this study is to verify that this APF of 1,000 can be achieved during actual use conditions.

Methods: The work involved removing paint containing lead from large steel structures. Eleven workers at three different sites were subjects in this study. While the respirators were being used, total airborne concentration levels of lead were measured simultaneously, both inside the Lancer's half mask facepiece and outside the respirator helmet. Lead was analyzed by graphite furnace atomic absorption spectroscopy. Respirators were tested with the minimum design air flow, which means that the combination of airline pressure, air hoses, and fittings used were selected to provide the minimum possible approved air flow to the respirators.

Results: Of the 11 time weighted average samples from inside the respirator, nine had non-detectable levels of lead. The limit of detection (0.11 micrograms/m³) was then used as the inside concentration. WPFs ranged from 20,200 to 791,600. The geometric mean was 111,900, and the g.s.d. was 3.00. The fifth percentile was 18,300.

Conclusions: All the WPFs measured in this study were significantly higher than 1,000. This confirms that the Lancer® respirator, when used according to the instruction manual, will meet OSHA requirements for respiratory protection in work environments with airborne concentrations of lead, up to at least 1,000 times the permissible exposure limit.

STUDY 5 Simulated Workplace Protection Factor Study of Supplied Air and Powered Air-Purifying Respirators

By Howard J. Cohen*, Lawrence H. Hecker**, Darrell K. Mattheis***,
James S. Johnson****, Arthur H. Biermann**** and Kenneth L. Foote****

Objectives: In response to the low assigned protection factor of 25 for hoods and helmets in NIOSH's Respirator Decision Logic, a group of ORC member companies from the pharmaceutical industry initiated a study to persuade OSHA, through research, that these respirators are capable of providing a much higher level of respiratory protection. An APF of 25 would restrict the use of these devices in the pharmaceutical industry where high protection may be required to protect workers handling biologically active compounds. Another objective of the study was to provide documentation on the performance level of the equipment used by industry participants. It was decided that a simulated workplace study would be performed because it is easier to control the variables in a laboratory setting vs. a workplace environment. Respirator brands and models were selected based on a survey that determined the most frequently used equipment at participating pharmaceutical companies. Eleven NIOSH-approved models of respirators were included in the study. The study was conducted at the Special Projects Division's respirator test facility of Lawrence Livermore National Laboratory.

Methods: The experimental protocol was developed jointly by ORC, LLNL, respirator manufacturers and experts at OSHA and NIOSH. 17 test subjects (10 male, 7 female) were used. The exercises were developed from the ANSI and OSHA procedures and adding 2 industry-specific exercises to simulate hand scooping and moving bagged material. The study was carried out at the LLNL respirator test facility. The aerosol used was polyethylene glycol 400 with a mass median diameter of 0.44 micrometer and a geometric standard deviation of 1.2. 11 respirator models were each tested by 12 different subjects performing 12 exercises, for a total of 144 tests for each model. 6 airline supplied-air respirators (SARs), 4 powered air-purifying respirators (PAPRs) with hoods/helmets and one loose-fitting PAPR (with a facial type seal) from 5 manufacturers were tested. Airline (SAR) respirators were tested with 200 ft. hoses, adjustable valves in the closed position, and air pressure set to the low end of the manufacturer's approved pressure range for 200 ft. hose. All subjects wore a Tyvek coverall and respirators with bibs were tested with the bib tucked inside the coveralls. Aerosol concentrations were continuously monitored in the chamber and in the respirator using forward light scattering photometers.

Results: Median simulated workplace protection factors for all tested respirators, with one exception, exceeded the

reporting limit of 250,000. Because of the large number of data points, the lower 5th percentiles were taken directly from the data, without having to estimate this value using the mean and standard deviation.

Lower fifth percentiles were above 100,000 for all tested respirators with the one exception previously noted. For the purpose of this study, recommended APFs were determined for each model of respirator by dividing the lower fifth percentile by a safety factor of 25. These APFs can be referred to as the "Study APFs". The Study APFs ranged from 3,400-10,000 for SARs, except for one SAR that had an APF of only 1, and 6,000-10,000 for PAPRs (including the one loose-fitting PAPR). The SAR respirator with a Study APF of 1 had no bib to tuck in, and when the identical device was tested with a bib, it performed comparably to the other SARs.

The following table compares the Study APFs for the supplied-air respirators included in the study.

RESPIRATOR	STYLE	STUDY APF
SAR 1	HELMET	10,000
SAR 2	TYVEK HOOD WITH BIB	6,800
SAR 3	TYVEK HOOD WITH BIB	3,400
SAR 4	TYVEK HOOD WITH BIB	6,000
SAR 5	TYVEK HOOD WITHOUT BIB	1
BULLARD CC20TIC	TYVEK HOOD WITH BIB	10,000

Conclusions: The results of this study demonstrate that SARs and PAPRs are capable of achieving protection factors much higher than the APF of 25 from the NIOSH RDL. SARs (with one exception) achieved simulated workplace protection factors that support an APF of 1,000 for supplied air hoods and helmets, as currently set in ANSI Z88.2-1992. This study has also demonstrated that simulated workplace protection factor studies can provide valuable data regarding the performance of respirators, and it allowed for direct comparison of different makes and models of respirators under controlled conditions.

Note: This work has been published in the American Industrial Hygiene Association Journal, Vol. 62, pages 595-604 (Sept.-Oct. 2001).

Assigned Protection Factor Reference Guide*

Type of Respirator	ANSI /Z88.2-1992	OSHA APFs														NIOSH RDL			
		AS	Pb	Pb-C	Cd	Bz	Fm	Ar	COV	CD	DBCP	AN	EtO	VC	MDA		BD	MC	
Air Purifying																			
Single Use, Quarter Mask	10	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	5
Half Mask, incl. Disposables	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Full Facepiece	100	50	50	50	50	50	50	50	100	50	50	50	50	25	50	50	50	50	50
Powered Air Purifying																			
Half Mask	50	100	1,000	50	50	50	50	50	>10	1,000	1,000	1,000	>100	25	50	50	50	50	50
Full Facepiece	1,000	100	1,000	50	250	50	50	100	>10	1,000	1,000	1,000	>100	25	50	50	50	50	50
Helmet/Hood	1,000	100	1,000	25	25	25	25	-	>10	1,000	1,000	1,000	>100	25	25	25	25	25	25
Loose-Fitting Facepiece (ANSI)	25	100	1,000	25	25	25	25	-	>10	1,000	1,000	1,000	>100	25	25	25	25	25	25
Continuous Flow																			
Half Mask	50	100	1,000	50	50	50	50	-	>10	10	1,000	1,000	10	1,000	-	-	25	50	50
Full Facepiece	1,000	100	2,000	50	250	50	250	100	>10	50	2,000	2,000	50	2,000	-	-	200(2)	50	50
Hood/Helmet	1,000	100	2,000	25(3)	25	25	25	100	>10	2,000	2,000	2,000	2,000	2,000	-	-	25	25	25
Loose-Fitting Facepiece (ANSI)	25	100	2,000	25	25	25	25	100	>10	2,000	2,000	2,000	2,000	2,000	-	-	25	25	25
Pressure-Demand																			
Half Mask	50	-	1,000	1,000	1,000	-	1,000	-	>10	1,000	1,000	1,000	-	-	-	1,000	-	1,000	1,000
Full Facepiece	1,000	1,000	2,000	2,000	2,000	1,000	1,000	-	>10	2,000	2,000	2,000	2,000	2,000	-	1,000	200(2)	2,000	2,000
Self-Contained Breathing App.																			
Pressure Demand																			
Open/Closed Circuit																			
Full Facepiece	(1)	>1,000	>2,000	>2,000	>1,000	>1,000	>1,000	>1,000	>10	>2,000	>2,000	>2,000	>2,000	>3,600	>1,000	>1,000	>200(2)	>1,000	10,000

(1) Normally 10,000, but recent studies have indicated that all users may not achieve protection factors of 10,000. For emergency planning purposes where hazardous concentrations can be estimated, an APF of no higher than 10,000 should be used.

(2) For MC, 200XPEL=DLH Concentration (5,000 ppm).

(3) OSHA has granted an APF of 1,000 to the Bullard model 88 abrasive blasting respirator for use under the Lead in Construction Standard.



VC: Vinyl Chloride 1910.1017
 MDA: Methylendianiline 1910.1050
 BD: 1,3-Butadiene 1910.1051
 MC: Methylene Chloride 1910.1052

COV: Coke Oven Emissions 1910.1029
 CD: Cotton Dust 1910.1043
 DBCP: 1,2-Dibromo-3-Chloropropane 1910.1044
 AN: Acrylonitrile 1910.1045
 EtO: Ethylene Oxide 1910.1047

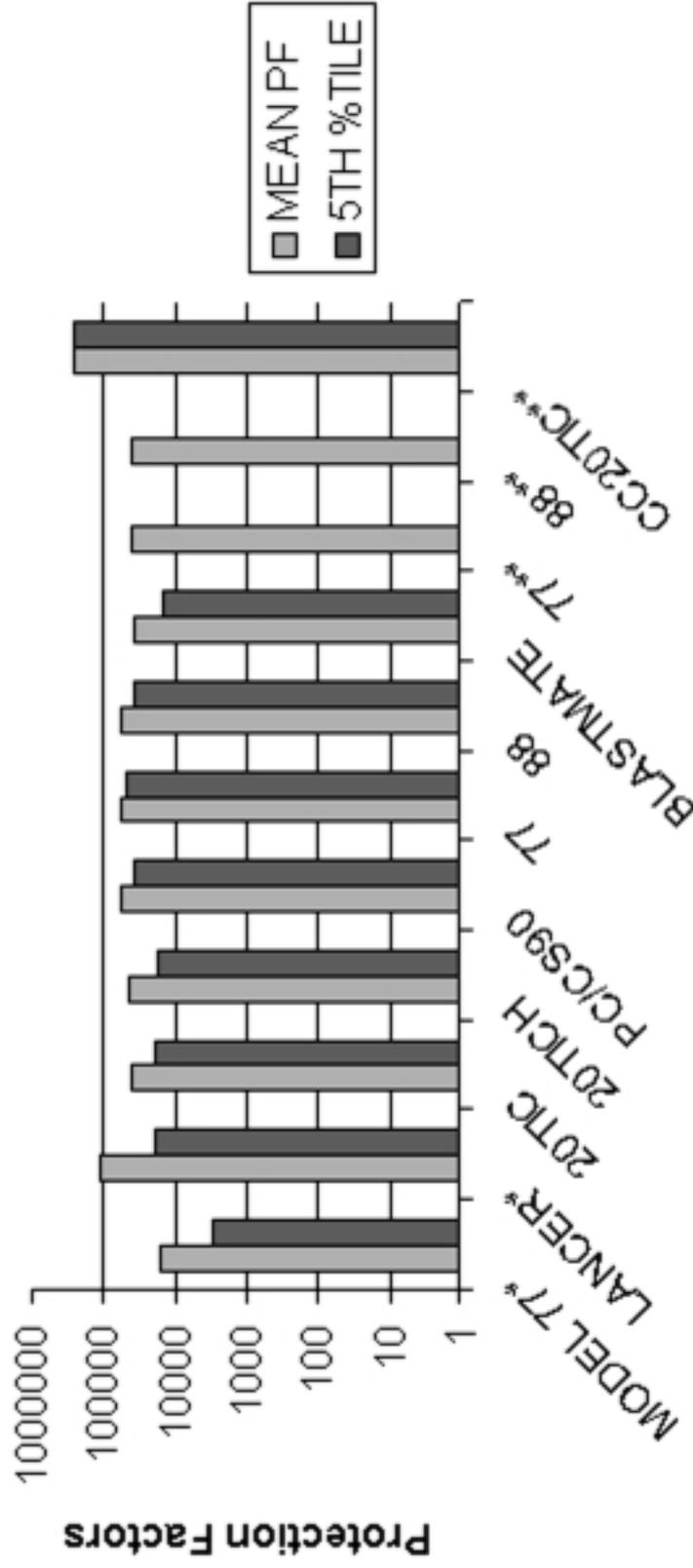
Pb-C: Lead in Construction 1926.62
 Cd: Cadmium 1910.1027
 Bz: Benzene 1910.1028
 Fm: Formaldehyde 1910.1048
 Ar: Arsenic 1910.1018

OSHA APFs:
 GI: General industry, i.e., substances for which there is no substance-specific standard covering respirator selection.
 As: Asbestos 1910.1001
 Pb: Lead in General Industry 1910.1025

* This guide is a compilation of Assigned Protection Factors published by various governmental agencies and the American National Standards Institute.

** General Industry numbers are not currently published. The numbers listed on this chart are the numbers that OSHA enforces to the best of our knowledge. For this reason, be sure to consult 29 CFR 1910.134, other established regulatory standards and/or your local OSHA representative. The Assigned Protection Factors herein do not constitute a recommendation by Bullard for the use of any respirator herein for any hazard.

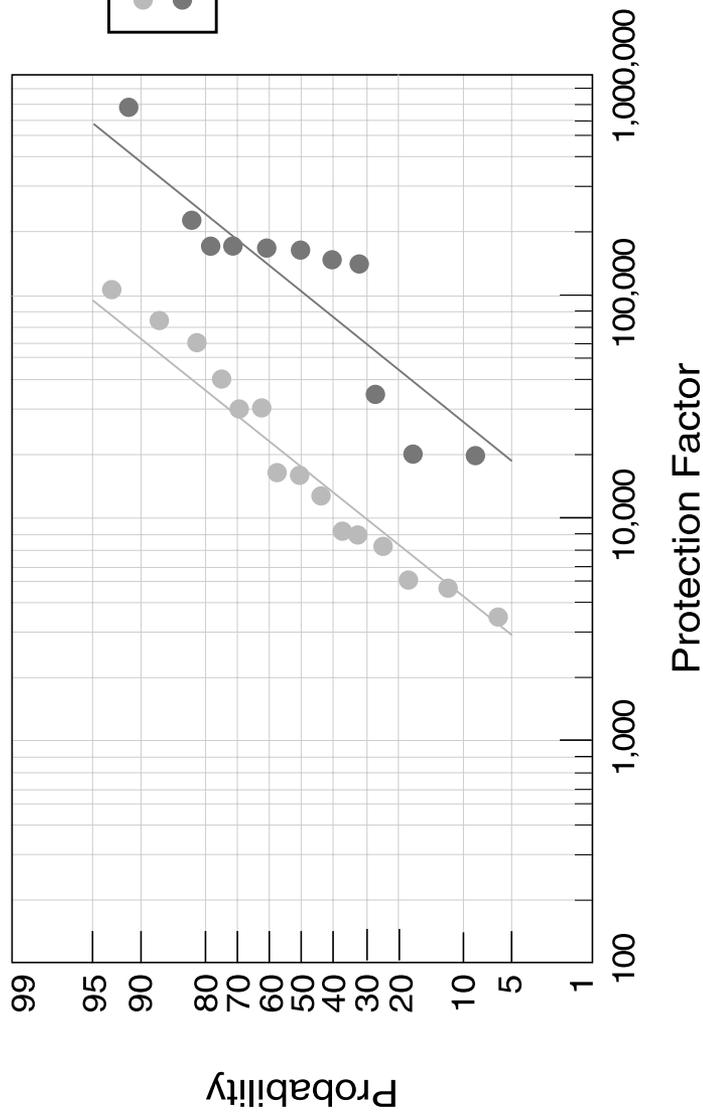
Mean and Fifth Percentile Protection Factors of Bullard Respirators



*These study results are workplace protection factors (WPFs). All others are simulated WPFs.

**These results are from the LLNL studies. All protection factors were greater than 40,000 for the 88, and greater than 250,000 for the CC20TTC. No 5th percentile was available for the 88.

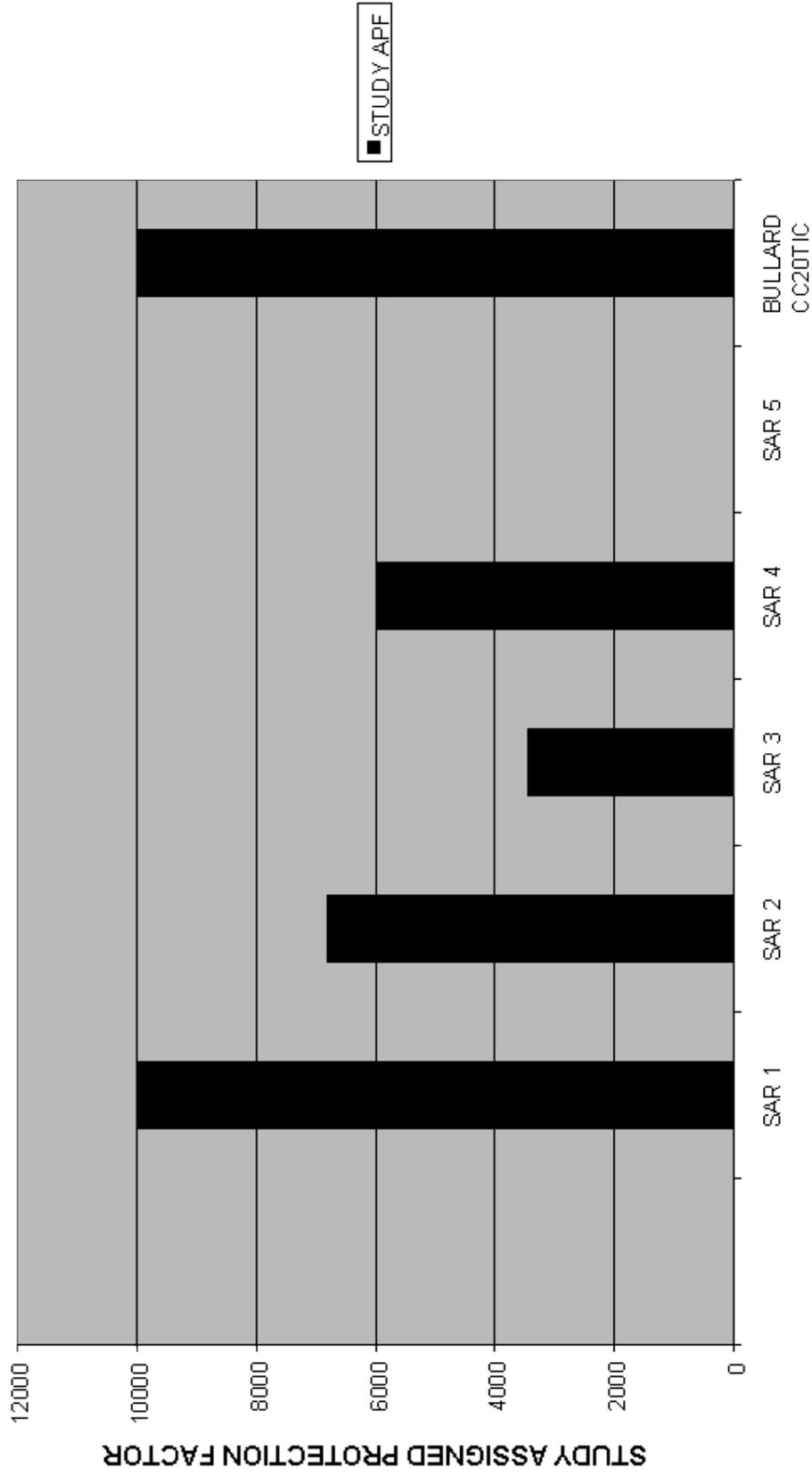
Workplace Protection Factors



Attachment 3



ORC STUDY ASSIGNED PROTECTION FACTORS





Head Protection



Respiratory Protection



Fire and Rescue Safety



Thermal Imaging

Bullard
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