PB82-229717

Final Report

on

PERFORMANCE OF CHEMICAL CARTRIDGE, HALF-MASK RESPIRATORS UNDER WORKING CONDITIONS IN A COPPER SMELTER

prepared by

Thomas J. Smith, Ph.D.
Principal Investigator

David E. Moore, M.S.P.H.
Coinvestigator

Division of Environmental and Occupational Health
Department of Family and Community Medicine
University of Utah Medical Center
Salt Lake City, Utah 84132

September 8, 1975

Prepared under supplement to contract no. CDC-99-74-5 to
Engineering Branch, DLCD, NIOSH.

Department of Family and Community Medicine

Performance of Chemical Cartridge, Half-Mask Respirators Under Working Conditions in a Copper Smelter

Final Report

Thomas J. Smith, Principal Investigator
David E. Moore, Coinvestigator

I. Introduction

Chemical cartridge half-mask respirators are commonly used by workers for protection against noxious atmospheres in many industrial settings. These may also be required to meet the minimum respirator requirements established by the Mine Enforcement and Safety Administration (MESA) for safe use under certain hazardous conditions. In order to assess the efficiency of a number of B.M. approved respirators filtering various aerosol atmospheres under laboratory conditions, considerable testing has been conducted at Los Alamos Scientific Laboratory by Hyatt, Pritchard, and Richards.[2,3] In spite of this extensive laboratory aerosol testing, there has been little field testing of respirator efficiency, nor has there been any for SO_2 gas.[4]

The present study was designed to measure the SO_2 protection factors of three chemical cartridge, half-mask respirators under actual working conditions in a copper smelter. For the purposes of this paper, a "protection factor" has been defined as the average SO_2 concentration measured outside the respirator mask divided by the average SO_2 concentration measured inside the respirator mask. The respirators for this study were chosen from among the models used in the Los Alamos studies and include two currently used by workers at the smelter. A specialized personal monitor unit was designed and used for data collection. An evaluation of the effect of face shape on protection factor was also attempted.

II. Test Group

Of the nine test participants, six were reverberatory furnace "feeders" and three were University of Utah personnel supervising the tests. The furnace feeders in this test series were chosen, first, for their frequent and regular high exposure to SO_2 and, second, for their willingness to participate. Because these two criteria defined a rather small population (the smelter was, at the time, on a reduced working schedule, with one of its three reverberatory furnaces shut down), no attempt was made to control the facial indices of the study group to conform to LASL test panel (1). The feeders' normal work involves charging copper concentrates into a reverberatory furnace (10 m. wide x 5 m. high x 33 m. long) four times per 8-hour shift. Each feed lasts 0.5 to 1.5 hours, during which the feeder stands on top of the furnace and directs the ore concentrate into a bank of chutes leading directly into the fired chamber. All respirator evaluations were made during furnace charging. Test supervisory personnel accompanied the feeders during respirator testing, both to act as well controlled test participants and to insure the proper operation of sampling equipment.

III. Methods and Materials

A. Sampling Unit

A personal sampling system was constructed to measure simultaneously SO_2 concentrations both inside and outside of a respirator while the respirator is being worn. A schematic diagram of the system is shown in Figure 1. Dual sampling trains, operating from matched impinger orifices and a common plenum chamber connected to an air pump, were used to sample SO_2 from the two source atmospheres. The impinger orifice tubes were constructed by fusing 0.5 mm. capillary tubes into the tube tips. The flow through the modified impinger tubes proved to be extremely stable, provided the vacuum source which produced that flow was itself stable. Impinger tubes were then "matched" into pairs which maintained stable flows within 0.1 liter/minute of each other when evacuated by a common plenum vacuum source. Bendix C115 sampling pumps were used as a vacuum source. These pumps are capable of maintaining a 2.0 liter/minute flow in excess of 8 hours. The demands of this study called for maintaining 1.0 liter/minute flow for 80-90 minutes. There was a slight tendency for the flow rate to decline during testing. Final flow measurements inside the mask averaged 90.8 $\pm$19.6% (mean $\pm$ S.D.) of their initial flows while final flows of outside-the-mask measurements were found to average 95.1 $\pm$18.8% of their respective initial flows. The "inside-the-mask" sampling train was prefiltered for particulates by the respirator itself, while a 35 mm., 5 micron membrane filter was used to prefilter the "outside-the-mask" sampling train. Sampling rates were sufficiently low (0.25-0.5 liters/minute) to avoid significant interference with the participant's own breathing volumes and to avoid significant pump induced negative pressures within the mask. The prefiltered gases were passed through the microimpingers and the SO_2 collected in acidified 0.5% (wt/wt)

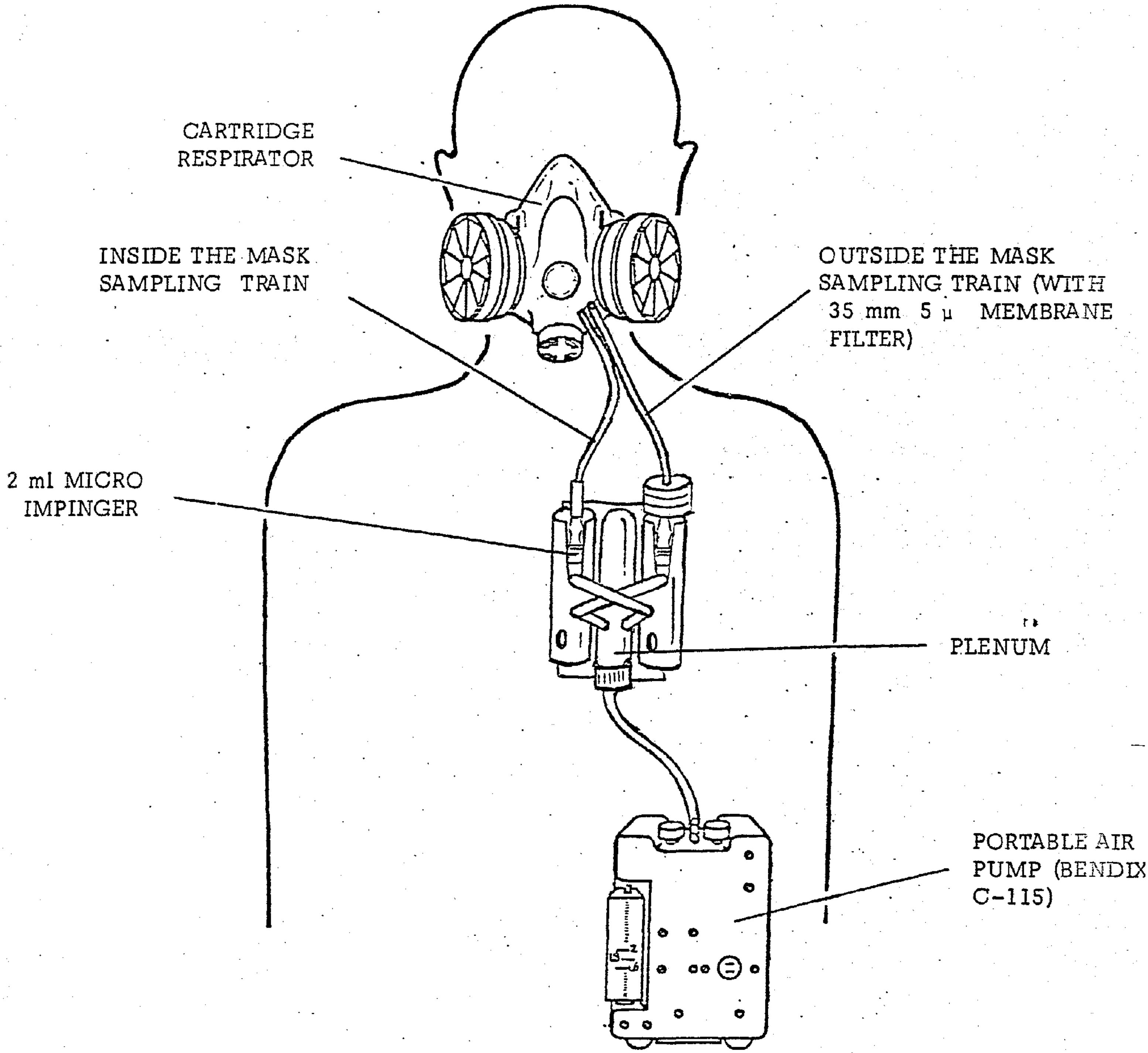

Figure 1. Schematic Diagram of Dual Sampling Device

hydrogen peroxide. Analysis of total sulfates was accomplished by precipitation with barium chloride and measurement of barium from redissolved barium sulfate with an atomic absorption spectrophotometer.[5]

B. Data Collection

Three different respirators, Welch 7500-11, American Optical (AO) R-8153, Mine Safety Appliance (MSA) Comfo II 459434 were fitted on each of the nine subjects. Three sampling runs (approximately 80 minutes long) were made to measure the inside- and outside-the-mask SO_2 concentrations for each subject/respirator combination. Lip length and menton-nasal root depression length were measured for each subject.[6] A total of 81 paired inside-outside-the-mask samples were collected. Sampling was conducted according to the protocol described in Appendix I. Each test was labelled with a three figure code to indicate the subject number, the mask identifier, and the test number for that subject/mask combination.

C. Data Analysis

The data were analyzed using t-tests, Mantel-Haenszel chi-square statistics, and regression techniques. The Mantel-Haenszel chi square is a nonparametric statistic used to test for differences in categorical data while considering the presence of ordering in the data and controlling for other variables of interest.[7]

IV. Results

Table 1 shows the average inside- and outside-the-mask SO_2 concentrates, and the average protection factors for each of the three masks tested. The outside-the-mask SO_2 levels averaged approximately 55 mg/m^3 (21 ppm) and

Table 1

Average SO_2 Concentrations Inside and Outside Respirator Masks and Average Protection Factors

Respirator	n	SO_2 (mg/m^3) Outside Mask Mean	Outside Mask S.D.	Inside Mask Mean	Inside Mask S.D.	Protection Factor Mean	Protection Factor S.D.
Welch 7500-11	26	61.1	40.2	5.0	4.0	22.1	22.6
American Optical R-8153	25	53.0	25.6	4.6	3.8	18.4	14.2
Mine Safety Appliance Comfo II 459434	25	53.0	35.6	6.2	4.5	12.9	11.0

ranged from 16.1-196.1 mg/m^3 (6.2-75.4 ppm). Statistical t-tests of the average outside-the-mask concentrations for each mask type reveal that no significant difference existed between the SO_2 atmospheres to which each mask type was exposed. Inside-the-mask concentrations averaged approximately 5 mg/m^3 (1.9 ppm) and ranged from 0.9-18.1 mg/m^3 (0.3-7.0 ppm). The protection factors showed a similar wide range, 2.6-83.1. The individual test results are given in Appendix 2. Five tests of the eighty-one (1 Welch, 2 AO, 2 MSA) were dropped from the data set because participants removed or lifted their respirators during sampling, thus causing inside-the-mask SO_2 accumulations to be unrealistically high.

Histograms showing the distribution of protection factors for the three masks are displayed in Figure 2. The protection factors were consistently grouped in the 2-20 range, with a few tests showing factors above 30. The Welch mask had 38.5% of its protection factors < 10, the AO had 30.4% < 10, and the MSA had 56.0% < 10. Median protection factors were 15.29 for the Welch, 13.72 for the AO and 9.59 for the MSA. Table 2 shows the average protection factors for each subject/mask combination. The lowest three-test average for a subject was 5.5 for the Welch, 6.9 for the AO and 6.7 for the MSA. It should be noted that the lowest three-test average for the Welch and MSA occurred for the same subject, #7.

In order to analyze the differences between masks, three contingency tables contained in Table 3 were formed. Mantel-Haenszel chi-square tests were performed on these contingency tables to assess the difference between protection factors of each respirator pair. The Mantel-Haenszel procedure

Figure 2

Distribution of Performance Factors by Mask

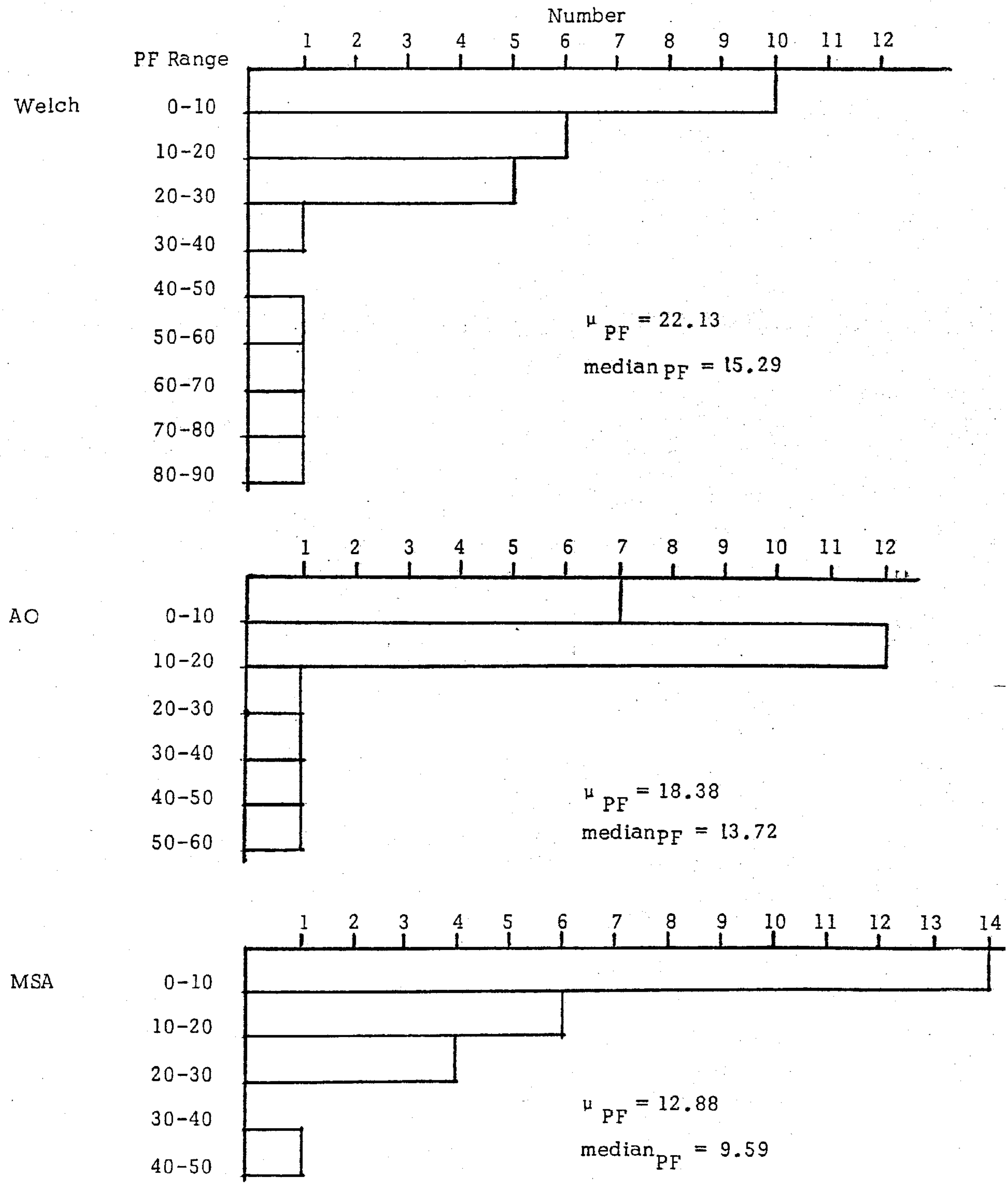

Table 2

Average Protection Factors and Facial Characteristics for Each Subject/Mask Combination

Subject	Length (mm) Lip	Length (mm) Face*	Respirator**	n	Protection Factor Mean	Protection Factor S.D.
1	62	124	W	3	18.397	8.569
			A	1	12.532	---
			M	3	19.517	24.067
2	59	118	W	3	40.207	23.377
			A	3	11.291	4.806
			M	3	20.313	11.930
3	64	125	W	3	12.018	10.501
			A	3	9.802	7.540
			M	3	11.426	8.234
4	60	121	W	3	48.630	27.822
			A	3	25.296	12.191
			M	3	7.665	2.378
5	50	131	W	2	16.306	13.419
			A	3	39.165	17.205
			M	3	8.496	6.052
6	53	126	W	3	10.806	8.166
			A	3	9.487	5.339
			M	2	15.953	16.385
7	65	120	W	3	5.510	2.319
			A	3	21.895	9.887
			M	2	6.754	5.545
8	56	119	W	3	9.665	12.145
			A	3	6.949	3.185
			M	3	10.018	6.167
9	57	127	W	3	35.661	41.132
			A	3	25.088	20.058
			M	3	14.730	12.402

* Face length = menton-nasal root depression length
**Code: W = Welch, A = AO, and M = MSA

Table 3

Mantel-Haenszel Chi Square Test

	0-10	10-20	>20	
Welch	10	6	10	26
AO	7	12	6	25
	17	18	16	51

$\chi^2_{MH} = 0$ p = 1.00

	0-10	10-20	>20	
Welch	10	6	10	26
MSA	14	6	5	25
	24	12	15	51

$\chi^2_{MH} = 1.75$ p = .18

	0-10	10-20	> 20	
AO	7	12	6	25
MSA	14	6	5	25
	21	18	11	50

$\chi^2_{MH} = 1.60$ p = .20

was used since the categories in the contingency tables were ordered and this procedure provides for a more powerful test to detect for trends for this type of data. No significant difference was found between the protection factors of the Welch and AO masks. However, as is shown in Table 3, both the Welch and AO appear somewhat superior to the MSA. Additional data would be necessary to attain acceptable statistical confidence in such a conclusion. A mixed model analysis of variance was also performed with similar results.

An attempt was made to correlate the "somewhat superior" performance of the Welch and AO masks relative to the MSA. This analysis is based on the assumption that, under working conditions, an uncomfortable mask will be adjusted less tightly than a comfortable one. Appendix 3 contains nine interview sheets listing each participant's subject assessment of respirator function. These data are summarized in Table 4. It is of interest to note that the participant's assessment of respirator seal was closely related to respirator comfort in seven of the nine men. Six of nine participants rated the Welch as more comfortable than the MSA. The remaining three rated Welch and MSA as equally comfortable. Seven of the nine men rated AO as more comfortable than MSA, while one rated them equal, and one preferred MSA. It should be noted that the subject's "best liked respirator" correlated with that man's best performance respirator in only two of the nine participants. The reason for this discrepancy is not apparent.

It was found that three of the nine study participants had lip lengths which exceeded the criteria of the Los Alamos Scientific Laboratory (LAS) male

Table 4

Summary of Questionnaire Data

Question	Respirator		
	Welch	AO	MSA
1. Which respirator did you like best?	3	6	0
2. Which respirator was worst?	0	2	7
3. Rate each respirator according to the following criteria:			
1 = good, 2 = fair, 3 = bad	Average Rating		
	Welch	AO	MSA
Ease	2.2	1.8	1.7
Seal	1.9	1.3	2.8
Comfort/Irritation	2.0	1.6	2.8
Draw	2.1	1.4	1.8
Ride down (tendency)	2.2	1.2	1.8
Visibility	1.3	2.6	1.7

panel for testing half-mask respirators and that all of the face lengths fell in the upper half of the panel. The lip lengths ranged 50-64 mm. and the face lengths ranged 118-127 mm. A linear regression analysis was performed to test correlation of each participant's lip and face length with average respirator protection factor. No significant relationship was found ($r^2 = .013$).

An apparent increase in protection factor with increasing ambient (outside-the-mask) SO_2 concentrations was noted in the data. The individual data points are shown in Figure 3. A linear regression was fitted to these data and found to be highly significant ($p < .001$) with $r = .56$. While the increasing trend is clear, it should be noted that the protection factor has an upper boundary because it is defined as a ratio of the inside and outside mask SO_2 concentrations and the inside mask concentration is limited by the analytical limit of detection (approximately 1 mg/m^3). As a result, the protection factor could not exceed a value approximately equal to the ambient SO_2 concentration. Although the lowest concentration observed approached the limit of detection, all samples contained detectable sulfate and were generally well above the limit. Hence, the apparent increase in protection factor was not an artifact of the analytical method, but a reflection of apparent improved SO_2 capture.

V. Discussion

The overall in-use SO_2 protection afforded by these three chemical cartridge respirators was poor. This is most clearly indicated by the percent of tests showing protection factors less than ten. The best mask had 30.4% of its tests with factors < 10, and the worst had 56.0% with factors < 10. Thus, if a worker were using one of these respirators with an SO_2 exposure near the

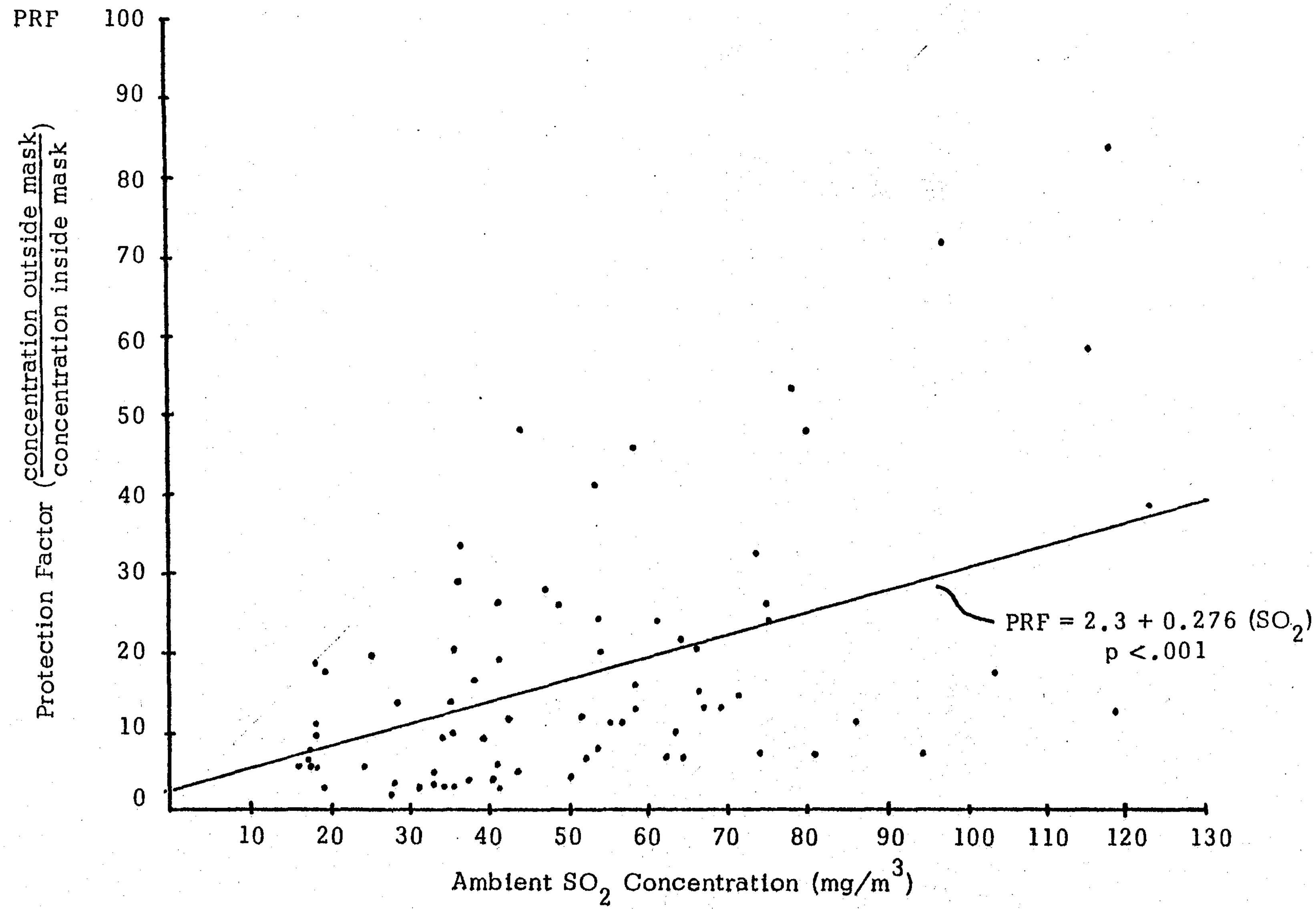

Figure 3. Protection factor plotted against ambient (outside-the-mask) SO_2 concentration including the maximum protection factor line occurring when there is a 1.0 mg SO_2/m^3 inside-the-mask concentration minimum.

allowable 50 ppm (130 mg/m^3) ceiling, the inside-the-mask SO_2 concentration would exceed 5 ppm a substantial portion of the time. It should be noted that these conditions rarely occur in the smelter environment even in the highest exposure category, the reverberatory furnace feeders.

Many variables which are easily controlled in the laboratory are not well controlled under working conditions. Three such variables are discussed below. We believe that these "working condition variables" significantly contributed to both the increased variability and decreased protection factors observed in this study, as opposed to earlier laboratory studies.

A. Respirator strap tension. The performance of half-mask respirators has been shown to be directly related to the tension of the head band straps.[2] Under working conditions, strap tensions are seldom, if ever, regulated. Since increasing the tightness of mask straps adversely affects the comfort, mask comfort is a secondary, but important, variable affecting the performance of the respirators. Respirator strap tension was not controlled or monitored in this study.

B. Facial hair. Hyatt, et al., have shown that beards and wide sideburns detrimentally affect the performance of half-mask respirators.[3] They have also observed that an order of magnitude decline in respirator performance can occur during the first day of facial hair growth following a shave. Participants in this study had neither beards nor wide sideburns. However, despite the fact that each was clean shaven, one could expect significant variation in facial hair as a function of daily shaving schedules.

C. Normal work activities. Hyatt, et al., have also demonstrated that many activities associated with normal work can adversely affect a respirator's performance.[3] These activities include smiling, talking, moving one's head, and deep breathing associated with heavy work. Such activities were, of course, observed in this study, but it was impractical to record them.

The test panel used in this study had generally larger faces than a majority of the LAS half-mask test panel.[8] The reason for this difference is not clear. It may be the result of a regional variation in body size or a chance occurrence. However, it does imply that perhaps the standard NIOSH test panel should be somewhat broader than the LAS panel. The finding of no relationship between facial size and protection factor is not conclusive because of the small sample size and relatively narrow range of face sizes in the workers available for the study.

The observed increase in protection factor with ambient SO_2 concentration (Figure 3) may have been the result of workers being more aware of mask leakage because of the irritation produced by the SO_2. While this is a reasonable explanation of the test results, no changes in worker behavior were observed to substantiate a difference in respirator usage at higher ambient SO_2 levels.

The sampling devices created for this study were found to be sturdy and reliable. The use of a common plenum with two matched orifaces provided well-balanced and stable flow rates. The investigators feel in retrospect, that had a larger impinger been used for data collection, some of the variability observed in the samples might have been reduced. The 2 ml. spillproof microimpingers were chosen to collect SO_2 because of their compact size and spillproof feature. However, the very low capacity of these impingers severely limited the flow rate and the quantity of solution available for analysis. The variability might have further been reduced had a longer sampling period been used instead of 80 minutes. The practical limitation of the workers' schedule was the primary factor for selecting the sampling period.

VI. Recommendations

1. Much more extensive testing should be done on all types of respirators under actual use conditions to identify realistic protection factors provided by chemical cartridge respirators. While laboratory testing is clearly useful and necessary, it does not provide information on the actual protection afforded by these respirators.

2. Means should be developed to assess the interaction of the respirator, and the subject in order to develop a testing program which can evaluate the acceptance a respirator will receive by the workers who use it, particularly with regard to its comfort.

3. Further testing should be conducted to verify the observed increase in protection factor with increasing ambient SO_2 concentrations. It may be that the irritant effect of SO_2 causes the workers to adjust their mask such that an upper SO_2 limit is not exceeded. This finding has important implications for the use of half-mask respirators for protection against substances with warning properties as opposed to those which do not.

4. Smelter workers might more effectively use their respirators if they

were properly trained in their use and made aware of the factors which affect the protection factor, i.e., strap tension, facial hair, and head and face movement. At present the workers receive no training in the use of the respirators.

VII. References

1. Respirator Protective Apparatus; Test for Permissibility; Fees Code of Federal Regulations, Title 30, Chapter I, Subchapter B, Part II, Subpart L. Federal Register, Vol. 37, No. 59, Part II, pp. 6267-6269, March 25, 1972.
2. Hyatt, E. C., Pritchard, J. A., and Richards, C. P. Respirator efficiency measurement using quantitative DOP-man tests. A.I.H.A. Journal 33:635-643, October 1972.
3. Hyatt, E. C., Pritchard, J. A., Richards, C. P., and Geoffrion, L. A. Effect of facial hair on respirator performance. A.I.H.A. Journal 34:135-142, April 1973.
4. Moore, D. E. and Smith, T. J. Respiration compensation of a portable air monitor, A.I.H.A. Journal 36:430-432, June 1975.
5. Wollin, A. Microdetermination of total sulfur by atomic adsorption spectrophotometry, Atomic Absorption Newsletter 9:43-45, 1970.
6. Hyatt, E. C., Pritchard, J. A., and Richards, C. P. Selection of Respirator Test Panels Representative of U.S. Adult Facial Sizes (LA-5488), United States Atomic Energy Commission, Contract W-7405 - Eng. 36, pg. 11, March 1974.

7. Mantel, N. Chi-square tests with one degree of freedom; extensions of the Mantel-Haenszel procedure. J. Am. Statistical Assoc. 58: 690 (1963).

Appendix 1

Protocol for the Use of Dual Sampling Train (DST)

A. Before shift

1. Insert charged battery into pump.

2. Charge microimpingers with 2 ml 0.5% wt/wt hydrogen peroxide solution. Inject solution from a large syringe fitted with a Wintrobe cannula.

3. Connect tubing (Figure 1) and set flow for both sides, measuring at the microimpingers,and attach mask. (Note: Steps 1-3 are performed at the lab.)

4. Record before-shift flows on both sides, unit number, time on, and mask type.

5. Have subject adjust web belt to fit himself.

6. Attach pump and DST assembly onto belt and then to subject and instruct subject in its use. Stress that he must be wearing his mask at all times while the pump is operating.

7. Have subject put on mask; then switch on pump.

B. During shift

Observe all tubing connections for integrity. Also observe microimpinger flows through the case portholes.

C. After shift

1. Turn off pump before removing mask and sampling device from

subject.

2. Note and record after-shift flows. Record time off.

3. After transporting sampling device to lab, break it down:

   a. Disconnect tubing

   b. Decant inside-the-mask sampling solution with clean syringe and cannula. Rinse out microimpinger and inside-the-mask sampling train with reagent grade distilled water.

   c. Place both sampling solution and rinse water into a clean, labelled polyethylene bottle and refrigerate it.

   d. Decant outside-the-mask sampling solution and rinse microimpinger. Bottle as before.

   e. Remove outside-the-mask membrane filter from its cartridge and place in a labelled polyethylene bag.

   f. Remove chemical cartridges from mask and place in a labelled polyethylene bag.

   g. Wash microimpingers and respirator mask.

4. Rebuild sampling device with clean microimpingers, new filter, and new chemical cartridge(s).

	CNO	CNI	PF
111	34.274953	3.8920276	8.8064514
112	64.377046	3.0528298	21.087662
113	75.035311	2.9661017	25.297619
123	67.535854	5.3889614	12.532258
131	80.174629	1.6949153	47.303030
132	17.731421	2.9262640	6.0594059
133	24.337245	4.6890369	5.1902438
211	18.126177	1.0004705	18.117647
212	183.92969	2.8433219	64.688310
213	123.06720	3.2543695	37.815990
221	62.515353	9.8957787	6.3173758
222	118.90425	10.209139	11.646845
223	58.158859	3.6556996	15.909091
231	48.925389	1.9172152	25.518987
232	94.842017	14.228918	6.6654410
233	196.15819	6.8215110	28.755827
311	28.248588	9.6516007	2.9268293
312	35.647028	3.7076272	9.6145124
313	61.311137	2.6075620	23.512820
321	74.358521	10.946328	6.7930107
322	43.400104	10.256928	4.2312965
323	41.538876	2.2598870	18.380952
331	40.778406	13.271297	3.0726766
332	54.449152	2.7871940	19.535473
333	52.019251	4.4569994	11.671361
411	115.95982	2.0217126	57.357219
412	97.217123	1.3684437	71.042105
413	19.254736	1.1008641	17.490566
421	53.966573	1.3367635	40.371069
422	54.048965	2.3178329	23.318750
423	58.380416	4.7865663	12.196722
431	63.831897	6.4302708	9.9267820
432	41.195858	7.9434063	5.1861702
433	53.609542	6.8005861	7.8830767
511	81.792502	11.996234	6.8181819
512	41.719286	1.6173701	25.794521
521	35.990793	1.8204645	19.770115
522	58.439266	1.2947269	45.136364
523	78.646638	1.4955135	52.588385
531	41.337527	18.079096	2.2864819
532	39.838818	4.5142351	8.8251534
533	71.273360	4.9579155	14.375671
611	56.850283	5.2713883	10.784689
612	66.547154	3.5058515	18.981738
613	33.270559	12.554928	2.6500000
621	52.083334	7.7683616	6.7045455
622	38.665255	2.4717514	15.642857
623	17.731033	2.9005246	6.1130434
631	33.615819	7.6977402	4.3669724
633	47.829447	1.7367650	27.539389
711	64.201336	10.614621	6.0483871
712	17.576899	2.3397821	7.5121949
713	19.334589	6.5128689	2.9686746
721	27.830090	2.0281038	13.722222
722	37.037037	1.1262509	32.885245

CNO = concentration inside-the-mask in mg/m^3

CNI = concentration outside-the-mask in mg/m^3

PF = protection factor

	CNO	CNI	PF
723	25.254852	1.3237261	19.078609
731	42.948316	4.0232838	10.674941
733	34.609751	12.218635	2.8325382
811	75.282487	3.1779662	23.688889
812	31.672659	11.816809	2.6803056
813	35.432166	13.497966	2.6250000
821	86.456977	8.3989104	10.293832
822	50.690522	12.826951	3.9518760
823	16.129390	2.4436495	6.6005331
831	66.854991	4.5511613	14.689655
832	37.809649	12.488849	3.0274725
833	69.402903	5.6259794	12.336146
911	118.64407	1.4270913	83.136986
912	55.434836	5.1527516	10.758298
913	35.283041	2.6956169	13.089041
921	44.632769	.93091939	47.944827
922	103.42122	6.1205273	16.897436
923	18.594509	1.7841213	10.422222
931	18.185028	3.1779661	5.7222221
932	36.252354	1.2554928	28.875000
933	18.065146	1.8832392	9.5925[illegible]4

CNO = concentration inside-the-mask in mg/m^3

CNI = concentration outside-the-mask in mg/m^3

PF = protection factor

NAME Lewis Luke 1

1 ≡ good
2 ≡ fair
3 ≡ bad

1. Which respirator did you like best?

AO

2. Which respirator was worst?

MSA

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	3	2	2	3	2	1
AO	1	1	1	1	1	3
MSA	2	3	3	2	2	2

4. Instruction on fitting self?

No

5. Has anyone checked fit?

No

6. How often change cartridges (dust things)?

1 set/day Don't wear them

How do you know when used up?

Can taste gas

NAME Allen Chapman 2

1. Which respirator did you like best?

AO

2. Which respirator was worst?

MSA

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	2	2	3	2	2	1
AO	1	2	2	2	3	1
MSA	2	3	3	3	1	1

4. Instruction on fitting self?

5. Has anyone checked fit?

6. How often change cartridges (dust things)?

How do you know when used up?

NAME Kich Coon 2

1. Which respirator did you like best? AO

2. Which respirator was worst? MSA

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	2	2	2	3	3	1
AO	1	1	1	1	1	3
MSA	3	3	3	2	3	2

4. Instruction on fitting self?

No

5. Has anyone checked fit?

No

6. How often change cartridges (dust things)?

1 set/day

Don't wear them because of increase in draw

How do you know when used up?

Taste gas

NAME Nuzzle, J. 4

-20-

1. Which respirator did you like best?

Welch

2. Which respirator was worst?

MSA

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	2	2	1	1	2	2
AO	2	2	2	1	2	3
MSA	1	3	3	1	2	2

4. Instruction on fitting self?

No

5. Has anyone checked fit?

No

6. How often change cartridges (dust things)?

1 - 3 days

How do you know when used up?

Smell & Visual

NAME David Moore

1. Which respirator did you like best?

AO

2. Which respirator was worst?

MSA

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	2	2	2	3	3	2
AO	2	1	1	1	1	3
MSA	1	3	3	2	2	2

4. Instruction on fitting self?

5. Has anyone checked fit?

6. How often change cartridges (dust things)?

How do you know when used up?

NAME Charles Hedger 6

1. Which respirator did you like best?

AO

2. Which respirator was worst?

MSA

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	2	2	3	2	3	2
AO	2	1	1	2	1	3
MSA	1	3	3	2	1	2

4. Instruction on fitting self?

5. Has anyone checked fit?

6. How often change cartridges (dust things)?

How do you know when used up?

NAME Sam Aguilar 7 2 9 8 1 0 8 ?

1. Which respirator did you like best?

Welch

2. Which respirator was worst?

AO

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	2	2	1	1	1	1
AO	2	2	3	1	1	3
MSA	1	2	2	1	1	1

4. Instruction on fitting self?

No

5. Has anyone checked fit?

No

6. How often change cartridges (dust things)?

Cartridge 1 day — 5 days Pads: every day

How do you know when used up?

1. Visual: turn black

2.

NAME T... ll, Mike 8

1. Which respirator did you like best?

Welch

2. Which respirator was worst?

AO

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	3	1	2	2	2	1
AO	2	1	2	2	1	3
MSA	1	2	2	1	2	2

4. Instruction on fitting self?

No

5. Has anyone checked fit?

No

6. How often change cartridges (dust things)?

Every Day   No

How do you know when used up?

Smell & Visual

NAME C. [illegible] 9 -25- 299-4786

1. Which respirator did you like best?

AO

2. Which respirator was worst?

MSA

3.

	Ease of Fitting	Seal	Comfort/ Irritation	Draw	Ride Down	Visibility
Welch	2	2	2	2	1	1
AO	2	1	1	2	1	1
MSA	3	3	3	2	1	1

4. Instruction on fitting self?

No

5. Has anyone checked fit?

No

6. How often change cartridges (dust things)?

2-5 days cartriges

How do you know when used up?

Visual