Workplace Protection Factors—Supplied Air Hood

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Several organizations list assigned protection factors. For supplied air hoods, the value of the assigned protection factors varies from <10 to 2000 depending on the organization. Workplace protection factors (WPFs) of a supplied air hood were measured during aircraft sanding and painting operations on several types of aircraft to evaluate whether the American National Standard Z88.2 (1992) assigned protection factor of 1000 was realistic. The primary contaminant during these activities is strontium chromate. Samples collected inside the hood show that employees during sanding and painting operations were not exposed to strontium. The respirator performed adequately. This study is consistent with other simulated and WPF studies in that the ANSI Z88.2 WPF of 1000 is supported.

Keywords: ANSI Z88.2, respirators, strontium chromate, workplace protection factor

An assigned protection factor (APF) is an estimate of respirator performance. The 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.[1] The percentage of users is not stated, but 95% of users has been suggested by the National Institute for Occupational Safety and Health (NIOSH).[2,3]

Respirators are assigned protection factors by a number of organizations. These include the Occupational Safety and Health Administration (OSHA), NIOSH and the American National Standards Institute (the American National Standard for Respiratory Protection, ANSI Z88.2). The values assigned by these organizations do not always agree. For supplied air helmets/hoods, NIOSH lists an APF of 25[2] and 1000 is listed in the ANSI Z88.2 (1992)[4] respiratory protection standard. OSHA, in various substance specific standards, lists varying values depending on the standard. The range of APFs is from <10[5] to 2000.[6]

During aircraft sanding and painting activities, personnel at Tinker Air Force Base used a supplied air hood. In 1994 the U.S. Air Force incorporated the NIOSH APF of 25 in Air Force Occupational Safety and Health (AFOSH) Standard 48–1 Respiratory Protection Programs.[7] This prompted a change in respiratory protection during these activities. Feasible administrative, work process, and engineering controls could not control worker exposure to less than 25 times the occupational exposure limit for strontium chromate, the contaminant with the highest exposure. As a result, personnel were required to stop wearing a supplied air hood and start wearing full-face supplied air respirators operated in the pressure demand mode to comply with AFOSH Standard 48–1.

This change affected personnel by potentially increasing heat stress, fatigue, and ergonomic-related issues, and limiting workers' field of vision and communication capability. Additional costs were incurred for the purchase of the new respirators and for workers' physicals and respirator fit tests.

A workplace protection factor (WPF) is a measure of the protection provided in the workplace, under the conditions of that workplace, by a properly selected, fit-tested, and functioning respirator when correctly worn and used.[4] It is defined as the workplace contaminant concentration the user would inhale if he or she were not wearing the respirator (C_o) divided by the workplace contaminant concentration inside the respirator facepiece (C_i). Both C_o and C_i are determined from samples taken simultaneously, while the respirator is worn and used during normal work activities.

The objective of this study was to measure the WPFs of a supplied air hood during aircraft sanding and painting operations on several types of aircraft. Based on the data collected and other studies of supplied air hood performance, the ANSI Z88.2 APF of 1000 could be evaluated.

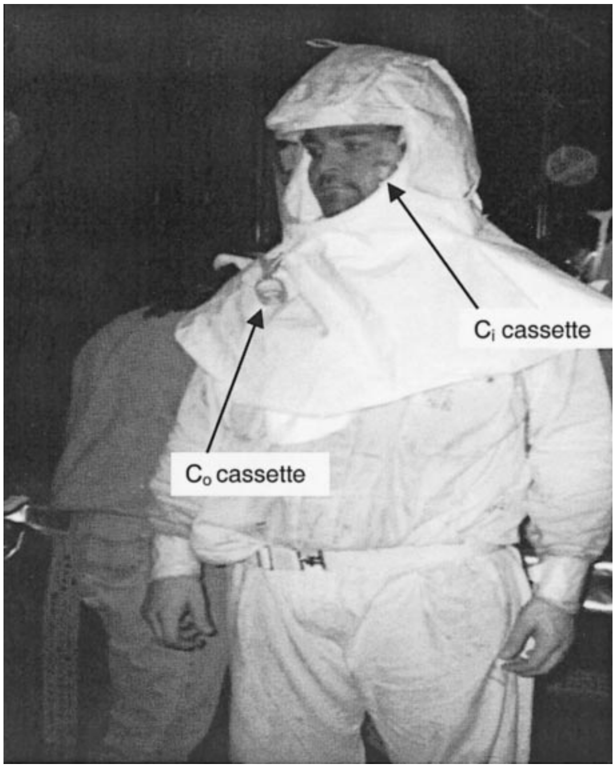

FIGURE 1. Placement of outside (C_o) and inside (C_i) cassettes

METHODS

WPF measurements were made while employees performed their normal work duties during sanding and spray application of a primer on aircraft. Three types of aircraft (C135, B52, and B1) were sampled. Metals in the primer and sanding dust were the contaminants measured.

Prior to the start of any sampling, the employees were instructed on the purpose of the study, the methods to be used, and the need for their cooperation. The sampling procedure was described. It was emphasized that they should remain connected to the air supply during sample collection and calibration to prevent sample contamination.

The employees wore 3M model H-422 series supplied air hoods (3M, St. Paul Minn.). The assembly consisted of the H-420 hood, W-3258 hard hat, W-2878 suspension, and a clamp to attach the breathing tube to the hood. The breathing tube used was the W-5114. The respirator was equipped with either the W-2862 vortex cooling assembly or the W-2863 vortex heater assembly. The assembled hoods were connected to an air supply manifold with 50 feet of W9435 ⅜-inch high pressure hose. The air pressure was regulated to 60–80 psi.

The samples were collected on 37- or 25-mm mixed cellulose ester filters mounted in three-piece plastic cassettes. The initial set of samples (1–19) used the 37-mm filters. The cassette size and irradiation times were changed to increase the sensitivity for C_i samples analyzed by proton induced X-ray emission (PIXE) after the initial round of sampling found no detectable amounts of strontium (Sr). With PIXE analysis, concentrating the analyte into a smaller area and increasing the radiation time lowers the detection limit of the method.

The C_o samples were clipped to the person at the shoulder (breathing zone) with the cassette pointed frontward and down and attached with ¼-inch tubing to an air sampling pump. The C_i samples were mounted with a hook and loop tape (Scotchmate™, 3M) inside the hood at a point midway between the nose and mouth (i.e., middle of viewing area) and to the side of the viewing area. The sampling locations are shown in Figure 1. The C_i sample location was selected based on the recommendations of Johnston et al. and so as not to interfere with the employee's vision.[8]

At the start of a sampling period, the employee put on the hood and attached the air supply hose. Air was then flowing into the hood creating a clean environment. This occurred in the work area. The C_i sample was attached to ¼-inch tubing with the inlet cap in place. The tubing for both samples was fitted with ¼-inch hose barbs to allow for in-line pump calibration. The inlet caps were removed, and specially designed adapters were placed on the filter cassette inlets to minimize particle losses.[9] Both pumps were started simultaneously. The pumps were calibrated with a bubble flow meter (MiniBuck model M-5, A.P. Buck, Orlando Fla.). Air was drawn through the cassettes at approximately 2 L/min. After calibration the calibrator was disconnected and the hoses reattached. The person then began working.

At the end of the sample period, the procedure was reversed. The pumps were calibrated in-line, the pumps turned off simultaneously, the special adapters removed, and the cassettes resealed. After the cassettes were removed, the employee was allowed to disconnect from the air supply and remove the respirator.

This procedure allowed the samples to be placed on the employee and the pumps to be turned on and calibrated while minimizing the possibility of sample contamination. To assess the magnitude of any sample contamination, a series of blank samples were collected. These included manufacturer's, field, and system blanks.

Filter manufacturer blanks (MB) were taken to identify any contamination that occurred during filter manufacture. An unused cassette was randomly chosen, marked, and stored with the other samples and sent in for analysis without ever being opened. One sample was sent to each laboratory that performed the analyses for each sampling session.

Field blanks (FB) were taken to identify potential contamination due to handling, field storage, and shipment. The blanks were treated in the same manner as the C_o and C_i samples except no air was drawn through the tubes. The cassette plugs were removed and replaced. The sealed cassette was then hung on the employee. At the end of the sample period, the FB cassette was again opened and closed, stored with the other samples, and sent in for analysis.

A system blank (SB) sample was taken in one building to determine if any contamination could be present from the air supply. The cassette was mounted in a hood as the other C_i samples and attached to an air pump set to flow at approximately 2 L/min. The hood was hung from scaffolding away from the work area. Airflow was started into the hood; after 1 min the cassette inlet plug was removed and air pulled through the cassette. After 2 hours the pump was stopped, and the cassette was plugged and removed from the hood.

The outside samples and one set of the MB samples were analyzed for Sr by NIOSH method 7300. The C_i, FB, SB, and one set of MB samples were analyzed for Sr by PIXE analysis.

RESULTS

The work performed by employees was judged light to moderate. The actions required hand and arm movement with a mod-

TABLE I. Summary of Field, Manufacturer, and System Blanks

Blank	μg/filter
MB1[A]	<0.042
MB2	<0.014
SB1[B]	<0.082
FB27	<0.022
FB31	<0.022
FB32	<0.014
FB35	<0.025

[A]37 = mm cassette.
[B]37 = mm cassette, normal radiation.

erate amount of walking. For sanding, the majority of work was done underneath the wing, requiring workers to reach above their heads. The remainder was done on top of the wing or on the fuselage. The priming was done mainly underneath the wings and fuselage. Both the painter and helper were sampled.

Manufacturer blanks for NIOSH method 7300 were at or below the level of quantification (0.8 μg/ filter for Sr). Table I lists the results for the MBs, SBs, and FBs for the PIXE analysis. They did not show the presence of Sr on the filter. The masses listed are at or below the limit of detection. The values listed vary because of the filter size and irradiation time. A higher detection limit occurs for the 37-mm filters and shorter irradiation time.

Sample times were approximately 2 hours for sanding and about 90 min for priming (the time it took to apply a single coat). Samples were voided if the tubing disconnected from the sample, a pump malfunctioned, or the air supply was disconnected before the samples were removed. Six samples were voided because of sampling errors.

Table II lists the sample sets collected, the type of activity (sanding or primer application), sample time and volume, concentrations inside and outside the hood, and the calculated WPF for the valid samples. Half the samples C_o collected during sanding had no detectable Sr on the C_o filter. If the detection limit was used for samples with no detectable Sr on the filter, the average C_o concentration was 8 μg/m³. This value is only 30 times greater than the mean of the detection limit for the C_i samples (0.26 μg/m³). The data from sanding is not a very useful indicator of respirator performance. Johnston has suggested that a concentration at least equal to the APF is required to be able to evaluate that APF.[8]

For the painting, the ambient concentrations of Sr ranged from

TABLE II. Summary of WPF Data

Sample Set	Date	Activity	Person	Time (min)	C_0 volume (L)	C_1 volume (L)	C_0 (μg/m³)	C_1 (μg/m³)	WPF
1	12/7/98	B52 sanding	void						
2	12/7/98	B52 sanding	1	127	262	270	<3	<0.20	
3	12/7/98	B52 sanding	void						
4	12/7/98	B52 sanding	2	118	241	252	29	<0.20	
5	12/7/98	B52 sanding	1	132	273	277	<3	<0.15	
6	12/7/98	B52 sanding	3	138	286	284	<3	<0.64	
7	12/7/98	B52 sanding	4	130	270	268	10	<0.21	
8	12/7/98	B52 sanding	2	137	281	286	10	<0.16	
9	12/8/98	B52 sanding	2	109	227	225	6	<0.24	
10	12/8/98	B52 sanding	3	102	210	206	<4	<0.22	
11	12/8/98	B52 sanding	4	114	237	234	<3	<0.26	
12	12/8/98	B52 sanding	1	108	224	224	8	<0.18	
13	12/8/98	B52 sanding	3	83	170	169	<5	<0.30	
14	12/8/98	B52 sanding	void						
15	12/8/98	B52 sanding	4	89	184	178	<4	<0.36	
16	12/8/98	B52 sanding	2	87	177	179	<5	<0.37	
17	12/8/98	B52 sanding	1	91	186	191	23	<0.35	
18	12/8/98	B52 sanding	4	38	80	80	<10	<0.53	
19	12/8/98	B52 sanding	3	101	206	210	<4	<0.33	
20	12/11/98	C135 primer	5	43	89	91	1240	<0.54	>2300
21	12/11/98	C135 primer	6	45	91	94	349	<0.38	>920
22	12/11/98	C135 primer	7	47	97	97	602	<0.51	>1200
23	12/11/98	C135 primer	8	45	95	94	638	<0.42	>1500
24	12/11/98	C135 primer	9	59	123	123	20 400	<0.39	>52 000
25	12/11/98	C135 primer	10	62	128	128	1510	<0.38	>4000
26	2/25/99	B52 primer	11	77	172	146	1040	<0.16	>6500
27	2/25/99	B52 primer	void						
28	2/25/99	B52 primer	12	80	174	208	820	<0.16	>5100
29	2/25/99	B52 primer	13	76	166	165	1940	<0.21	>9200
30	2/25/99	B52 primer	void						
31	2/25/99	B52 primer	14	88	194	192	2000	<0.09	>22 000
32	2/26/99	B1 primer	void						
33	2/26/99	B1 primer	15	60	129	112	2600	<0.20	>13 000
34	2/26/99	B1 primer	16	51	114	133	341	<0.16	>2100
35	2/26/99	B1 primer	17	50	109	110	572	<0.19	>3000
36	2/26/99	B1 primer	18	63	134	139	1670	<0.15	>11 100
37	2/26/99	B1 primer	19	69	150	152	1010	<0.16	>6300

Note: Sample sets 20–37 were collected on 25-mm cassettes.

340 to 24,529 μg/m³. There was no Sr detected on any C_i sample. Analyses of variance of the C_o concentrations from the painting of the three aircraft show that the geometric mean concentrations are not significantly different ($p=0.86$). The geometric mean concentrations were 1312, 1347, and 968 for the C135, B52, and B1 aircraft, respectively. Combining the C_o concentrations from the three aircraft gives an overall geometric mean concentration of 1200 μg/m³ Sr with a GSD of 2.6.

As shown in Table I, the respirators protected the employees from exposure to Sr. Since no detectable amounts of strontium were found on any C_i sample, an estimate of the level of performance of the respirator cannot be made directly. To calculate a WPF requires that a measured amount of material be found inside the respirator. It is known that for painting, the WPFs were greater than 1200 for all samples with a mass of Sr on the C_o samples 1000 times the detection limit for the C_i samples. One sample has less than 1000 times the mass of the detection limit.

DISCUSSION

The WPFs from this study are consistent with measured WPFs or simulated WPFs found by other researchers. Johnston conducted a WPF study on a helmet/hood type supplied air respirator.[10] This study was conducted during sandblasting of a barge. Samples were analyzed for silicon by PIXE. A relationship was found between the loading on the outside filters and the mean WPF found. When samples with mean loadings greater than 1000 times the mean blank loading are used, the estimate the 5th percentile WPF is 1038. Colton measured WPFs during a furnace teardown and rebuilding.[11] The mean WPF was 9532, with a GSD of 2.4 and a fifth percentile WPF of 2229. Skaggs studied a helmet/hood type in a simulated workplace study.[12] The mean simulated WPFs for the various conditions ranged from 7500 to 20,000.

A similar type of respirator is a powered air purifying hood/helmet. The minimum airflow into the hood is required to be the same as that for a supplied air hood. Keys et al. reported on the performance of three helmet/hood type powered air purifying respirators in a pharmaceutical manufacturing facility.[13] The respirators were a Racal Breathe Easy 10, Bullard Quantum, and the 3M Whitecap II. Samples from inside the inlet covering were collected for 30 min to 3 hours and analyzed for estradiol benzoate by a radio immunoassay technique. Samples from outside the respirator were analyzed by high pressure liquid chromatography. Probe loss was determined to be less than 1%. The best estimate of the fifth percentile WPF was 1470.

Comparing the NIOSH and ANSI APFs, NIOSH lists an APF of 25 for loose-fitting inlet coverings. ANSI describes two types of loose-fitting inlet coverings, loose-fitting facepieces and helmets/hoods. The ANSI APF for a loose-fitting facepiece is 25 and 1000 for the hood/helmet. The results of this analysis support a higher APF for a helmet/hood.

CONCLUSIONS

Employees using the supplied air hood during sanding and painting operations were not exposed to Sr. The respirator performed adequately. This study is consistent with other simulated and WPF studies in that the ANSI Z88.2 WPF of 1000 is supported.

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