National Paint & Coatings Association

July 21, 1994

NIOSH Docket Office
Robert A. Taft Laboratories
Mail Stop C34
4676 Columbia Parkway
Cincinnati, OH 45226

Dear Sir/ Madam,

Enclosed please find submission of comments in triplicate in reference to the Respiratory Protective Devices Proposed Rule (59 Fed. Reg. 26850, May 24, 1994), 42 CFR Part 84, Docket No. RIN 0905-AB58.

Thank you for your consideration.

Respectfully yours,

H. Allen Irish

H. Allen Irish
Environmental Counsel

JUL 22 1994

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ORIGINAL

Before the

Department of Health and Human Services

Submission of Comments

In Re:

42 C.F.R. Part 84
Docket No. RIN 0905-AB58
Respiratory Protective Devices; Proposed Rule

Request for Comments

(59 Fed. Reg. 27257, July 22, 1994)

On Behalf of the

National Paint and Coatings Association, Inc.

Date Submitted:

July 22, 1994

Submitted by:

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Before the

Department of Health and Human Services

Submission of Comments

In Re:

42 C.F.R. Part 84
Docket No. RIN 0905
Respiratory Protective Devices; Proposed Rule

Request for Comments

(59 Fed. Reg. 27257 July 22, 1994)

I. THE ISSUE

The National Institute of Occupational safety and Health (NIOSH) has examined modifications of the standard on Respiratory Protective Devices (30 C.F.R. Part 11) since assuming primary responsibility for performance testing of respirators from the Mine Safety and Health Administration (MSHA).[1] The proposed regulatory changes contained within this Notice of Proposed Rulemaking (NPR) signal NIOSH's intent to promulgate modifications to 42 C.F.R. Part 84 in a series of modules over approximately the next three years.

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[1] In order to clarify its current authority, NIOSH has taken steps to shift the provisions of 30 C.F.R. Part 11 (Department of the Interior, under MSHA) to 42 C.F.R. Part 84 (Department of Health and Human Services, under NIOSH).

This first module, released as a Proposed Standard on May 24, 1994 (59 Fed. Reg. 26850) begins the process of modifying 42 C.F.R. Part 84, starting with testing procedures and criteria for certifying particulate respirators.

As set forth in the NPR, the proposed changes are intended to reflect advances in respiratory protection technology and involve, among other things:

- Testing respirator filters on their ability to remove a standard sized test particle, rather than testing individual types of particles such as asbestos, fumes and paint spray;

- Changing the classification of respirators to a three-tiered system based on the percent efficiency of the filter;

- Changing filter classification terminology to agree with the new testing classifications;

- Adding/updating information on testing of Powered Air Purifying Respirators (PAPR).

This NPR asserts that these proposed revisions to existing respirator standards will simplify respirator selection for all users of particulate respirators and, additionally, will provide a wider range of respiratory protection choices for use by the health care industry as protection against tuberculosis.

II. STATEMENT OF INTEREST

The National Paint and Coatings Association, Inc. (NPCA) is a voluntary, nonprofit industry trade association representing some 500 member companies engaged in the manufacture and distribution of paint, varnish, lacquer and allied products and the component materials used in the manufacture of such products. Collectively, NPCA's membership produces approximately 80 percent of the total dollar volume of paint and coatings sold in the United States.

NPCA serves as ally and advocate for the coatings industry on legislative, regulatory and judicial issues at the federal, state and local levels. In addition, NPCA provides member companies such services as research and technical information, statistical management information, compliance guidance and community service support.

Respiratory protective devices are frequently and widely used in coatings manufacturing (for example, during the handling, of dry pigments, solvents, and coatings additives). Additionally, respiratory protective devices are widely used by consumers of coatings products, including manufacturers of both durable and nondurable goods (most of which apply coatings during the manufacturing process) and users of architectural and industrial maintenance coatings. Particulate respirators and paint mist filters/prefilters are recommended for use where paints and coatings are spray applied.

NPCA has been involved in respiratory protection issues for over 20 years. For example, as early as November 1973, NPCA issued a Safety and Health Bulletin providing guidelines for developing respiratory protection programs in coatings manufacturing facilities. NPCA's Guide to Respirator Fit Testing was published and distributed to the coatings industry in April 1982. Additionally, in the late 1980s and early 1990s, NPCA collaborated with West Virginia University in Morgantown to study workplace protection factors for elastomeric and disposable half facepiece respirators.[2]

NPCA and its members maintain their interest in issues that affect the respiratory protective devices used by the coatings industry, its suppliers and customers.

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[2] This study was conducted with technical support from Occupational Health and Safety Administration, the Environmental Protection Agency, the Department of Defense, NIOSH, experts and the results have been forwarded previously to these agencies.

III. THE PROPOSED CERTIFICATION CRITERIA WILL NOT PRODUCE FILTERS THAT ARE APPROPRIATE FOR PROTECTION AGAINST PAINT SPRAY

The proposed standard authorizes two tests for the certification of particulate filters, one using solid particulates and one using liquid particulates. This effectively eliminates specialized tests for individual contaminants, such as asbestos, fumes, and – of particular interest to NPCA – paint spray. While the proposed tests are likely to simplify the choice of respirator filters by limiting certification to only a snall number of few filter types, which presumably would be suitable for many applications, the tests will fail to develop standards for filters which would be appropriate for protection against paint spray, as is shown in the following discussion.

a. The proposed test particles are excessively fine compared to paint spray, and the proposed filter efficiencies are much higher than practical for paint particles.

The proposed certification calls for particulate filter tests using solid particles of count median diameter between 0.06 - 0.11 μ (with a standard geometric deviation of 1.86μ).[3] If a filter is designed for use with liquid particulates, the specified liquid particulate test aerosols must have a count

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[3] 59 Fed. Reg. 26885, to be codified as 42 C.F.R. § 84.184, May 24, 1994.

median diameter between 0.17 - 0.22 μ (with a standard geometric deviation not exceeding 1.60).[4]

However, these proposed test standards, while correct and appropriate for many respirator uses, will result in filter standards which will fail to meet the needs of the many users of paints and coatings, since it prescribes test particulates which are significantly smaller than the overspray particles generated during spray painting processes.

Research conducted by one spray gun manufacturer indicate that paint spray particles of 10 -100 μ typically make up 95 percent of the aerosolized volume of coating. Additionally, 99 percent of the sprayed volume is typically produced as particles greater than 3 μ.[5] The optimal aerosol size for paint application is about 20 μ, since smaller particles tend to dry *en route* and not adhere to the target surface.[6] Moreover, for many uses, paint

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[4] Id. While it is unclear whether paint overspray from spray gun application processes should be classified as a liquid or solid (larger particles may be semi-solid, while small particles have larger surface-to-volume ratios that speed evaporation, and most will no longer be in a liquid state by the time they impact on the respirator filter), the proposed standard is inappropriate in either scenario, as these comments will demonstrate.

[5] Telephone interview with Dale Hemming, Paint Spray Gun Technical Consultant, Graco, Inc., Technical Center, a manufacturer of spray guns & equipment, (source of information was stated to be Graco internal product performance studies.) (July 13, 1994).

[6] Telephone Interview with Mike Odum, Technical Consultant, DeVilbiss, Inc., (source of information was internal product development research (July 14, 1994).

aerosols are considered too small to create an adequate finish if a significant portion of the particles are 10 μ or less.[7] While one published study contains sampling data from paint sprays which demonstrate mass median aerodynamic diameters as small as 2.9 - 9.7 μ,[8] a second study found geometric mean aerodynamic diameters of 20-40 μ,[9] which, while not an equivalent measure, is more consistent with the values reported by spray equipment manufacturers. Comparison of the reported sizes of paint overspray particles with NIOSH's proposed test particle demonstrates that the test particle is between 5 and 150 times smaller than the bulk of particles in typical paint overspray to which workers are exposed.

Accordingly, this proposal will result in 100 percent removal efficiency for paint overspray, even at the lowest specified efficiency level (95%), since, as noted above, 99 percent of the volume of paint overspray is thought to be greater than 3 μ.[10]

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[7] General Motors, Inc., "Service Technical Group Training Program" (Document 22001.42-1), (July 1990).

[8] D'Arcy, J.B. and Chan, T.L.: Chemical Distribution in High-Solids Paint Overspray Aerosols. 51 American Industrial Hygiene Association Journal 132 (1990).

[9] Brosseau, L.M., et al., "Particle Size Distribution of Automobile Paint Sprays." 7 Applied Occupational and Environmental Hygiene, 607 (1992).

[10] Even a respirator certified to remove 0.17 - 0.22 μ particles at the 90 percent efficiency level would provide virtually complete filtration for typical paint application processes involving 10 - 100 μ particles.

b. The filters certified under the proposed standard will have greater minimum breathing resistance, and will eliminate the existence limit on maximum breathing resistance, resulting in an added cost to users.

It is well known that higher efficiency filters have an inherently greater breathing resistance and, without special prefilters, offer a shorter service life compared to filters designed to remove larger particles. This situation is exacerbated in the case of paint overspray, which has a tendency to cause rapid clogging of standard particulate filters. This problem has created a requirement for the paint, lacquer and enamel filters produced by most respirator manufacturers.[11]

By eliminating a test for breathing resistance after filter loading, the proposed standard will result in filters that clog more rapidly and thus increase the rate at which users must replace them.[12] This excessively shortened service life (and more frequent filter replacement) will unnecessarily increase the

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[11] These will be eliminated from 42 C.F.R. § 84.206 by this proposed standard. NIOSH currently certifies paint, lacquer and enamel filters (e.g., 3M Company Models 7256, paint spray prefilter). No functional equivalent is proposed by this NPR.

[12] Additionally, the filters certified under the Proposed Standard will have increased initial (baseline) breathing resistance as compared to currently available paint spray filters.

cost associated with use of filters under the proposed certification standard.[13]

The costs associated with increased frequency of replacement will be exacerbated by the requirement for use of high efficiency filters in place of the current paint spray filters, which have been shown to provide adequate protection. In the Preamble to the Proposed Standard, NIOSH suggests that market forces will influence filter development (and presumably cost, breathing resistance and service life) as employers purchase more cost-effective respirators.[14] In NPCA's view, this result is unlikely to come about, since many respirator users have built their existing respiratory protection programs around a particular brand of respirator. Each respirator, in turn, is designed to accept only replacement filters made by the specific manufacturer, limiting the user's ability to substitute better performing and more cost-effective products.

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[13] For example, in one safety equipment supply catalogue, High Efficiency Particulate Air (HEPA) filters cost roughly four times more than paint spray filters ($4 verses $1 respectively). For a small paint shop where ten workers are exposed to high concentrations of paint spray particulates, a switch to high efficiency filters (which must be changed daily rather than weekly due to decreased service life) would impose a significant financial burden. Under these circumstances the annual cost of filters for the respiratory protection program would increase from approximately $500 to $10,000, with no corresponding increase in worker protection.

[14] 59 Fed. Reg. 26859

c. <u>NIOSH needs to include an alternative particle or lower efficiency certification option to meet the needs of painters.</u>

In NPCA's view, difficulties noted herein will not result in improved compliance rates with existing needs for respiratory protection requirements for paint applicators. In fact, these factors are likely to have an adverse effect on workplace respiratory protection programs. As NIOSH must consider all impacts of its rulemaking activities in developing standards, including economic burdens, NPCA contends that NIOSH should modify the proposed standard in a manner appropriate for respirator use in paint applications, particularly as this would not degrade respiratory protection programs in any manner.

Accordingly, to reduce the impact of the Proposed Standard on the paint manufacturing and application industries (which currently use enough respirator filters to warrant specially designed and tested paint spray filters that are able to handle the large diameter, high concentration paint overspray), NIOSH should offer an alternative standard test particulate of larger mean diameter that is more typical of paint particles. This would allow manufacturers to obtain certification for respirator filters suitable for paint overspray.

Alternatively, NIOSH could expand the allowed filter efficiency to include a filter standard which would be that is 90 percent efficient when tested with the finer diameter test particle. This would still offer near-complete filtration for larger particle applications, with a better chance of reducing breathing resistance, increasing service life, and decreasing costs to users.

IV. NIOSH FAILS TO SHOW THAT THE PROPOSED "INSTANTANEOUS PENETRATION-FILTER TEST" PRODUCES RESULTS APPLICABLE TO REAL LIFE LOADING CONDITIONS.

The preamble to this NPR relates that the instantaneous penetration-filter test (high volume, high concentration) is not designed to simulate loading of the filter at the worksite. In NPCA's view, however, filter efficiency during loading under real worksite conditions is ultimately the only factor relevant to ensuring worker protection.

Workplace conditions generally involve intermittent exposures, requiring time-weighted averaging of air sampling, rather than a constant high level exposure.[15] The test concentration of 200 mg/m^3 proposed by NIOSH is more than ten times higher than OSHA's permissible exposure limit (PEL) and five times higher than the usual maximum of about 50 mg/m^3 encountered in a spray painting

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[15] Threshold Limit Values for Chemical Substances and Physical Agents, American Conference of Governmental Industrial Hygienists (ACGIH) (1993-94) at 3.

operation.[16] The resultant higher loading concentrations will cause filters to have a rapidly increasing efficiency as particles collect on the filter and add to its effectiveness. However given the slower, more intermittent loading of the workplace, filters could experience longer periods of lower efficiency than would be seen with the instantaneous penetration-filter test method. While this is not expected to be a problem for paint spray, it could present a hazard to workers, handling pigments, who need protection against smaller respirable particulates.

While, NPCA recognizes that the instantaneous penetration-filter test is a time-efficient means of evaluating respirators. Prior to using this test, NIOSH must first demonstrate, through a comparative study, that workers will be able to rely on respirators tested using this method.[17]

V. PLACEMENT OF THE SECTIONS ON POWERED AIR PURIFYING RESPIRATORS WITHIN THE PROPOSED STANDARD SHOULD BE RATIONALIZED IN THE FINAL RULE.

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[16] NIOSH, Control Technology for Autobody Repair and Paint Shops, (Report Numbers ECTB 179-11a,12a,13a,14a,16a, and 18a) (1993).

[17] NPCA estimates that the length of time for the proposed 200 mg of particulates to contact the filter at the proposed flow rate of 42.5 l/min. and concentration of 200 mg/m^3 is approximately 20 minutes. This is in contrast to the 156 minutes required for a paint spray filter test under the current 30 CFR Part 11.

The added sections on Powered Air Purifying Respirators (PAPRS) are disbursed throughout the section on particulate filter testing. Some of these PAPR sections, such as § 84.185 on flow requirements, will apply equally to organic vapor and chemical PAPR cartridges.

NIOSH could both simplify the organization of the proposed standard and assist users looking for information by rearranging Part 84 to include a separate section addressing basic requirements for PAPRs.

VI. SUMMARY

NPCA supports NIOSH efforts to update the respiratory Protective Device standard and to provide a wider range of respirators able to protect health care workers against tuberculosis. However, this effort should not be made at the expense of those whose protection does not require the combination of smaller test particles and higher efficiency ratings.

NIOSH must consider the increased cost, greater breathing resistance, decreased service life and subsequent decrease in compliance with respiratory protection programs that this standard, as proposed, will cause among the many employees who work with large diameter dusts. NPCA advocates alternatively, NIOSH's amending this standard to authorize an alternative, larger diameter test particle or reduce the low end filter efficiency to 90 percent.

NPCA further recommends that NIOSH rearrange 42 C.F.R, Part 84 to include a section on PAPRs, rather than mixing specific PAPR information among general particulate filter sections.

NPCA will be pleased to meet with NIOSH to provide additional assistance or information concerning any of these recommendations. Additionally, to assist NIOSH in development of future Respiratory Protective Device modules under 42 C.F.R., Part 84, NPCA encloses a copy of a respiratory protection factors study it cosponsored as an attachment to this document.

Respectfully submitted,

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Manager, Health Affairs

H. Allen Irish
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Workplace Protection Factor Study Conducted at Kelly Air Force Base San Antonio, Texas

Prepared by:

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January 1993

Sponsored by

National Paint and Coatings Association

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Introduction

During the period of June 27 and 28, and July 25 and 26, 1990 workplace protection factor (WPF) measurements were made on 22 painters from the 365 paint shop. Workplace protection factor testing was done during the day, evening, and night shifts on those dates. Evening shift had responsibility for starting to prime the aircraft. Night shift had responsibility for finishing priming if need and starting application of top coat. Day shift finished putting on top coat and stenciling of the aircraft. All workers participating in the study were volunteers.

The half facepiece respirators evaluated in the study were the AO 5-Star silicon facepiece, the MSA Comfo II facepiece, and the Scott Model 65 facepiece. All were equipped with HEPA filter/organic vapor cartridge combination air-purifying elements. Respirators were randomly assigned to individual painters and their suitability to wear a particular respirator was assessed with quantitative fit testing. Details of the fit testing procedures are given in the study protocol in Appendix 2.

This report contains the ambient airborne concentration, in-facepiece concentration, and WPF data collected during the study.

Methods

Ambient Airborne Concentration

Estimates of ambient airborne concentration outside the respirator (Co) were made with traditional lapel sampling methods. Cassettes used to estimate Co were located on or in the general area of the worker's lapel. Locating cassettes on the right or left lapel area rested on the decision of those "suiting up" the workers for testing. Sampling substrates were chosen based upon sampling recommendations made by recognized authorities(i.e. NIOSH, ACGIH, etc.) and for compatibility with the analytical procedure.

Outside facepiece sampling for paint overspray was done with a 25 mm closed faced cassette, hose, and sampling pump. Each 25 mm cassette incorporated a polypropylene backup pad, and a polycarbonate pore filter (pore size of 0.5 um). A reducing ring was attached to the under side of the filter to restrict aerosol deposition to a centrally located 18 mm circle on the filter. This was done to keep the paint over spray deposition within the center of the filter and in a circular area small enough to be entirely covered by the proton beam used in the PIXE analysis.

A flowrate of 1 LPM was used for sample collection. Sampling pumps were calibrated to this flow and were checked before and after each WPF test period.

The ambient sample volume V_o was calculated from equation 1.

$$V_o(m^3) = \frac{(T_s * R_o)}{1000\frac{L}{m^3}} \tag{1}$$

where:
T_s is the sample collection period (min); and
R_o is the calibrated ambient sampling rate (LPM)

The ambient concentration Co was calculated from equation 2.

$$Co(ug/m^3) = \frac{(Mo-Mb)}{V_o} \tag{2}$$

where:
Mo is the mass on the ambient filter (ug);
Mb is the mass on the blank filter (ug); and
V_o is the ambient sample volume (m^3).

In-facepiece Sampling

The in-facepiece sample (Ci) was collected through a probe inserted through the facepiece. The mouth of the probe was positioned roughly opposite the front of the mouth of the wearer. The probe was inserted so that it was approximately 0.5 inch off the wall of the respirator facepiece. The in-facepiece sample was taken continuously over both the inhalation and exhalation phases of the respiratory cycle. The inlet probe used for the collection of in-mask samples complied with Davies's criteria for sampling through inlet tubes and its sampling efficiency has been experimentally defined(1). A detailed description of this in-facepiece sampling procedure and it's associated sampling bias and precision has been reported by Myers and Hornung.(2)

The sampling train for in-facepiece sampling was similar with the Co sampling train. The 25 mm closed faced cassette was attached directly to the facepiece probe. A hose connected the cassette to the sampling pump. Each 25 mm cassette incorporated a polypropylene backup pad, and a polycarbonate pore filter (pore size of 0.5 um). A reducing collar was attached to the under side of the filter to restrict aerosol deposition to a centrally located 18 mm circle on the filter. This was done to keep the paint over spray deposition within the center of the filter and in a circular area small enough to be entirely covered by the proton beam used in the PIXE analysis.

Rates for in-facepiece sampling were approximately 2 LPM. Sampling pump flows were calibrated and checked before and after each WPF test collection period.

The in-facepiece sample volume V_i was calculated from equation 3.

$$V_i\,(m^3) = \frac{(T_s x R_i)}{1000\frac{L}{m^3}} \qquad (3)$$

where:
T_s is the sample collection period (min); and
R_i is the calibrated in-facepiece sample rate (LPM)

The in-facepiece concentration Ci was calculated from equation 4.

$$Ci\,(ug/m^3) = \frac{(Mi - Mb)}{V_i} \qquad (4)$$

where:
Mi is the mass on the in-facepiece filter (ug);
Mb is the mass on the blank filter (ug); and
V_i is the in-facepiece sample volume (m^3).

Personal Sampling Pumps

The personal sampling pumps were all constant flow pumps. They were calibrated at the study site by technical support personnel prior to and immediately after each complete WPF sampling period. Pumps were calibrated using bubble flowmeter. Calibration was done on a completely assembled sampling train. Sampling pump flowrates outside the specified range were readjusted to the proper flow rate. The operation of each pump was monitored, roughly every 15-20 minutes, throughout the WPF sampling period to assure that the pumps were working.

Working Blanks

Approximately twenty percent of the workers involved with WPF testing on any given shift were equipped with a "working blank." The working blanks were opened and closed each time the WPF sampling cassettes were opened and closed during the test period. While the test cassettes were in the sampling trains, the working blanks were plugged and attached to the front of the worker's shirt about chest or shoulder level. The working blank cassettes were handled like the test cassettes in all ways. The average value of blank filters served as a correction factor that estimates the background contamination level of the exposure agent.

In addition, unused cassettes were sent to be analyzed as laboratory blind samples for the purpose of further validating the results obtained with blank cassettes.

Sampling Procedure

The respirator and sampling trains worn by study participants were donned in a "clean area" separate from the work area. The clean area was the "non smoking" lunch room. This clean area was used to remove and redon sampling equipment and respirators at all break periods and at the end of each WPF sampling period. New cassettes were used at the start of each new WPF sampling period.

Prior to the beginning of each work shift and at the end of all scheduled and unscheduled break periods, the pumps of both sampling trains were started or stopped simultaneously. Sampling pumps were not started, however, until the worker's respirator had been completely donned. Sampling pumps were stopped simultaneously before permitting a worker to remove his respirator.

Workplace Protection Factor

Workplace protection factor (WPF) is a measure of how well the respirator works when properly used and conscientiously worn. It is calculated by dividing the ambient concentration by the concentration measured inside the respirator.

The following formulas is used to calculate the WPF:

$$WPF=\frac{Co}{Ci} \tag{5}$$

where:

Co is the ambient or outside concentration (ug/m^3); and
Ci is the in-facepiece concentration (ug/m^3)

Results and Discussion

Working Blanks and Filter Blanks

Eleven working blank samples were used and analyzed. Six filter blanks (unused filters loaded into unused cassettes) were used as laboratory blinds and also analyzed. The mass on the working blank filters (Mb) is expressed in terms of total mass (Mb_TM), titanium (Mb_Ti), chromium (Mb_Cr), silicon (Mb_Si) and strontium (Mb_Sr). The average values for these elements were determined to be 0.4748, 0.0079, 0.0456, and 0.0004 ug respectively.

The mass measured on the filter blanks can also be expressed in terms of total airborne mass and elemental mass. The average values for TM, Si, Ti, Cr, and Sr measured on the filter blanks were 1.4006, 0.2518, 0.0176, 0.0548, and 0.0068 ug respectively.

The elemental mass found on the working blanks are compared to those found on the filter blanks in Figure 1. The average total mass measured on the filter blanks seems to be greater than the average total mass found on the working blanks. However, the elemental masses for Ti, Cr, and Sr are about the same. No unusual mass was measured on the working blank filters as compared to the filter blank samples. This suggests that the outside and in-facepiece sampling cassettes have not been subject to any systematic contamination during cassette assembly, handling, and analysis and that any random contamination that occurred is very small.

The working blanks were also analyzed with SAS general linear model (GLM) procedure. The dependent variables were filter mass expressed as Mb_TM, Mb_Ti, and Mb_Cr. The independent variables were paint type, job location, and date of sampling.

None of these statistical models were significant. In other words, the elemental masses measured on the blank filter were not significantly dependent on the type of paint applied, job location, or date of sampling. Therefore, the mass loadings on the working blanks were averaged. The average mass (TM Ti Cr etc.) on the working blanks was then used as a background correction factor for estimating the contamination level of the exposure agent (see Eq. 2 and 4).

Ambient Sampling Results

A total of thirty-eight WPF samples (38 ambient and 38 in-facepiece concentration data points) of paint overspray were collected during application of primer and top coat to aircraft. The ambient concentrations levels can be expressed in terms of total airborne mass (Co_TAM). Total airborne mass represents the total mass of airborne overspray collected on the filter. The TAM on the ambient sample filters is comprised primarily of Ti, Cr, Sr, Si, Cl, and Al. The average percentage of these elements in the TAM are illustrated in Figure 2. It can be seen from the figure that the percentage of Cr, Sr, and Ti in the TAM is dependent on the type of paint being used. Chromium and strontium being the major components of the TAM of the primer and titanium the major component of the TAM of the top coat.

The SAS UNIVARIATE procedure was used to identify potential outliers in the Co_TAM data distribution. One data point was identified as an outlier based on a low Co_TAM concentration of 80.49 ug/m^3. One data point was also identified as an outlier based on a high Ci_TAM concentration of 80.49 ug/m^3. This data point is discussed in the section on "In-facepiece Sampling Results". These data points and their corresponding WPF data sets were excluded from further analysis.

The ambient concentration of chromium is theoretically considered to be linearly related with the ambient concentration of strontium. This reasoning is based on the fact that the ratio of the amounts of these elements is fixed by molecular formula. A correlation analysis was done to verify this relationship.

The following regression function was obtained by using the SAS GLM procedure:

$$Co\_Cr = 0.723 \times Co\_Sr \quad (6)$$

The R^2 for this regression model is 0.9994 which is considered to be a very good fit of the data. Because of the strength of the regression model only concentrations of chromium will be reported. Concentration estimates for strontium can be made by using eq. 6. The SAS output listing of the regression model is given in Appendix 1-A1.

Another correlation analysis was run to evaluate levels of:

1. Co_TAM associated with top coat application and corresponding levels of titanium concentration (Co_Ti);
2. Co_TAM associated with primer application and corresponding levels of chromium concentration (Co_Cr).

The analysis found that Co_TAM and Co_Ti are strongly correlated for top coat ($R^2 = 0.9925$) and Co_TAM and Co_Cr are strongly correlated for primer ($R^2 = 0.9274$).

Based on the strength of these regression models it is possible to estimate exposures to total airborne mass of top coat or primer overspray given the mass of titanium or chromium in a sample. Conversely airborne concentrations can also be estimated for titanium (Co_Ti) and chromium (Co_Cr) given Co_TAM measurements for top coat or primer applications respectively.

The ANOVA tables for the two models are given in Appendix 1-A2. The regression equations resulting from the correlation analysis are expressed as follows.

Primer Application:

$$Co\_TAM = 1{,}458.43 + 2.0086 \times Co\_Cr \tag{7}$$

Top Coat Application:

$$Co\_TAM = 263.07 + 2.1858 \times Co\_Ti \tag{8}$$

The ambient airborne concentration data were checked for normality using the Shapiro-Wilk test. The variables included were Co_TAM, log(Co_TAM), Co_Ti, Log(Co_Ti), Co_Cr, and log(Co_Cr). The reason the log transformation of the concentration data was checked is that environmental data is commonly found to be log-normally distributed. The test statistic (W) and the associated probability (PROB$<$W) for testing the hypothesis (alpha=0.05) that the data come from a normal distribution are summarized in Appendix 1-A3. PROB<W must be greater than or equal to 0 and less than or equal to 1, with small values of PROB<W leading to rejection of the null hypothesis.

Based on the normality test we cannot reject the null hypothesis that Co_TAM, log(Co_TAM), Co_Ti, Log(Co_Ti), Co_Cr, and log(Co_Cr) distributions are normally distributed. Therefore it can be assumed that these variables are normally distributed. For presentation, analysis, and discussion the data will be treated as log-normally distributed.

Ambient concentrations of paint overspray measured on each worker/respirator combination are summarized in Table I. This table identifies the shift, location, type of respirator and type of paint used by each worker.

Ambient paint overspray concentrations, expressed as Co_TAM, for primer application ranged from 1944.6 ug/m^3 to 10,722.7 ug/m^3 (1.944 mg/m^3 to 10.723 mg/m^3). Ambient paint overspray concentrations, expressed as Co_TAM, for top coat application ranged from 385.2 ug/m^3 to 6360.4 ug/m^3 (0.385 mg/m^3 to 6.36 mg/m^3). Ambient titanium concentrations during application of top coat ranged from 7.6 ug/m^3 to 2,870.1 ug/m^3. None of the measured ambient titanium concentrations exceeded the OSHA PEL value of 10,000 ug/m^3.

Ambient chromium concentrations during application of primer ranged from 0.4 ug/m^3 to 4,283.3 ug/m^3. Almost all the measured ambient chromium concentrations for primer application are greater than the OSHA PEL value for chromium (as soluble chromate salts) of 500 ug/m^3. However, the ambient chromium concentrations did not exceed 10 times the OSHA PEL value.

The SAS general linear models (GLM) procedure was used to identify significant differences in ambient airborne concentrations expressed as Co_TAM, Co_Ti, or Co_Cr. The SAS GLM procedure was used to perform the analysis of variance. The response variables were Co_TAM, Co_Ti, and Co_Cr and the independent variables were sample date, location, and their interaction term. Tests on means were done with a Duncan's Multiple Range Test with an alpha=0.05. Because of the strong correlation between Co_Ti and Co_TAM during application of top coat and Co_Cr and Co_TAM during application of primer the ambient exposure data will be discussed in terms of Co_Ti, and Co_Cr. A brief summary of the SAS output for this analysis of variance is given in Appendix 1-A4.

Significant differences between the June and July sampling trips were found in the mean Co_Cr levels measured during application of primer. During June the mean Co_Cr level was 2644 ug/m^3 while during July it was 946 ug/m^3. The reason for this difference is not known. No significant differences were found in the mean Co_Ti levels measured during top coat application between the June (1338 ug/m^3) and July (1469 ug/m^3) sampling periods. In subsequent analyses, the primer and top coat exposure data from these different sampling periods was pooled.

The exposure data was broken down into three groups by the location where the paint was applied. These were top of the fuselage and wings (top), side of the fuselage (side), and under the wings and fuselage (under). The geometric mean (GM) concentration, expressed as Co_TAM, Co_Ti, and Co_Cr, measured in each job location is presented in Table II.

The highest ambient GM concentration of chromium (2,445 ug/m^3), was measured on workers painting on the top of the aircraft (Table II). The lowest ambient levels of chromium (906 ug/m^3) occurred while painting on the side of fuselage. There is a significant difference between the Co_Cr levels measured at the side of the aircraft and those measured on top or underneath of the fuselage and wings (Figure 3).

The highest ambient GM concentrations of titanium (1,632 ug/m^3) was measured on workers applying top coat under the fuselage and wings of the aircraft (Table II). The lowest titanium levels were associated with painting the top of the aircraft (273 ug/m^3). The mean Co_Ti level while painting on top of the fuselage was significantly lower than mean Co_Ti levels measured at the other locations (Figure 4).

During top coat application Co_Ti levels measured during the day shift were significantly greater than those measured during the night shift. It is believed this difference is due to the larger number of painters painting on day shift versus night shift (almost two to one). This leads to higher ambient levels of paint overspray and therefore higher Co_Ti levels.

The SAS GLM procedure was also used to evaluate differences between different brands of respirator. However, there is no significant difference found in the ambient concentrations in which the different respirator were used.

In-facepiece Sampling Results

From the SAS Univariate procedure one in-facepiece data point was identified as an outlier based on a high total airborne mass concentration of 98.86 ug/m^3. An examination of the elemental composition of this in-facepiece sample found that titanium and chromium each comprised less than 0.5% of the total mass. While chlorine and potassium were each found to comprise greater than 30% of the total mass. These facts suggest that the high Ci_TAM was not directly attributable to a high inboard leakage of the respirator. However, to adhere to data handling procedures, this data point and its corresponding WPF data set was excluded from further analysis.

As with the ambient samples the in-facepiece chromium concentration should be linearly related with the in-facepiece strontium concentration because of their presents in the paint as $SrCrO_4$. The following regression function was obtained using the SAS GLM procedure to run a regression on the data:

$$Ci\_Cr = 0.7221 \times Ci\_Sr \tag{9}$$

The R^2 for this regression model is 0.9948 which is considered to be a very good fit of the data. Because of the strength of the regression model only in-facepiece concentrations of chromium will be discussed. Concentration estimates for strontium can be made by using eq. 9. It is important to note the similarity in the coefficients of eq. 6 and 9 (0.723 vs 0.722). Theoretically they should be the same. However, it is worthwhile noting that ambient and in_facepiece filter masses differed by several orders of magnitude. Yet the PIXE analysis was stable and sensitive enough to give virtually identical ratios of these elements. The SAS output listing of the regression model is given in Appendix 1-B1.

Another correlation analysis was run on the in-facepiece data to evaluate levels of:

1. Ci_TAM associated with top coat application and corresponding levels of titanium concentration (Ci_Ti);
2. Ci_TAM associated with primer application and corresponding levels of chromium concentration (Ci_Cr).

The analysis found that Ci_TAM and Ci_Ti are some what correlated for application of top coat ($R^2 = 0.1721$). Ci_TAM and Ci_Cr were more strongly correlated for application of primer ($R^2 = 0.5859$). The reason that these relationships are not as strong as with the ambient samples is illustrated in Figure 5. The major components of the in-facepiece filter mass are not Ti and Cr as with the ambient samples but Cl and Si. Chlorine, most likely as chlorine salts, is present in such large quantity because of the perfuse sweating of the workers. The source of the Si is not known. The amount of Ti and Cr on average represents only a few percent of the total in-facepiece mass. Therefore they are less well correlated.

The ANOVA tables for the two models are given in Appendix 1-B2. The regression equations resulting from the correlation analysis are expressed as follows.

Primer Application

$$Ci\_TAM = 7.90 + 3.41 \times Ci\_Cr \tag{10}$$

Top Coat Application

$$Ci\_TAM = 8.65 + 10.76 \times Ci\_Ti \tag{11}$$

The in-facepiece concentration data were also checked for normality using the Shapiro-Wilk test. The variables include Ci_TAM, log(Ci_TAM), Ci_Ti, Log(Ci_Ti), Ci_Cr, and log(Ci_Cr). The test statistics and the associated probability (PROB<W) for testing the hypothesis that the data are normally distributed are the same as discussed previously and are summarized in Appendix 1-B3.

All the data were found to be log-normally distributed. As a result all subsequent analyses are done on the transformed data.

The in-facepiece concentrations measured on each worker/respirator combination are also given in Table I. The in-facepiece concentrations (Ci) are expressed in terms of total airborne mass (Ci_TAM), titanium (Ci_Ti), chromium (Ci_Cr) and strontium (Ci_Sr). Total airborne mass (TAM) represents the total mass of airborne material collected on the in-facepiece filter. The SAS general linear models (GLM) procedure was used to identify significant difference in the in-facepiece concentrations expressed as Ci_TAM, Ci_Ti, and Ci_Cr. Tests on means were done with a Duncan's Multiple Range Test with an alpha=0.05.

There was no significant difference found in the GM levels of Ci_TAM, Ci_Ti, or Ci_Cr between the June and July sampling trips for either type of paint applied. In subsequent analyses, the primer and top coat in-facepiece exposure data from these different sampling periods was pooled.

The in-facepiece sampling results are summarized by location and type of paint applied in Table III. All the GM concentration levels measured inside the half facepiece respirators for a given location were dramatically less than the corresponding GM ambient concentration levels associated with those locations.

Of those elements reported, chromium is probably the most critical because of its low PEL of 500 ug/m^3. During the period of our sampling, the painters applying primer had average airborne chromium level exceeding this PEL (Table II). However, the corresponding GM in-facepiece Cr levels measured at the top of the fuselage were 0.12 ug/m^3 (range < 0.06 to 0.24 ug/m^3), under the fuselage and wings 0.40 ug/m^3 (range 0.01 to 14.75 ug/m^3), and at the sides of the fuselage 0.18 ug/m^3 (range 0.08 to 0.44 ug/m^3). These mean in-facepiece Cr exposures were not significantly different.

The GM in-facepiece concentration of Ti experienced by workers applying top coat to the side of the aircraft fuselage was found to be significantly greater than the in-facepiece Ti exposures experienced while painting on top of the aircraft.

The geometric mean in-facepiece concentration resulting from respirator use, is presented graphically in Figure 6 and 7. A brief summary of the SAS output for this analysis of variance is given in Appendix 1-B4.

When the in-facepiece concentration data were summarized by type of respirator a significant difference in in-facepiece concentration was found (Table VI). Respirator E3 had a significantly higher in-facepiece concentration of chromium during application of primer. No other differences in in-facepiece concentration were found.

The SAS GLM procedure was also used to evaluate the data for differences in in-facepiece concentrations between shifts. No significant difference was found in in-facepiece concentrations between shifts.

Workplace Protection Factor Results

The results of individual workplace protection factor calculations are given in Table IV for each worker/respirator combination. Workplace protection factor calculations made for application of primer is based on Cr concentrations and for application of top coat they are based on Ti. Workplace protection factors were not calculated using TAM because of the presence of proportionally large amounts of chlorine in the in-facepiece sample mass while virtually no chlorine was present in the ambient sample mass.

The WPFs were checked for normality using the Shapiro-Wilk test. The variables again included WPF_Ti, Log(WPF_Ti), WPF_Cr, and log(WPF_Cr). The test statistics and the associated probability (PROB$<$W) for testing the hypothesis that the data come from a normal distribution are as discussed previously. All the data were found to be log-normally distributed. As a result all subsequent analyses are done on the transformed data. Results of the normality test are summarized in Appendix 1-C1.

The geometric mean WPFs measured for each painting location and type of paint applied are summarized in Table V. and shown graphically in Figure 8 and 9. The SAS general linear models (GLM) procedure was again used to identify significant differences in the WPF measurements calculated from Ti and Cr levels. Tests on means were done with a Duncan's Multiple Range Test with an alpha=0.05. A brief summary of the SAS output for this analysis of variance is given in Appendix 1-C2.

The highest GM WPF value for priming (GM=20,455) was observed during application of primer to the top of the fuselage. This value while considerably higher than the GM WPFs calculated for the other painting locations is not significantly higher. This may be due to the low number of samples collected during priming on top of the fuselage. This painting location also had the highest ambient Cr levels during application of primer.

The highest GM WPF value for applying top coat (GM=5802) was achieved during application of top coat under the fuselage and wings of the aircraft. This is also where the highest ambient levels of Ti were measured. The only significant difference worth mentioning is that the GM WPF achieved while applying top coat under the fuselage and under the wings of the aircraft was significantly higher than the GM WPFS achieved at the other painting locations.

A significant difference was observed in the performance of one of the respirators during the application of primer. Respirator E3 had a significantly lower WPF than the two other respirators (Table VI and Figure 10). The lower WPF is a reflection of the significantly higher in-facepiece concentration of chromium noted previously for this respirator. No significant difference was observed in the performance of respirators during the application of top coat (see Figure 11).

In all painting locations for application of both primer and top coat the average WPFs provided by the half facepiece respirators were substantially higher than 10.

The SAS GLM procedure also indicated that there was no significant differences GM WPFs calculated for different shifts.

Conclusions

The half facepiece elastomeric respirators used in this study when equipped with high efficiency/organic vapor combination air purifying elements appear to provide excellent adjunct exposure control measures to the existing local exhaust ventilation controls. When these respirators are conscientiously worn, used in conjunction with existing controls, and are properly maintained they provide, "effective worker protection."

Table I. Ambient and In-facepiece Concentrations, Reported as Total Airborne Mass, Titanium, Chromium and Strontium by Shift/Date, Location, Worker, Respirator and Type of Paint Application.

Shift/ Date[1]	Loca- tion[2]	Worker	Resp	Co_TAM (ug/m^3)	Ci_TAM (ug/m^3)	Co_Ti (ug/m^3)	Ci_Ti (ug/m^3)	Co_Cr (ug/m^3)	Ci_Cr (ug/m^3)	Co_Sr (ug/m^3)	Ci_Sr (ug/m^3)	Paint Type
D-6	T	31	E2	2365.9	19.9	871.4	0.1	1.1	0.24	1.9	0.00	Top Coat
D-6	T	32	E1	511.9	3.9	175.6	0.1	1.2	0.13	0.5	0.02	Top Coat
D-6	U/F	27	E3	6281.8	15.6	2647.3	0.5	1.3	0.27	3.9	0.02	Top Coat
D-6	U/F	28	E3	6360.4	23.7	2788.4	3.4	1.1	0.58	2.1	0.00	Top Coat
D-6	U/F	29	E1	5346.8	17.4	2131.0	0.2	1.1	0.38	1.5	0.12	Top Coat
D-6	U/F	33	E3	6353.2	3.1	2759.4	0.5	1.1	0.67	2.7	0.84	Top Coat
D-6	U/F	33	E3	2938.6	6.1	1267.4	0.2	0.8	0.02	1.5	0.00	Top Coat
D-6	S	30	E1	1840.4	2.5	694.6	0.5	1.0	0.31	0.6	0.00	Top Coat
D-6	S	34	E1	4806.5	19.3	2076.1	1.6	1.0	0.30	2.9	0.11	Top Coat
E-6	T	37	E2	5837.9	3.7	9.7	0.0	2402.2	0.19	3246.6	0.06	Primer
E-6	U/W	35	E3	4121.2	6.5	9.4	0.0	1656.0	2.16	2341.2	3.03	Primer
E-6	U/F	36	E3	7005.1	2.0	10.9	0.0	2808.3	0.74	3974.1	1.00	Primer
E-6	U/W	39	E2	6063.0	43.6	12.0	2.3	2488.0	0.05	3372.2	0.08	Primer
E-6	S	38	E1	5900.5	6.4	12.1	0.1	2404.2	0.34	3284.6	0.14	Primer
N-6	T	41	E2	10722.7	6.8	19.9	0.7	4283.3	0.14	6059.6	0.00	Primer
N-6	T	42	E2	1955.1	2.1	704.2	0.1	1.0	0.08	1.2	0.00	Top Coat
N-6	S	44	E1	2195.4	94.5	851.0	1.5	0.7	0.34	0.8	0.28	Top Coat
N-6	U/W	45	E3	2206.8	2.7	848.4	0.1	0.4	0.04	4.4	0.00	Top Coat
N-6	U/W	46	E2	5950.7	3.7	12.0	1.0	2465.0	0.28	3279.9	0.04	Primer
N-6	U/W	48	E2	1984.3	2.6	738.0	0.1	0.7	0.00	0.5	0.00	Top Coat

Note: [1] D is 7 a.m. to 3 p.m., E is 3 p.m. to 11 p.m., N is 11 p.m. to 7 a.m., 6 is June 27 and 28 1990, and 7 is July 25 and 26 1990.
[2] T - top of fuselage, U/F - under fuselage, U/W - under wing, and S - side of fuselage.

Table I. (Cont'd) Ambient and In-facepiece Concentrations, Reported as Total Airborne Mass, Titanium, Chromium and Strontium by Shift/Date, Location, Worker, Respirator and Type of Paint Application.

Shift/ Date[1]	Location[2]	Worker	Resp	Co_TAM (ug/m^3)	Ci_TAM (ug/m^3)	Co_Ti (ug/m^3)	Ci_Ti (ug/m^3)	Co_Cr (ug/m^3)	Ci_Cr (ug/m^3)	Co_Sr (ug/m^3)	Ci_Sr (ug/m^3)	Paint Type
N-6	S	47	E3	497.6	4.8	174.8	0.2	1.3	0.09	2.0	0.00	Top Coat
D-7	U/F	35	E1	3552.5	33.6	1627.5	0.2	0.7	0.37	1.3	0.48	Top Coat
D-7	U/F	29	E2	3312.9	11.4	1427.7	0.2	0.8	0.04	1.6	0.04	Top Coat
D-7	U/F	33	E2	2719.2	2.1	1165.7	0.4	0.6	0.01	1.2	0.00	Top Coat
D-7	S	30	E2	1918.4	11.0	790.8	0.3	0.6	0.08	0.8	0.00	Top Coat
D-7	S	34	E3	6311.4	17.5	2870.1	0.2	1.3	0.44	2.1	0.00	Top Coat
E-7	T	37	E1	5685.1	5.6	861.4	0.1	1419.9	0.06	1953.5	0.07	Primer
E-7	U/F	36	E2	1944.6	9.0	158.0	0.3	263.4	0.31	357.3	0.20	Primer
E-7	U/W	39	E3	2599.3	2.0	379.5	0.4	628.6	0.52	869.4	0.63	Primer
E-7	U/W	40	E3	5643.3	60.2	897.7	11.2	1484.4	14.75	1955.4	20.44	Primer
N-7	T	42	E3	385.2	2.9	51.6	0.2	78.7	0.15	113.4	0.13	Top Coat
N-7	U/W	43	E3	5095.0	1.9	2351.4	0.2	0.8	0.02	15.2	0.04	Top Coat
N-7	U/W	46	E1	2129.7	12.7	389.3	0.1	428.0	0.13	601.5	0.02	Primer
N-7	U/W	48	E1	5350.9	9.5	7.6	0.2	2187.8	0.03	3006.9	0.12	Primer
N-7	S	44	E2	3403.9	13.0	557.6	0.1	735.1	0.18	1013.3	0.02	Primer
N-7	S	47	E1	1894.3	1.8	281.0	0.1	421.4	0.10	599.6	0.00	Primer

Note: [1] D is 7 a.m. to 3 p.m., E is 3 p.m. to 11 p.m., N is 11 p.m. to 7 a.m., 6 is June 27 and 28 1990, and 7 is July 25 and 26 1990.
[2] T - top of fuselage, U/F - under fuselage, U/W - under wing, and S - side of fuselage.

Table II. Geometric Mean Concentration of Ambient Levels of Total Airborne Mass, Titanium, and Chromium, for Different Painting Locations.

Location	Airborne Exposure	N	Co_TAM ug/m^3	GSD	Co_Ti ug/m^3	GSD	Co_Cr ug/m^3	GSD
Top	Primer	3	7087	1.4	--	--	2445^{A}	1.7
Under	Primer	9	4115	1.6	--	--	1233^{AB}	2.4
Side	Primer	3	3363	1.8	--	--	906^{B}	2.4
Top	Top Coat	4	977	2.5	273^{B}	3.7	--	--
Under	Top Coat	11	3862	1.5	1632^{A}	1.6	--	--
Side	Top coat	6	2212	2.4	887^{A}	2.7	--	--

Values with different superscripts are significantly different (α = .05)

Table III. Geometric Mean In-facepiece Concentration Levels of Total Airborne Mass, Titanium, and Chromium for Different Painting Locations.

Location	Airborne Exposure	N	Ci_TAM ug/m^3	GSD	Ci_Ti ug/m^3	Ci_Cr GSD	ug/m^3	GSD
Top	Primer	3	5.2	1.4	--	--	0.12	1.8
Under	Primer	9	8.7	3.3	--	--	0.40	6.5
Side	Primer	3	5.3	2.7	--	--	0.18	1.8
Top	Top Coat	4	4.7	2.7	0.13^{B}	1.3	--	--
Under	Top Coat	11	6.7	2.9	0.28^{AB}	2.7	--	--
Side	Top coat	6	12.7	3.5	0.49^{A}	2.6	--	--

Values with different superscripts are significantly different (α = .05)

Table IV. Workplace Protection Factors Calculated from Titanium and Chromium Exposures by Shift/Date, Location, Worker, Respirator and Type of Paint Application.

Shift	Location	Worker	Resp.	WPF_Ti	WPF_Cr	Paint
D-6	T	31	E2	6332	--	Top Coat
D-6	T	32	E1	1242	--	Top Coat
D-6	U/F	27	E3	4852	--	Top Coat
D-6	U/F	28	E3	810	--	Top Coat
D-6	U/F	29	E1	10529	--	Top Coat
D-6	U/F	33	E3	5824	--	Top Coat
D-6	U/F	33	E3	7290	--	Top Coat
D-6	S	30	E1	1341	--	Top Coat
D-6	S	34	E1	1269	--	Top Coat
E-6	T	37	E2	--	12647	Primer
E-6	U/W	35	E3	--	768	Primer
E-6	U/F	36	E3	--	3797	Primer
E-6	U/W	39	E2	--	45767	Primer
E-6	S	38	E1	--	7131	Primer
N-6	T	41	E2	--	29643	Primer
N-6	T	42	E2	7214	--	Top Coat
N-6	S	44	E1	580	--	Top Coat
N-6	U/W	45	E3	9876	--	Top Coat
N-6	U/W	46	E2	--	8696	Primer
N-6	U/W	48	E2	4984	--	Top Coat
N-6	S	47	E3	891	--	Top Coat
D-7	U/F	35	E1	9869	--	Top Coat
D-7	U/F	29	AO	8801	--	Top Coat
D-7	U/F	33	AO	2803	--	Top Coat
D-7	S	30	AO	2441	--	Top Coat
D-7	S	34	E3	16039	--	Top Coat
E-7	T	37	E1	--	22828	Primer
E-7	U/F	36	E2	--	841	Primer
E-7	U/W	45	E3	--	1201	Primer
E-7	U/W	40	E3	--	101	Primer
N-7	T	42	E3	305	--	Top Coat
N-7	U/W	43	E3	11908	--	Top Coat
N-7	U/W	46	E1	--	3344	Primer
N-7	U/W	48	E1	--	65654	Primer
N-7	S	44	E2	--	4191	Primer
N-7	S	47	E1	--	4084	Primer

Note: [1] D is 7 a.m. to 3 p.m., E is 3 p.m. to 11 p.m., N is 11 p.m. to 7 a.m., 6 is June 27 and 28 1990, and 7 is July 25 and 26 1990.
[2] T - top of fuselage, U/F - under fuselage, U/W - under wing, and S - side of fuselage.

Table V. Geometric Mean WPF Estimates Based on Titanium and Chromium as a Function of Painting Location and Paint Type.

Location	Paint	N	WPF_Ti	GSD	WPF_CR	GSD
Top	Primer	3	--	--	20455^{A}	1.5
Under	Primer	9	--	--	3093^{B}	7.9
Side	Primer	3	--	--	4961^{B}	1.4
Top	Top Coat	4	2040	4.5	--	--
Under	Top Coat	11	5802	2.2	--	--
Side	Top coat	6	1803	3.2	--	--

Values with different superscripts are significantly different ($\alpha = .05$)

Table VI. Geometric Mean In-facepiece Concentration of Titanium and Chromium and Resulting Workplace Protection Factor Calculation.

Respirator Type	Paint	N ug/m³	Ci_Ti ug/m³	Ci_Cr	WPF
E1	Primer	5	--	0.10^{A}	$10{,}786^{A}$
E1	Top Coat	6	0.42	--	2243
E2	Primer	6	--	0.17^{A}	8958^{A}
E2	Top Coat	6	0.19	--	4892
E3	Primer	4	--	1.87^{B}	770^{B}
E3	Top coat	9	0.29	--	3532

Values with different superscripts are significantly different ($\alpha = .05$)

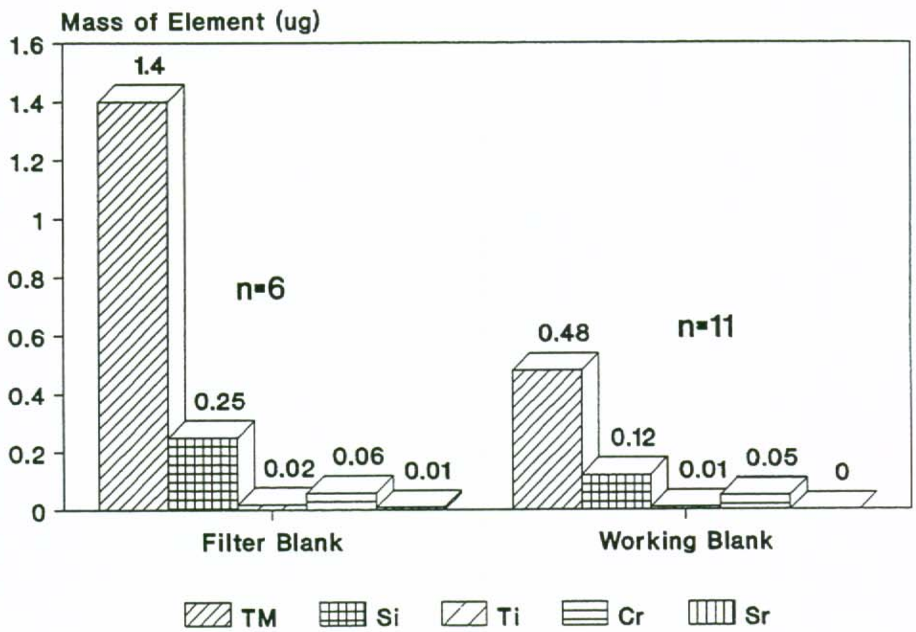


Figure 1 Total Mass and Mass of Various Elements Found on Working Blank and Filter Blank Samples.

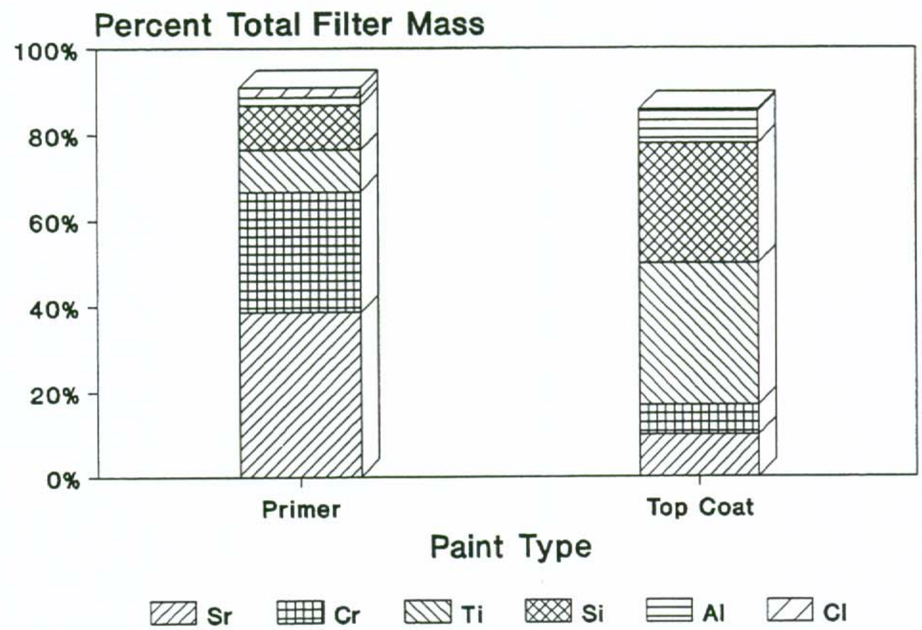


Figure 2 Percent of the Total Ambient Airborne Mass Represented by the Six Major Elements of the Sample.

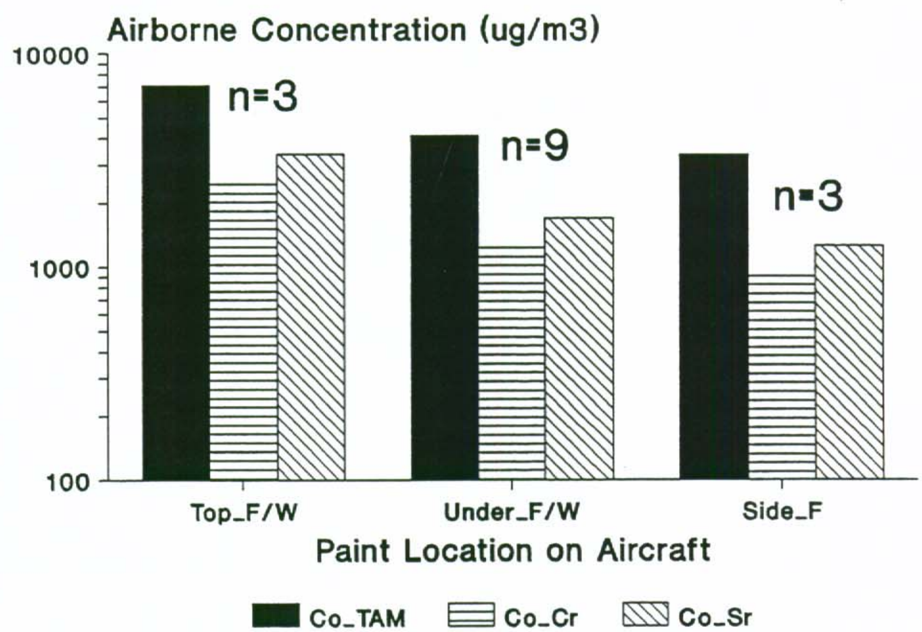


Figure 3. Geometric Mean Concentrations of Total Airborne Mass, Chromium, and Strontium for Primer Application by Location on Aircraft.

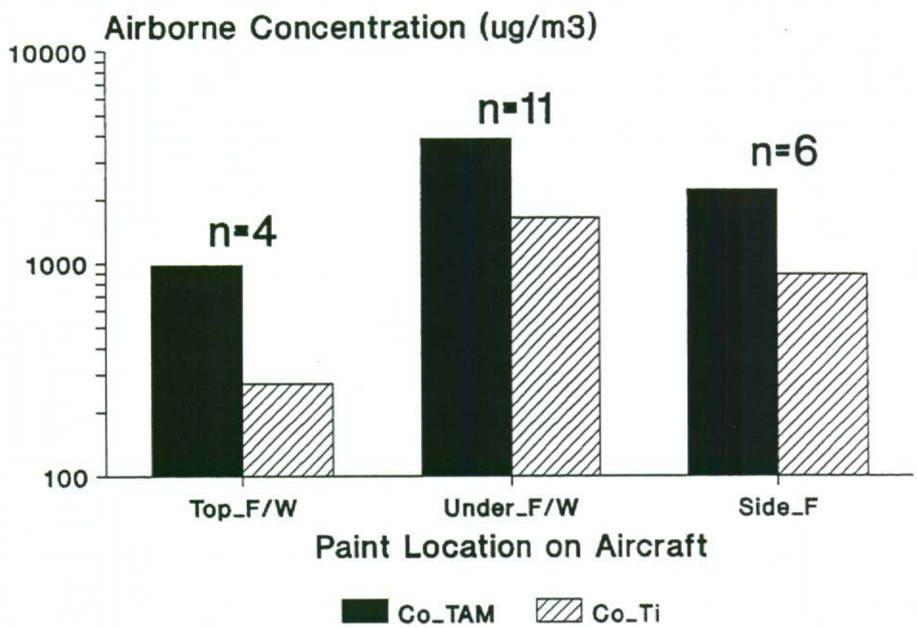


Figure 4 Geometric Mean Concentrations of Total Airborne Mass and Titanium for Application of Top Coat by Location on Aircraft.

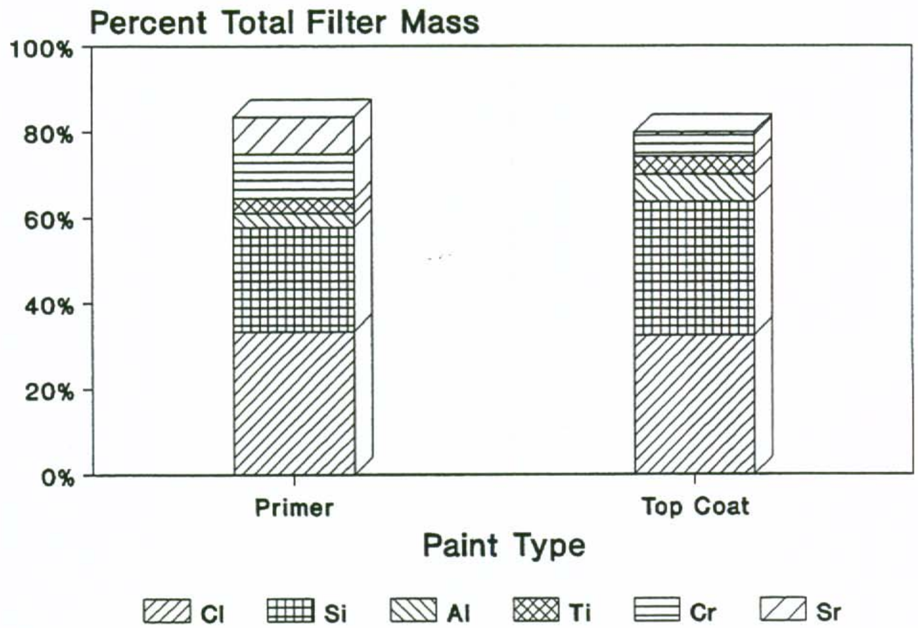


Figure 5 Percent of the Total Airborne Mass Collected on In-facepiece Samples Represented by the Six Major Elements of the Sample.

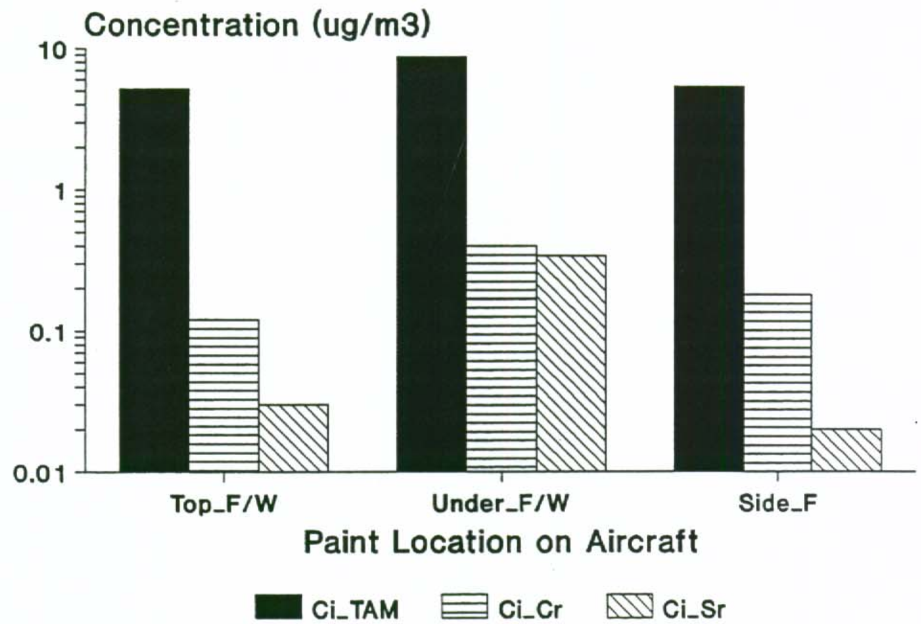


Figure 6. Geometric Mean In-Facepiece Concentrations of Total Airborne Mass, Chromium, and Strontium for Application of Primer by Location on Aircraft.

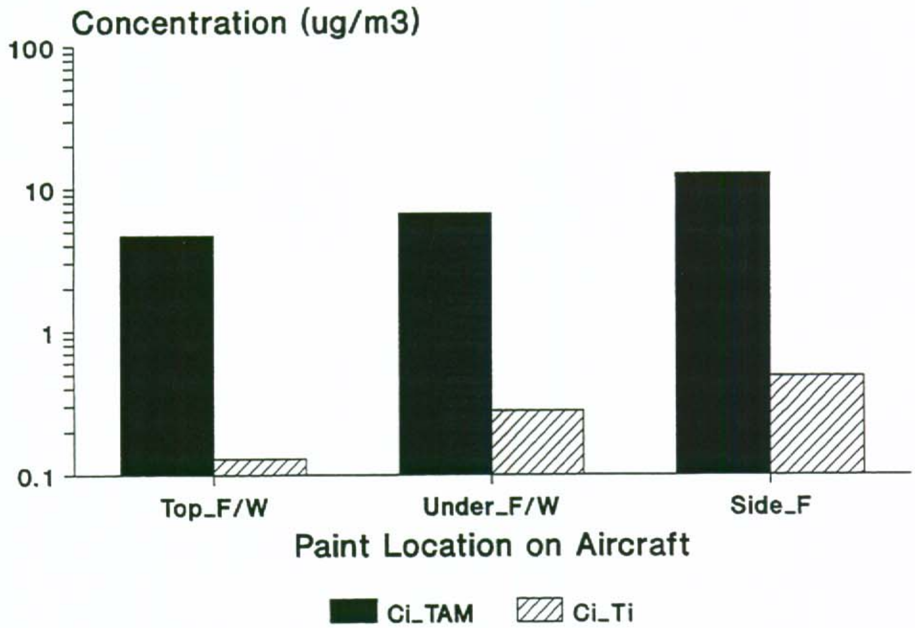


Figure 7. Geometric Mean In-Facepiece Concentrations of Total Airborne Mass and Titanium for Application of Top Coat by Location on Aircraft.

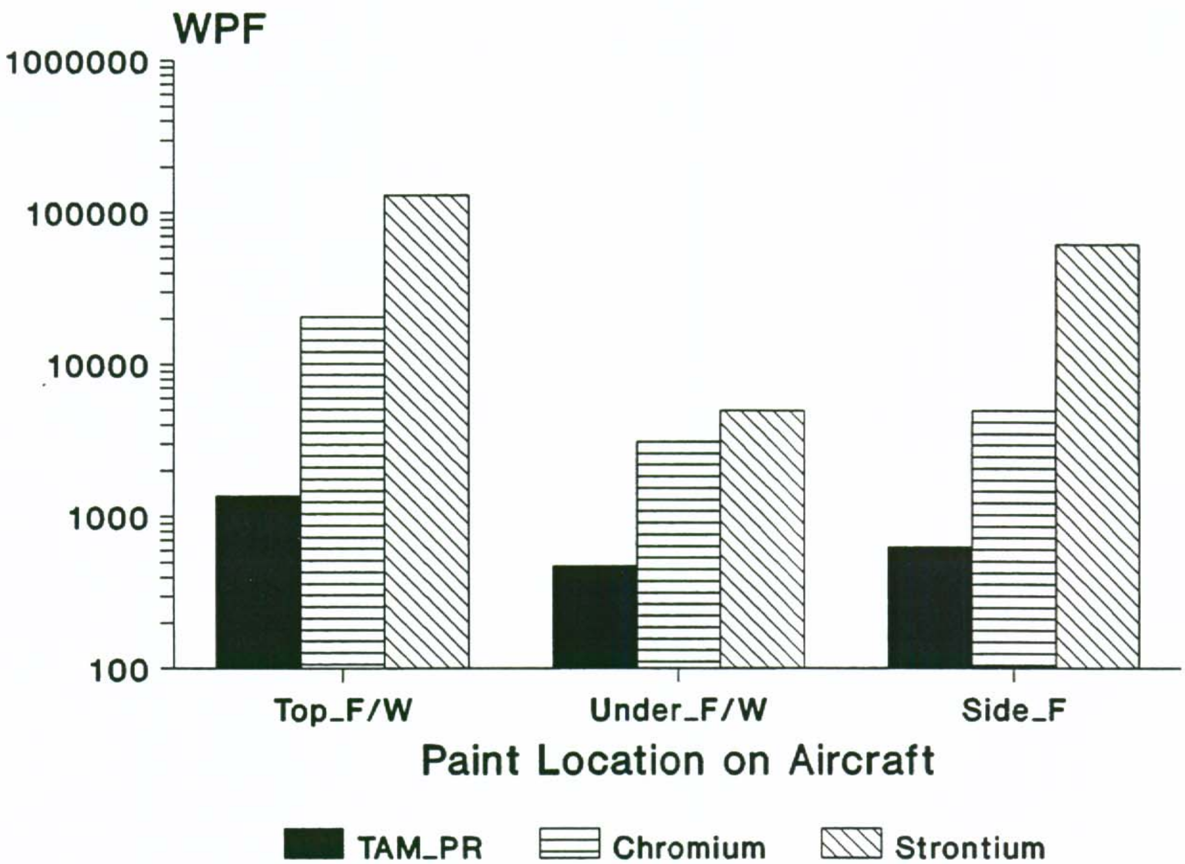


Figure 8. Geometric Mean WPF Measurements for Application of Primer Based on Total Airborne Mass, Chromium, and Strontiumm by Location on Aircraft.

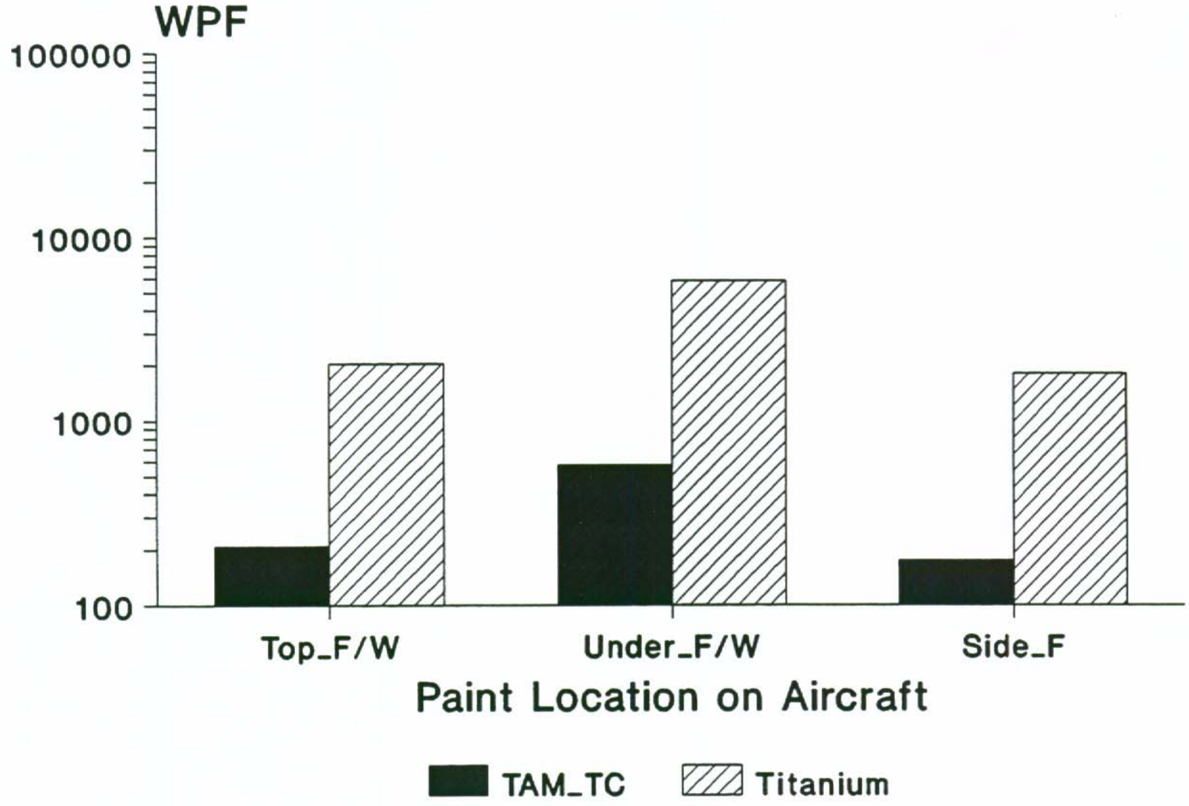


Figure 9. Geometric Mean WPF Measurements for Application of Top Coat Based on Total Airborne Mass and Titanium by Location on Aircraft.

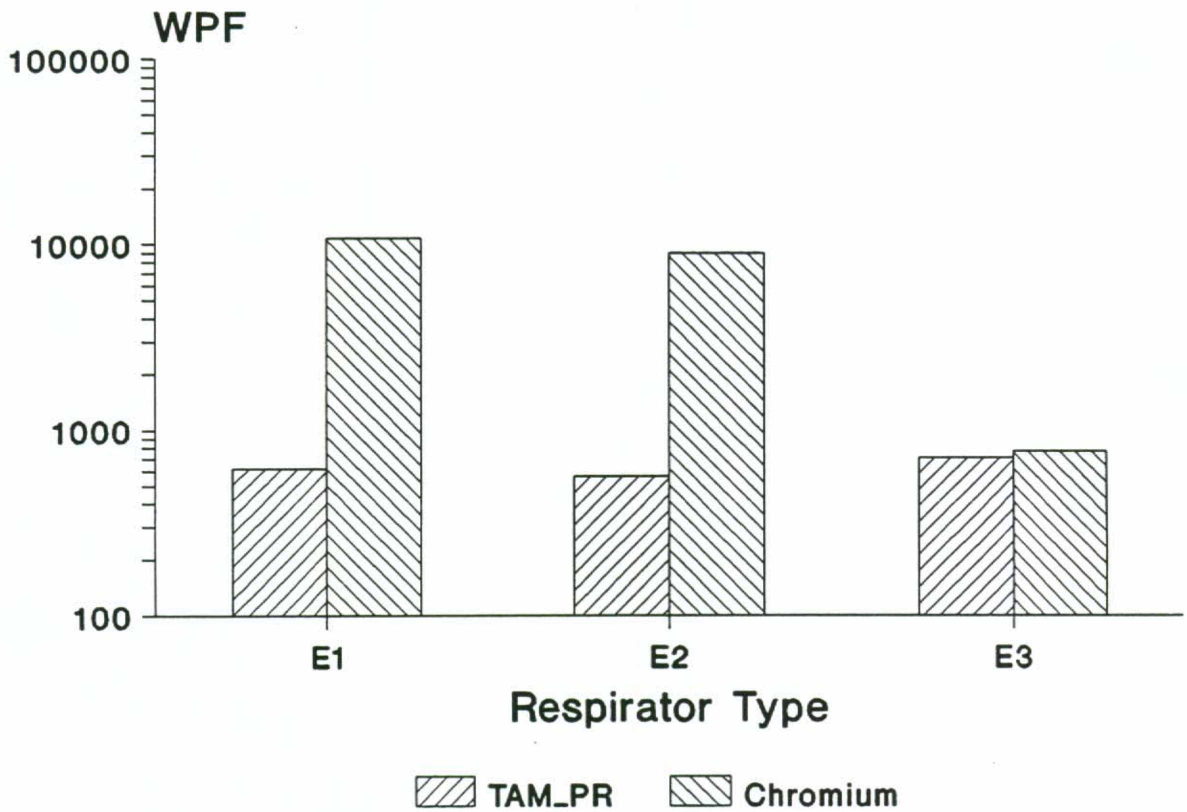


Figure 10 Geometric Mean WPF Measurements for Application of Primer Based on Total Airborne Mass and Chromiun by Respirator Type.

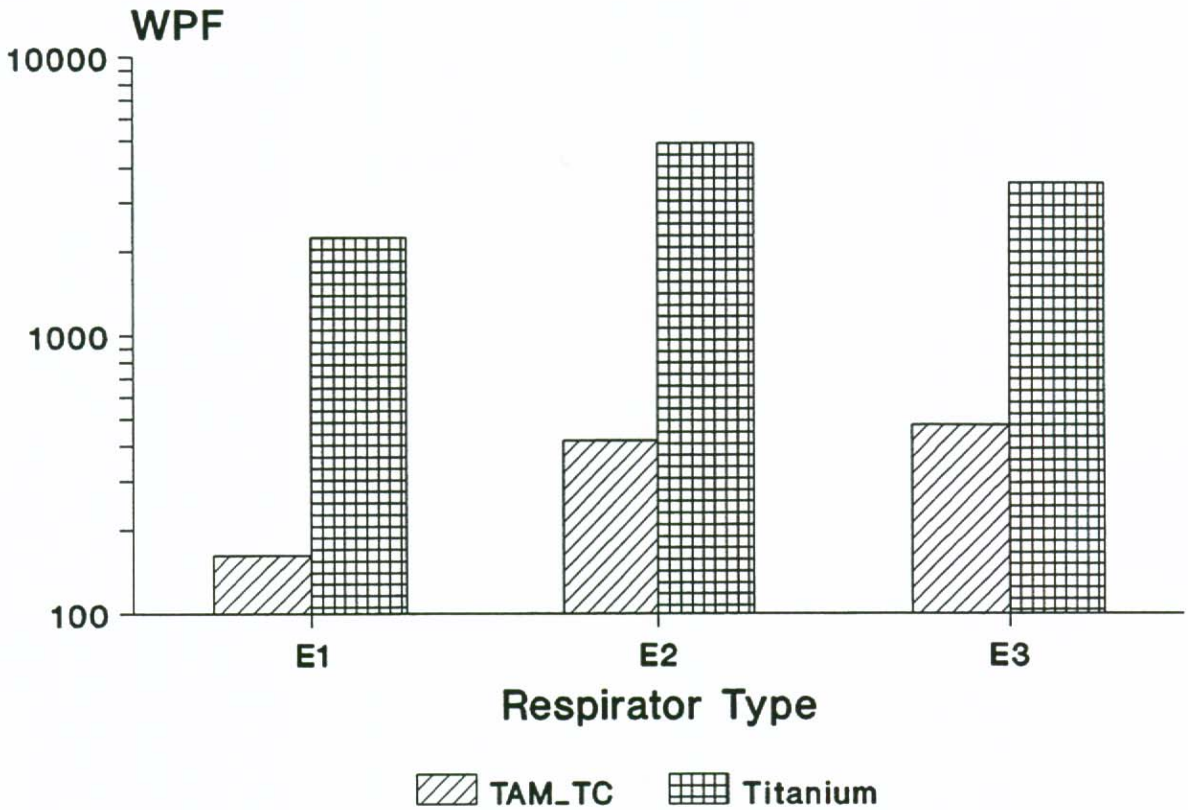


Figure 11 Geometric Mean WPF Measurements for Application of Top Coat Based on Total Airborne Mass and Titanium by Respirator Type.

References

1. Liu, B. Y. H., K. Sega, K. L. Rubow, S. W. Lenhart, and W. R. Myers. In-Mask Aerosol Sampling for Powered Air Purifying Respirators. Am. Ind. Hyg. Assoc. J., 45(5): 278-283 (1984).

2. Myers, W.R. and R.W. Hornung: Evaluation of New In-Facepiece Sampling Procedures for Full and Half Facepieces, IAG No. DW 75931135-01-2, with Water Engineering Research Laboratory, Office of Research and Development, USEPA, Cincinnati, OH.

Appendix 1

Appendix 1-A1 SAS Output Listing for GLM Procedure

Model Co_Cr = Co_Sr

Number of observations in data set = 36

Dependent Variable: Co_cr

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	63134350.9979	61581.8	0.0001
Error	35	35882.3647		
Uncorrected Total	36	63170233.3626		

R-Square	C.V.	Co_Cr Mean
0.999432	4.404089	727.026718

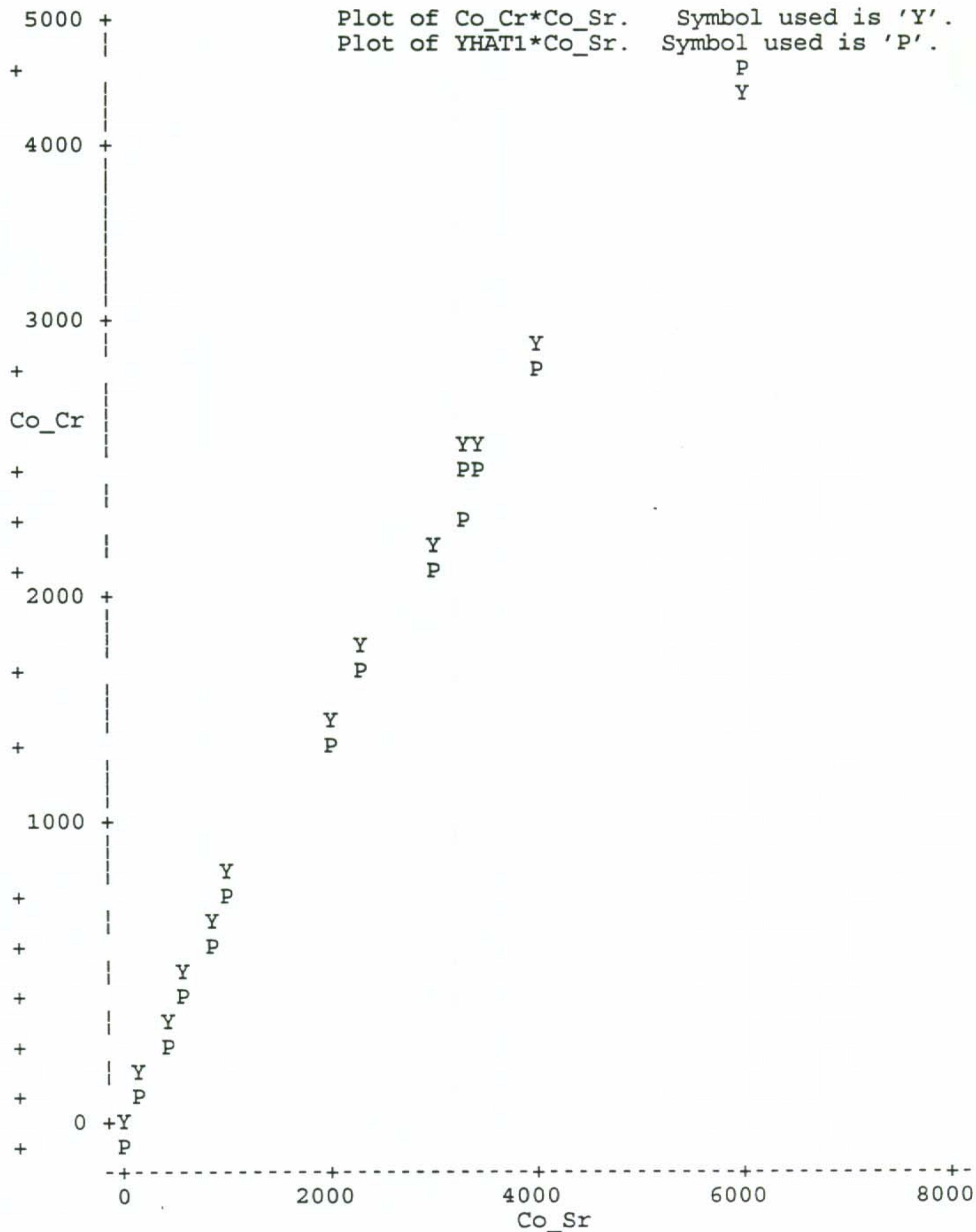
NOTE: No intercept term is used: R-square is not corrected for the mean.

Source	DF	Type I SS	F Value	Pr > F
Co_Sr	1	63134350.9979	61581.8	0.0001

Source	DF	Type III SS	F Value	Pr > F
Co_Sr	1	63134350.9979	61581.8	0.0001

Parameter	Estimate	T for Ho: Parameter=0	Pr > |T|	Std Error of Estimate
Co_Sr	0.7230007407	248.16	0.0001	0.00291348

Appendix 1-A1 (Continued) SAS Output Listing for GLM Procedure



Appendix 1-A1 (Continued) SAS Output Listing for GLM Procedure

```
   Plot of RESID1*YHAT1.  Legend: A = 1 obs, B = 2 obs, etc.
Residual
       |
   100 +
       |                           A
       |
       |
       |
    75 +
       |                A
       |
       |
       |                           A
    50 +                            A
       |
       |
       |
       |                           A
    25 +
       |
       |                        A
       |
       |   A            A
     0 +R      AA
       |AA   A
       |A    A
       |
       |
   -25 +
       |
       |                   A
       |
       |
   -50 +
       |
       |
       |                                A
       |
   -75 +
       |
       |
       |
       |
  -100 +                                                 A
       -+----------+----------+----------+----------+----------+
        0        1000       2000       3000       4000       5000

                           Predicted Co_Cr
```

Appendix 1-A2 SAS Output Listing for GLM Procedure

Model Co_TAM = Co_Cr (Primer Application)

Number of observations in by group = 15

Dependent Variable: Co_TAM

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	71957593.5270	166.16	0.0001
Error	13	5629834.3021		
Corrected Total	14	77587427.8291		

	R-Square	C.V.	Co_TAM Mean
	0.927439	13.29404	4950.15921

Source	DF	Type I SS	F Value	Pr > F
Co_Cr	1	71957593.5270	166.16	0.0001

Source	DF	Type III SS	F Value	Pr > F
Co_Cr	1	71957593.5270	166.16	0.0001

Parameter	Estimate	T for Ho: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	1458.426272	4.56	0.0005	319.76172302
Co_Cr	2.008628	12.89	0.0001	0.15582503

Appendix 1-A2 (Continued) SAS Output Listing for GLM Procedure

Model Co_TAM = Co_Ti (Top Coat Application)

Number of observations in by group = 21

Dependent Variable: Co_TAM

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	81229017.8639	2510.63	0.0001
Error	19	614726.9384		
Corrected Total	20	81843744.8023		

R-Square	C.V.	Co_TAM Mean
0.992489	5.479207	3282.81635

Source	DF	Type I SS	F Value	Pr > F
Co_Sr	1	81229017.8639	2510.63	0.0001

Source	DF	Type III SS	F Value	Pr > F
Co_Sr	1	81229017.8639	2510.63	0.0001

Parameter	Estimate	T for Ho: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	263.0651138	3.66	0.0017	71.92207997
Co_Sr	2.1857923	50.11	0.0001	0.04362321

Appendix 1-A3. W Statistics and the Associated Probability (Ambient Concentrations)

Paint Type	Variables	W Statistics	Probability<W
All	Co_TAM	0.9257	0.0226
All	log(Co_TAM)	0.8721	0.0004
All	Co_Ti	0.8407	0.0001
All (n=36)	log(Co_Ti)	0.8329	0.0001
All	Co_Cr	0.6996	0.0001
All	log(Co_Cr)	0.7445	0.0001
Primer	Co_TAM	0.8950	0.0807
Primer	log(Co_TAM)	0.8959	0.0832
Primer	Co_Ti	----	----
Primer (n=15)	log(Co_Ti)	----	----
Primer	Co_Cr	0.9257	0.2331
Primer	log(Co_Cr)	0.9042	0.1113
Top Coat	Co_TAM	0.9039	0.0387
Top Coat	log(Co_TAM)	0.8650	0.0064
Top Coat	Co_Ti	0.9157	0.0681
Top Coat (n=21)	log(Co_Ti)	0.8483	0.0030
Top Coat	Co_Cr	----	----
Top Coat	log(Co_Cr)	----	----

Appendix 1-A4 SAS Output Listing for GLM Procedure

--------------------------- Primer -------------------------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
DATE	2	1 2
TASK	3	11 12 13

Number of observations in by group = 15

General Linear Models Procedure

Dependent Variable: Log(Co_TAM)

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	2.14564965	4.80	0.0226
Error	11	1.64056169		
Corrected Total	14	3.78621134		

R-Square	C.V.	LMASSO Mean
0.566701	4.602518	8.39081996

Source	DF	Type I SS	F Value	Pr > F
DATE	1	1.64584797	11.04	0.0068
TASK	2	0.49980168	1.68	0.2316

Source	DF	Type III SS	F Value	Pr > F
DATE	1	1.20747615	8.10	0.0159
TASK	2	0.49980168	1.68	0.2316

Appendix 1-A4 (Continued) SAS Output Listing for GLM Procedure

-------------------------- Primer ------------------------

General Linear Models Procedure

Dependent Variable: Log(Co_Cr)

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	6.17979288	6.17	0.0103
Error	11	3.67386498		
Corrected Total	14	9.85365787		

	R-Square	C.V.	LCRCO Mean
	0.627157	8.035194	7.19231789

Source	DF	Type I SS	F Value	Pr > F
DATE	1	5.58689639	16.73	0.0018
TASK	2	0.59289649	0.89	0.4392

Source	DF	Type III SS	F Value	Pr > F
DATE	1	4.57503455	13.70	0.0035
TASK	2	0.59289649	0.89	0.4392

```
-------------------------- Primer ------------------------

               General Linear Models Procedure

     Duncan's Multiple Range Test for variable: Log(Co_TAM)
 NOTE: This test controls the type I comparison wise error
     rate, not the experiment wise error rate

            Alpha= 0.05  df= 11  MSE= 0.149142
            WARNING: Cell sizes are not equal.
          Harmonic Mean of cell sizes= 7.466667

                  Number of Means      2
                  Critical Range  .4391

  Means with the same letter are not significantly different.

       Duncan Grouping              Mean      N  DATE

                     A            8.7449      7    1
                     B            8.0810      8    2


-------------------------- Primer ------------------------

               General Linear Models Procedure

     Duncan's Multiple Range Test for variable: Log(Co_Cr)
 NOTE: This test controls the type I comparison wise error
     rate, not the experiment wise error rate

            Alpha= 0.05  df= 11  MSE= 0.333988
            WARNING: Cell sizes are not equal.
          Harmonic Mean of cell sizes= 7.466667

                  Number of Means      2
                  Critical Range  .6571

  Means with the same letter are not significantly different.

       Duncan Grouping              Mean      N  DATE
                       A            7.8448     7  1
                       B            6.6214     8  2
```

```
--------------------------- Primer ------------------------

              General Linear Models Procedure


      Duncan's Multiple Range Test for variable: Log(Co_TAM)
 NOTE: This test controls the type I comparison wise error
       rate, not the experiment wise error rate

              Alpha= 0.05  df= 11  MSE= 0.149142
              WARNING: Cell sizes are not equal.
            Harmonic Mean of cell sizes= 3.857143

                 Number of Means      2    3
                 Critical Range   .6109 .6395

 Means with the same letter are not significantly different.

       Duncan Grouping              Mean       N  TASK

                     A            8.8660       3  11
                     A
               B     A            8.3225       9  12
               B
               B                  8.1207       3  13

--------------------------- Primer ------------------------

              General Linear Models Procedure

       Duncan's Multiple Range Test for variable: Log(Co_Cr)


                 Number of Means      2    3
                 Critical Range   .9142 .9570
 Means with the same letter are not significantly different.

       Duncan Grouping              Mean       N  TASK

                     A            7.8016       3  11
                     A
               B     A            7.1168       9  12
               B
               B                  6.8095       3  13
```

--------------------------- Top Coat -------------------------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
DATE	2	1 2
TASK	3	11 12 13

Number of observations in by group = 21

General Linear Models Procedure

Dependent Variable: Log(Co_TAM)

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	5.71921326	3.86	0.0284
Error	17	8.40526615		
Corrected Total	20	14.12447941		

R-Square	C.V.	LMASSO Mean
0.404915	8.971268	7.83785878

Source	DF	Type I SS	F Value	Pr > F
DATE	1	0.00325088	0.01	0.9363
TASK	2	5.71596238	5.78	0.0122

Source	DF	Type III SS	F Value	Pr > F
DATE	1	0.02422619	0.05	0.8275
TASK	2	5.71596238	5.78	0.0122

Appendix 1-A4 (Continued) SAS Output Listing for GLM Procedure

-------------------------- Top Coat -------------------------

General Linear Models Procedure

Dependent Variable: Log(Co_Ti)

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	9.56744481	4.45	0.0175
Error	17	12.17636822		
Corrected Total	20	21.74381303		

R-Square	C.V.	LTICO Mean
0.440008	12.29597	6.88290236

Source	DF	Type I SS	F Value	Pr > F
DATE	1	0.00309935	0.00	0.9483
TASK	2	9.56434546	6.68	0.0072

Source	DF	Type III SS	F Value	Pr > F
DATE	1	0.11086451	0.15	0.6989
TASK	2	9.56434546	6.68	0.0072

--------------------------- Top Coat ---------------------------

General Linear Models Procedure

Duncan's Multiple Range Test for variable: Log(Co_TAM)
NOTE: This test controls the type I comparison wise error rate, not the experiment wise error rate

Alpha= 0.05 df= 17 MSE= 0.494427
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 9.333333

Number of Means 2
Critical Range .6856

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	DATE
A	7.8555	7	2
A	7.8291	14	1

--------------------------- Top Coat ---------------------------

General Linear Models Procedure

Duncan's Multiple Range Test for variable: Log(Co_Ti)
NOTE: This test controls the type I comparison wise error rate, not the experiment wise error rate

Alpha= 0.05 df= 17 MSE= 0.716257
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 9.333333

Number of Means 2
Critical Range .8252

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	DATE
A	6.8915	14	1
A	6.8657	7	2

Appendix 1-A4 (Continued) SAS Output Listing for GLM Procedure

--------------------------- Top Coat -------------------------

General Linear Models Procedure

Duncan's Multiple Range Test for variable: Log(Co_TAM)
NOTE: This test controls the type I comparison wise error rate, not the experiment wise error rate

Alpha= 0.05 df= 17 MSE= 0.494427
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 5.910448

Number of Means	2	3
Critical Range	.8616	.9043

Means with the same letter are not significantly different.

Duncan Grouping		Mean	N	TASK
	A	8.2588	11	12
B	A	7.7015	6	13
B		6.8847	4	11

--------------------------- Top Coat -------------------------

General Linear Models Procedure

Duncan's Multiple Range Test for variable: Log(Co_Ti)

Alpha= 0.05 df= 17 MSE= 0.716257
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 5.910448

Number of Means	2	3
Critical Range	1.037	1.088

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TASK
A	7.3978	11	12
A	6.7878	6	13
B	5.6095	4	11

Appendix 1-B1 SAS Output Listing for GLM Procedure

Model Ci_Cr = Ci_Sr

Number of observations in data set = 36

General Linear Models Procedure

Dependent Variable: Ci_Cr

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	223.99617600	6637.04	0.0001
Error	35	1.18122981		
Uncorrected Total	36	225.17740582		

R-Square	C.V.	Ci_Cr Mean
0.994754	26.93334	0.68209201

NOTE: No intercept term is used: R-square is not corrected for the mean.

Source	DF	Type I SS	F Value	Pr > F
Ci_Sr	1	223.99617600	6637.04	0.0001

Source	DF	Type III SS	F Value	Pr > F
Ci_Sr	1	223.99617600	6637.04	0.0001

Parameter	Estimate	T for Ho: Parameter=0	Pr > |T|	Std Error of Estimate
Cr_Sr	0.7221101745	81.47	0.0001	0.00886373

Appendix 1-B2 SAS Output Listing for GLM Procedure

Model Ci_TAM = Ci_Cr (Primer Application)

Number of observations in by group = 15

General Linear Models Procedure

Dependent Variable: Ci_TAM

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	2288.69613536	18.40	0.0009
Error	13	1617.12703286		
Corrected Total	14	3905.82316823		

R-Square	C.V.	Ci_TAM Mean
0.585970	89.61312	12.4459710

Source	DF	Type I SS	F Value	Pr > F
Ci_Cr	1	2288.69613536	18.40	0.0009

Source	DF	Type III SS	F Value	Pr > F
Ci_Cr	1	2288.69613536	18.40	0.0009

Parameter	Estimate	T for Ho: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	7.900028434	2.57	0.0231	3.06857753
Ci_Cr	3.410388998	4.29	0.0009	0.79507893

Appendix 1-B2 (Continued) SAS Output Listing for GLM Procedure

Model Ci_TAM = Ci_Ti (Top Coat Application)

Number of observations in by group = 21

General Linear Models Procedure

Dependent Variable: Ci_TAM

Source	DF	Sum of Squares	F Value	Pr > F
Model	1	1441.76042130	3.95	0.0615
Error	19	6934.47809767		
Corrected Total	20	8376.23851897		

R-Square	C.V.	Ci_TAM Mean
0.172125	134.3102	14.2239744

Source	DF	Type I SS	F Value	Pr > F
Ci_Ti	1	1441.76042130	3.95	0.0615

Source	DF	Type III SS	F Value	Pr > F
Ci_Ti	1	1441.76042130	3.95	0.0615

Parameter	Estimate	T for Ho: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	8.65123895	1.72	0.1013	5.02405388
Ci_Ti	10.75599000	1.99	0.0615	5.41170270

Appendix 1-B3. W Statistics and the Associated Probability

(In-facepiece Concentrations)

Paint Type	Variables	W Statistics	Probability<W
All	Ci_TAM	0.6021	0.0001
All	log(Ci_TAM)	0.9382	0.0578
All	Ci_Ti	0.3913	0.0001
All (n=36)	log(Ci_Ti)	0.9629	0.3343
All	Ci_Cr	0.2582	0.0001
All	log(Ci_Cr)	0.9692	0.4917
Primer	Ci_TAM	0.6214	0.0001
Primer	log(Ci_TAM)	0.9279	0.2505
Primer	Ci_Ti	0.4208	0.0001
Primer (n=15)	log(Ci_Ti)	0.9602	0.6629
Primer	Ci_Cr	0.3702	0.0001
Primer	log(Ci_Cr)	0.9109	0.1405
Top Coat	Ci_TAM	0.5921	0.0001
Top Coat	log(Ci_TAM)	0.9140	0.0627
Top Coat	Ci_Ti	0.5539	0.0001
Top Coat (n=21)	log(Ci_Ti)	0.8622	0.0056
Top Coat	Ci_Cr	0.8998	0.0320
Top Coat	log(Ci_Cr)	0.9239	0.1003

Appendix 1-B4 SAS Output Listing for GLM Procedure

-------------------------- Primer --------------------------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
DATE	2	1 2
TASK	3	11 12 13

Number of observations in by group = 15

General Linear Models Procedure

Dependent Variable: Log(Ci_TAM)

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	1.39941919	0.19	0.9585
Error	9	13.18678432		
Corrected Total	14	14.58620352		

R-Square	C.V.	LMASSI Mean
0.095941	61.65061	1.96340924

Source	DF	Type I SS	F Value	Pr > F
DATE	1	0.26788726	0.18	0.6790
TASK	2	0.86064018	0.29	0.7524
DATE*TASK	2	0.27089175	0.09	0.9126

Source	DF	Type III SS	F Value	Pr > F
DATE	1	0.02570318	0.02	0.8975
TASK	2	0.66335083	0.23	0.8018
DATE*TASK	2	0.27089175	0.09	0.9126

Appendix 1-B4 (Continued) SAS Output Listing for GLM Procedure

-------------------------- Primer --------------------------

General Linear Models Procedure

Dependent Variable: Log(Ci_Cr)

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	5.01593349	0.32	0.8881
Error	9	28.11879121		
Corrected Total	14	33.13472471		

R-Square	C.V.	Log(Ci_Cr) Mean
0.151380	-134.2298	-1.31682494

Source	DF	Type I SS	F Value	Pr > F
DATE	1	0.18433556	0.06	0.8135
TASK	2	4.06147267	0.65	0.5449
DATE*TASK	2	0.77012526	0.12	0.8855

Source	DF	Type III SS	F Value	Pr > F
DATE	1	1.03205620	0.33	0.5795
TASK	2	4.04184418	0.65	0.5464
DATE*TASK	2	0.77012526	0.12	0.8855

Appendix 1-B4 (Continued) SAS Output Listing for GLM Procedure

-------------------------- Top Coat --------------------------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
DATE	2	1 2
TASK	3	11 12 13

Number of observations in by group = 21

General Linear Models Procedure

Dependent Variable: Log(Ci_TAM)

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	3.07163836	0.42	0.8271
Error	15	21.90336140		
Corrected Total	20	24.97499976		

R-Square	C.V.	Log(Ci_TAM) Mean
0.122989	59.83619	2.01950915

Source	DF	Type I SS	F Value	Pr > F
DATE	1	0.05333470	0.04	0.8510
TASK	2	2.72760664	0.93	0.4147
DATE*TASK	2	0.29069703	0.10	0.9058

Source	DF	Type III SS	F Value	Pr > F
DATE	1	0.16285629	0.11	0.7430
TASK	2	2.97772874	1.02	0.3844
DATE*TASK	2	0.29069703	0.10	0.9058

Appendix 1-B4 (Continued) SAS Output Listing for GLM Procedure

-------------------------- Top Coat -------------------------

General Linear Models Procedure

Dependent Variable: Log(Ci_Ti)

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	6.10744106	1.43	0.2701
Error	15	12.81685487		
Corrected Total	20	18.92429593		

R-Square	C.V.	Log(Ci_Ti) Mean
0.322730	-73.94479	-1.25007917

Source	DF	Type I SS	F Value	Pr > F
DATE	1	0.85471263	1.00	0.3331
TASK	2	4.30731201	2.52	0.1138
DATE*TASK	2	0.94541642	0.55	0.5864

Source	DF	Type III SS	F Value	Pr > F
DATE	1	0.55645423	0.65	0.4323
TASK	2	2.11554616	1.24	0.3180
DATE*TASK	2	0.94541642	0.55	0.5864

```
-------------------------- Top Coat -------------------------

              General Linear Models Procedure

      Duncan's Multiple Range Test for variable: Log(Ci_Ti)

NOTE: This test controls the type I comparison wise error
      rate, not the experiment wise error rate

             Alpha= 0.05  df= 15  MSE= 0.854457
             WARNING: Cell sizes are not equal.
           Harmonic Mean of cell sizes= 5.910448

                Number of Means     2     3
                Critical Range  1.144 1.200

Means with the same letter are not significantly different.

       Duncan Grouping             Mean       N  TASK

                    A           -0.7097       6  13
                    A
            B       A           -1.2681      11  12
            B
            B                   -2.0112       4  11
```

Appendix 1-C1. W Statistics and the Associated Probability (Workplace Protection Factor)

Paint Type	Variables	W Statistics	Probability<W
All	WPF_TAM	0.8017	0.0001
All	log(WPF_TAM)	0.9719	0.5687
All	WPF_Ti	0.8223	0.0001
All (n=36)	log(WPF_Ti)	0.8957	0.0024
All	WPF_Cr	0.4941	0.0001
All	log(WPF_Cr)	0.8885	0.0014
Primer	WPF_TAM	0.8378	0.0113
Primer	log(WPF_TAM)	0.9365	0.3325
Primer	WPF_Ti	0.5692	0.0001
Primer (n=15)	log(WPF_Ti)	0.9693	0.8101
Primer	WPF_Cr	0.7324	0.0004
Primer	log(WPF_Cr)	0.9645	0.7348
Top Coat	WPF_TAM	0.7350	0.0001
Top Coat	log(WPF_TAM)	0.9773	0.8651
Top Coat	WPF_Ti	0.9172	0.0732
Top Coat (n=21)	log(WPF_Ti)	0.9212	0.0883
Top Coat	WPF_Cr	0.3827	0.0001
Top Coat	log(WPF_Cr)	0.9040	0.0390

Appendix 1-C2 SAS Output Listing for GLM Procedure

--------------------------- Primer ---------------------------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
DATE	2	1 2
TASK	3	11 12 13

Number of observations in by group = 15

General Linear Models Procedure

Dependent Variable: Log(WPF_TAM)

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	5.19943437	0.85	0.5459
Error	9	10.96311159		
Corrected Total	14	16.16254596		

R-Square	C.V.	Log(WPF_TAM) Mean
0.321696	17.17155	6.42741072

Source	DF	Type I SS	F Value	Pr > F
DATE	1	3.24174383	2.66	0.1373
TASK	2	1.73534361	0.71	0.5162
DATE*TASK	2	0.22234693	0.09	0.9136

Source	DF	Type III SS	F Value	Pr > F
DATE	1	1.22018463	1.00	0.3430
TASK	2	1.78245976	0.73	0.5077
DATE*TASK	2	0.22234693	0.09	0.9136

Appendix 1-C2 (Continued) SAS Output Listing for GLM Procedure

-------------------------- Primer --------------------------

General Linear Models Procedure

Dependent Variable: Log(WPF_Cr)

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	11.14833155	0.64	0.6769
Error	9	31.43757533		
Corrected Total	14	42.58590688		

R-Square	C.V.	Log(WPF_Cr) Mean
0.261785	21.96430	8.50914282

Source	DF	Type I SS	F Value	Pr > F
DATE	1	3.74158797	1.07	0.3277
TASK	2	6.48233032	0.93	0.4301
DATE*TASK	2	0.92441326	0.13	0.8777

Source	DF	Type III SS	F Value	Pr > F
DATE	1	0.67206427	0.19	0.6713
TASK	2	7.05530599	1.01	0.4021
DATE*TASK	2	0.92441326	0.13	0.8777

-------------------------- Top Coat --------------------------

General Linear Models Procedure
Class Level Information

Class	Levels	Values
DATE	2	1 2
TASK	3	11 12 13

Number of observations in by group = 21

General Linear Models Procedure

Dependent Variable: Log(WPF_TAM)

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	7.36208520	1.18	0.3625
Error	15	18.64689632		
Corrected Total	20	26.00898151		

R-Square	C.V.	Log(WPF_TAM) Mean
0.283059	19.16275	5.81834963

Source	DF	Type I SS	F Value	Pr > F
DATE	1	0.08292068	0.07	0.7997
TASK	2	6.63016613	2.67	0.1021
DATE*TASK	2	0.64899839	0.26	0.7737

Source	DF	Type III SS	F Value	Pr > F
DATE	1	0.00094499	0.00	0.9784
TASK	2	5.82146862	2.34	0.1303
DATE*TASK	2	0.64899839	0.26	0.7737

Appendix 1-C2 (Continued) SAS Output Listing for GLM Procedure

-------------------------- Top Coat -------------------------

General Linear Models Procedure

Dependent Variable: Log(WPF_Ti)

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	16.39451982	4.96	0.0071
Error	15	9.92216901		
Corrected Total	20	26.31668882		

R-Square	C.V.	Log(WPF_Ti) Mean
0.622970	10.00018	8.13298153

Source	DF	Type I SS	F Value	Pr > F
DATE	1	0.75487407	1.14	0.3023
TASK	2	6.34617513	4.80	0.0245
DATE*TASK	2	9.29347061	7.02	0.0070

Source	DF	Type III SS	F Value	Pr > F
DATE	1	0.03561544	0.05	0.8196
TASK	2	7.92746626	5.99	0.0122
DATE*TASK	2	9.29347061	7.02	0.0070

------------------------- Top Coat -------------------------

General Linear Models Procedure

Duncan's Multiple Range Test for variable: Log(WPF_Ti)

NOTE: This test controls the type I comparison wise error rate, not the experiment wise error rate

Alpha= 0.05 df= 15 MSE= 0.661478
WARNING: Cell sizes are not equal.
Harmonic Mean of cell sizes= 5.910448

Number of Means	2	3
Critical Range	1.007	1.056

Means with the same letter are not significantly different.

Duncan Grouping	Mean	N	TASK
A	8.6659	11	12
B	7.6208	4	11
B			
B	7.4975	6	13

Appendix 2

RESEARCH PROTOCOL TO MEASURE WORKPLACE PROTECTION FACTORS ON SELECTED ELASTOMERIC AND DISPOSABLE HALF FACEPIECE RESPIRATORS

sponsored by
THE NATIONAL PAINTS AND COATINGS ASSOCIATION

SUMMARY

The National Paints and Coatings Association is sponsoring a series of field studies to measure workplace protection factors (WPF) for elastomeric and disposable half facepiece respirators against particulate contaminants. Field studies are anticipated in foundries, silica sand processing operations and aircraft and ship maintenance and repair operations. Particulate contaminants anticipated from these industries/operations include dust, fume, and pigments of various metal composition (i.e. lead, copper, iron, tin, etc.) and silica dust.

This protocol is modelled after a workplace protection factor protocol developed by a team of NIOSH scientists for field studies conducted by the Field Investigations Section, Injury Research Prevention Branch, Division of safety Research. All applicable components, procedures, and criteria of the NIOSH protocol were adopted. Some additional components were added to the NIOSH protocol to deal with the unique features of the facilities and contaminants covered by this protocol.

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INTRODUCTION

The National Paint and Coatings Association (NPCA), is an industry trade group based in Washington that represents the manufacturers of paints and coatings and their suppliers. The National Paint and Coatings Association has had a strong involvement in research activities to improve the safety and health of employees and customers for many years. These activities include development of the Hazardous Materials Identification System (HMIS), development of fit test training materials, and epidemiology studies of the effects of solvents on the nervous system of paint manufacturing employees. As part of this on going research involvement, the NPCA is sponsoring a study on the workplace performance of respirators. Respirators play an important role in the protection of paint applicators. Use of paints does not lend itself readily to control through engineering means. Examples of such activities are maintenance painting of large objects such as bridges, storage tanks, and aircraft.

The National Paint and Coatings Association is serving as the umbrella organization for this effort, providing a forum for various groups to interact and agree on a test protocol. A steering committee has been formed to provide input and technical guidance and comment on the development of this research protocol. The steering committee has representatives from government, labor, industry, trade associations national laboratories and academia. A list of attending groups is attached as Appendix C. The presence of representatives from government agencies was to provide opportunity for these agencies to provide technical comment on the research and does not imply in any way formal endorsement of this study by those agencies.

PROTOCOL

The main goal of this research study is to provide data on the workplace performance of negative-pressure, half facepiece respirators against airborne particulate contaminants. Included within this class of respirator are elastomeric and disposable facepiece designs. Performance will be assessed by determining workplace protection factors (WPF). The WPF is defined as 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. It is defined as the workplace contaminant concentration which the user would inhale if he 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, only while the respirator is properly worn and conscientiously used during normal work activities.

When dealing with assessments of workplace performance, it is important to distinguish between WPF and program protection factor (PPF). The program protection factor is defined as a measure of the respiratory protection provided to a worker by an established respirator program. It is defined as the contaminant concentration which the user would inhale if he were not wearing the respirator(C_o) divided by the contaminant concentration inside the respirator facepiece measured as the respirator is used in the context of the existing respirator program(C_i). The inside of the respirator facepiece concentration may be estimated indirectly from biological monitoring as the airborne concentration expected to produce the measured biological index. The program protection factor is a measure of the effectiveness of the complete respirator program. Factors which may effect the program protection factors are respirator training, maintenance, storage, supervision, program administration and monitoring, and any other variable that affects program effectiveness. If any of these program elements are deficient, the program protection factor could be adversely affected. It is not the objective of this study to measure the PPF achieved with half facepiece respirators in the workplaces and under the *in situ* respirator program conditions that may exist in individual plant facilities at the time of this study. Rather the data is to provide information in the form of WPFs. These data can then be used with WPF data collected by other researchers and research organizations to set assigned protection factors (APF) on half facepiece respirators. 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. The maximum use concentration for a respirator is generally determined by multiplying a contaminant's exposure limit by the protection factor assigned to a particular class of respirator.

The term "fifth percentile WPF" will be used to denote the value which divides the WPF distribution for some subgroup of data (e.g. respirator wearers exposed to a particular agent) into the lower 5% and the upper 95%. For this study the fifth percentile WPF determined for a population of six half facepiece respirators against various airborne particulate agents, work tasks, worker activity levels and work sites will be referred to as an assigned protection factor (APF). These data may be limited in number therefore, when or if they are combined with other WPF data, calculated APF levels may be different than those calculated and reported on in this study.

This protocol contains an outline of 1) the study design and 2) a detailed description of the sampling strategy data collection, and field activities.

STUDY DESIGN

This section summarizes the primary and secondary objectives of the study, the general approach to accomplish them, and hypotheses to be tested. The primary and secondary objectives are as follows.

A. Primary Objective 1
Measure workplace protection factors (WPF) for three elastomeric and three disposable half facepiece respirators against several particulate exposure agents. Potential agents include lead dust and fume, silica dust, various metal dusts and fumes, and various metal pigments.

Each field study will measure WPF's for a sample of workers, chosen as randomly as practical, exposed to a specific exposure agent(s). An exposure agent(s) will be selected if there is a sufficient number of exposed workers who could be sampled and if analytical/sampling procedures are available to accurately measure the relatively low concentrations anticipated inside the respirator. Facilities, job tasks, and finally, individual workers will then be chosen, when practical, who are subject to quantifiable workplace concentrations of those agents. Facial anthropomorphic measurements will not be taken.

The actual workers sampled will be chosen as randomly as practical from a pool of workers who meet this criteria. Selection for these parameters may be done more as a "representative" rather than a "random" sample. It will still be more appropriate, however, to think of these factors as random rather than fixed because we have no special interest in the individual ones which are chosen. Any necessary restrictions on the sampling will help determine the definition of the final population sampled.

B. Primary Objective 2

Determine with the pooled WPF data, estimates of geometric mean, geometric standard deviation(assuming for discussion a lognormal distribution), and the fifth percentile WPF with confidence intervals for the class of half facepiece respirator, as represented by the half facepieces used in this study, against all exposure agents studied.

The WPF data will be used to compute a single estimated APF with confidence intervals for the entire population of workers and half facepiece respirators studied. The methods to be applied for the statistical analysis and interpretation of the WPF data and for estimating the APF will follow the tenor of those outlined in the NIOSH field study protocol.[1]

C. Secondary Objective 1

If the data fulfills statistical conditions of normality, homogeneity of variance, etc. it will be used to determine if a statistically significant difference exists between the geometric means and estimated fifth percentile WPF values for the different exposure agents studied. The method for estimating the subgroup APF is outlined in the NIOSH field study protocol.[1]

SAMPLING STRATEGY AND DATA COLLECTION

Exposure Agent Selection

Candidate particulate exposure agents will be selected by the research manager based on the following criteria:

A. It exists in the occupational environment at exposure levels and exposure durations that would allow quantitative determination of inside facepiece concentrations;
B. A sensitive analytical method exists for the material which is capable of measuring up to 500 fold reductions in 1 hour time-weighted exposure estimates;
C. The efficiency of the sampling substrate will not be severely compromised by the high humidity encountered when collecting the inside facepiece samples;
D. A sufficient number of potentially exposed workers can be identified from which to select the sample; and
E. Particulates that are selected are relatively non-hygroscopic.

Some potential candidates that may meet the above criteria are listed below.

A. Welding fume(s);
B. Silica in silica milling and processing;
C. Metal particulate and fume - foundries, primary or secondary smelting, etc.; and
D. Metal pigments.

Final selection of exposure agents, sampling methods, and sampling sites will be made after walk through surveys have been conducted.

Facility Selection

Selection of facilities by the research project manager will be based on the following criteria:

A. That half facepiece negative pressure respirators are in use at the facility;
B. The facility will be operational and will be operationally stable for the duration of the study;
C. That sufficient workers, approximately fifteen or more, are present at the work site or at nearby work sites so that a field survey could be cost effectively conducted;
D. Workers have been or can be trained in the wearing of respirators;
E. That a quantifiable ambient concentration for each exposure agent is present at a level such that analytical detection of the reduced concentrations inside the facepiece is possible;
F. That a minimum sampling period of one hour exists during any one uninterrupted period of wear; and
G. That the exposure agents meet the criteria given in Section I. Exposure Agent Selection.

Whether a facility has satisfactorily met the criteria will be based upon information gathered from interviews and observations made through walk-through surveys of the facility as well as documentation of their respiratory protection program and industrial hygiene sampling records.

Worker Selection and Instruction and Monitoring

A. Selection

The actual workers to be sampled will be randomly selected from a pool of those meeting potential exposure criteria. Should a facility have a small number of respirator wears it is likely that 100% of them may be studied.

Worker participants will be selected based on consideration of the following:

1. They must wear a respirator as part of their work activity and be willing, voluntarily to participate in the study;
2. Their ambient exposure levels need to be within the use constraints of a half facepiece respirator;
3. They meet the criteria specified in 29 CFR 1910.134 for respirator wearers such as exclusion of beards, sideburns, etc and that they not chew gum or tobacco; and
4. They have passed a fit test for each type/brand of half facepiece they would be asked to wear during the research study.

Once a test site has been selected and work tasks with sufficient exposure identified, workers will be selected, briefed on the aspects of the study and asked to participate. The briefing will detail the points listed in the following outline:

1. Purpose of the study
   a. Determine performance in the work place
   b. Add to data base of information
2. What will take place
   a. Testing several brands of respirators
   b. Being fit tested to determine which ones they can wear
   c. Measuring performance by taking air samples from inside the facepiece and the ambient air
   d. They will wear a given respirator, for which they have received a satisfactory fit test, for the complete work shift and sampling pumps and sampling trains for that part of the time we will take WPF samples
3. What are fit tests
   a. Quantitative - measure leakage with an instrument
   b. Qualitative - use sense of taste to tell if leakage occurs
4. Description of respirators
   a. Elastomeric type - facepiece on which filters attach
   b. Disposable - the facepiece is the filter
5. What they can do to help
   a. Follow all instructions and cooperate
   b. Let someone know if any problems develop
   c. Don't remove facepiece without assistance
   d. Go about normal work activity, we're not here to "check up" on you

The "consent to participate" and the "letter to participant" forms (Appendix A and B appended to the final protocol) will be explained to the workers, and they will be asked for their signed consent. In accordance with the requirements prescribed in the OSHA hazard communication standard, 29 CFR 1910.1200[2], the test subject will be provided a copy of the MSDS for the testing agent. A test subject will be allowed to decide not to participate in the study based on the MSDS. Signed forms of workers who agreed to participate will be maintained on file in the Project Research Manager's office Room 729, Dept. of Ind. Eng., College of Eng., West Virginia University, Morgantown, WV.

B. Instruction and Monitoring

Each worker will be instructed in the proper use of his respirator by a member of the field study team. These instructions will be provided in accordance with respirator manufacturer's instructions regarding the use of the respirator. Each worker participating in this study will also be given explicit instructions not to remove or otherwise intentionally break the facepiece seal while in his work area. To assure that this requirement is not disregarded, the activities of participating workers will be monitored by a research field team member during all periods that air samples are being collected for each test respirator being worn.

Respirator Selection, Inspection, and Use

Only NIOSH/MSHA approved respirators will be included in the study. Six half facepiece respirators, three elastomeric and three disposable will be tested. Specific brand/model selection will be based upon the brand/model of respirator(s) used in the test facilities. Based upon initial contact with three foundry test sites the elastomeric facepieces will be MSA, Scott, and AO used in both a dust and a fume filter respirator configuration. The disposable facepieces will be the 3M 9920(fume), 8710(dust), and Gerson(dust).

Respirators will be purchased on the "open market". They will be visually inspected and will not be used if found to have missing and/or defective parts or do not conform to the NIOSH/MSHA approved configuration as stated on the NIOSH/MSHA approval label. Samples of each lot of air purifying filters and disposable facepieces will be kept for record material.

Respirators probed for quantitative facepiece fit testing and WPF measurement will also be inspected to verify that attachment of the probe assembly did not compromise the integrity of the facepiece. The probe connection will be visually checked for sources of leakage at the facepiece - probe interface. Respirator probing will be done in such ways as to minimize any impact of the probe and accompanying in-facepiece sampling train on the form, fit, or function of the respirator. All respirators will be maintained by the research field team according to manufacturer's instructions.

Elastomeric respirators will be cleaned inside and out and the valves and head straps inspected for damage at the end of each shift. During times when the respirator is not worn on the face(i.e. breaks, lunch,etc.) the probe mouth will be plugged to prevent contamination of the in-facepiece sample however, the facepiece will not be wiped out or cleaned unless such cleaning represents standard practice by the worker or the employer. The probe mouth will be unplugged when the respirator is worn and in-facepiece sampling is being conducted. When the respirator is being worn and in-facepiece sampling is not being conducted the probe will also be plugged.

Air purifying filters will be changed as a minimum at the end of each shift unless employer use policy dictates filters are to be changed more often or the worker detects an increase in breathing resistance. Replacement of disposable respirators will be done as a minimum at the end of each shift unless the use policy of the employer allows the worker to change respirators more frequently or unless the respirator becomes difficult to breath through or becomes damaged.

Analytical Methods

The analytical method of choice for this field study is Proton Induced X-Ray Emission (PIXE)[3-6]. PIXE is an X-Ray spectroscopic technique, which can be used for the non-destructive, simultaneous analysis of solid, liquid or aerosol filter samples. The X-ray spectrum is initiated by energetic protons exciting the inner shell electrons in the target atoms. The expulsion of these inner shell electrons results in the production of X-rays. The energy of the X-rays, which are emitted when the created vacancies are filled again, are uniquely characteristic of the elements from which they originate and the number of X-Rays emitted is proportional to the mass of that corresponding element in the sample being analyzed. Data reduction is then completed by the normalization of the measured sample X-ray intensities detected against the intensity measured from pure element standards for each element which has been corrected for sample thickness differences.

The detection limits that can be achieved for PIXE analysis on aerosol type substrates will range from 75 ng/cm2 to 1 ng/cm^2 for the elements from Na to U. The detection limits for specific elements will vary based upon such factors as atomic number (X-ray production cross-sections, and X-ray absorption are atomic number dependant), irradiation time, matrix interferences, detector efficiency (solid angle and X-ray energy dependant), and beam intensity. For example, sodium has a very high X-ray production cross-section but because the energy of it's X-ray is so low it is severely absorbed and therefore has the worst detection limit for PIXE analysis. The intensity of the "bremsstrahlung" background produced during irradiation is proportional to the substrate thickness and will directly affect achievable detection limits. In general, the detection limits will vary with the square root of the irradiation time, so that increasing the irradiation by a factor of 4 will lower the detection limits by a factor of two. This is also true for beam current with the exception that there is a limit to the amount of beam that can be placed on target. Applying a sensitivity for lead of, for example, 10ng/cm_2 to the inside facepiece concentration and assuming an outside facepiece concentration of 100 microgram/m^3 (2xPEL for lead), a limit of quantification of 100 nanogram per cm^2 (10xLOD), a filter collection area represented by a 15mm diameter circle (area of 1.77cm^2), and a sample volume of 200 L (2 LPM x 100 minutes) respirator protection factors of up to approximately 1000 can be determined.

Sample Collection Methods

The selection of sampling methods to be used will be dictated by the particulate exposure agent being sampled. Integrated sampling techniques will be employed throughout the sampling period. Workers will wear the respirator for the full period of time that constitutes their normal work shift. Workplace protection factor test samples will be collected over two separate time periods during the shift. One set of WPF test samples will be taken during the first half of the period and a second set of WPF samples will be taken during the second half of the shift. Sampling periods will constitute at least one hour and possibly up to four hours of continuous uninterrupted wear. Both outside and in-facepiece cassettes will be washed (interiors only). The wash will be filtered and analyzed. Total mass collected will constitute the sum of the masses on the cassette filter as well as the wash filter.

A. Outside Facepiece Sampling

Once the particulate agent is selected, estimates of concentration outside the respirator(C_o) will be made with traditional lapel sampling methods. Cassettes used to estimate C_o will be located on or in the general area of the worker's lapel. Locating cassettes on the right or left lapel area will rest on the decision of those "suiting up" the workers for testing. Sampling substrates will be chosen based upon sampling recommendations made by recognized authorities(i.e. NIOSH, ACGIH, etc.) and for compatibility with the analytical procedure.

Sampling trains for fumes will consist of 25mm closed faced cassettes, hose, and sampling pump. Cassettes will incorporate polypropylene backup pads and mylar collar between backup pad and filter to restrict deposition to a centrally located 15mm circle for PIXE analysis.[7] Sampling rates for fumes will be approximately 2 LPM unless a lower flowrate is needed to prevent "over loading" of the filter for PIXE analysis. Sampling pump flows will be checked before and after each WPF test collection period.

Outside facepiece sampling for dusts will use a respirable dust setup employing a 10mm cyclone. A flowrate of 1.7 LPM will be used for the respirable dust samples. In other respects the "fume" and "dust" sampling trains will be similar.

B. In-facepiece Sampling

The in-facepiece sample will be collected from a probe inserted through the facepiece to an area roughly opposite and 1/4 inch in front of the mouth of the wearer. The sample will be taken continuously over both inhalation and exhalation. The inlet probe for the collection of in-mask samples complies with Davies's criteria for sampling through inlet tubes and its sampling efficiency has been experimentally defined[8]. A detailed description of this in-facepiece sampling procedure and it's associated sampling bias and precision has been reported by Myers and Hornung.[9] The in-facepiece concentration will be corrected for average sampling method bias and for pulmonary system retention by using lung deposition curves of Rudolf et.al[10] and empirical models of particle size dependent leakage through face seal leaks proposed by Hinds and Bellin[11].

The sampling train for in-facepiece sampling will be consistent with the C_o sampling train using a 25mm closed faced cassettes attached to the facepiece probe, a hose, and sampling pump. Cassettes will incorporate polypropylene backup pads and mylar collar between backup pad and filter to restrict deposition to a centrally located 15mm circle for PIXE analysis. In-facepiece cassettes with liquid condensate present will be vacuum desiccated. The appropriate blank cassettes will also be desiccated. Sampling rates will be as high as the sampling pumps can achieve with this sampling configuration. Past experience indicates flowrates will be approximately 2 LPM but in no case would they exceed 5 LPM. Sampling pump flows will be checked before and after each WPF test collection period.

C. Personal Sampling Pumps

All personal sampling pumps will be constant flow pumps. They will be calibrated by technical support personnel prior to the start of each days sampling. Pump will be calibrated using bubble flowmeters or calibrated hot wire flowmeters upon arrival at each study site. Calibration will be done on a completely assembled sampling train. Sampling pump flowrates outside the specified range will be readjusted to conform to this range. The flowrate of each pump will be monitored roughly every 20 minutes throughout the WPF sampling period to assure that pumps are working and flowrates remain approximately as calibrated. Flowrates will be rechecked upon completion of sampling.

D. Working Blanks

Twenty percent of workers will be equipped with a "working blank" to be worn in his or her breathing zone (similar to the lapel sample). The working blanks of all workers in a particular work area having the same type of particulate(i.e.dust, fume, etc.) will be analyzed and the results averaged. The average value obtained will serve as a correction factor that estimates the background contamination level of the exposure agent. The working blanks will be opened and closed each time the test cassettes are opened and closed. When test cassettes are in the sampling train blanks will plugged and worn. Blank cassettes will be handled like the test cassettes in all ways.

E. Manufacturer's Blanks

"Manufacturer's blanks" (media blanks) will also be used to determine whether the samples contain any background amounts of exposure agent by virtue of its raw materials, its manufacturing process, or prior exposure. Five percent of the filters in each lot of 100 will be randomly selected for "Manufacturer's blanks".

F. Sampling Procedure

Samples (in-mask and breathing zone) will be disconnected (from the facepiece and cyclone as appropriate), plugged, and removed whenever an individual worker leaves his work area. Observers will concurrently turn the sampling pumps off. Working blank samples will also be removed at this time. A method of labeling or identifying both the blanks and air samples will be employed such that the following can easily be discerned; whether the sample is an in-mask sample, breathing zone sample, or a working blank; the facility; the worker; the observer; the date; and the sampling period for the sample and the period of wear for the working blanks (start time and stop time to the nearest half minute according to the time of day). The respirator and sampling trains worn by study participants will be donned in a "clean area" separate from the work area. The same clean area will also be used to remove and redon this equipment at all break periods and to remove the equipment at the end of each worker's shift. Sample cassettes will be removed, for analysis, at the end of each sampling period or when the respirator facepiece has been lifted (not readjusted) or removed from the face. Replacement cassettes will be used at the start of each WPF sampling period.

Prior to the beginning of each work shift and at the end of all scheduled and unscheduled break periods, the pumps of both sampling trains will be started simultaneously just before each worker participant leaves the clean area. Sampling pumps will not be started, however, until the worker's respirator facepiece has been completely donned. Sampling pumps will be stopped simultaneously before permitting a worker to remove his respirator facepiece. Should a worker need an adjustment of his test equipment or require an unscheduled break from work activities while wearing test equipment, he/she will be instructed to first notify the nearest research team member, who will provide assistance. Monitors will immediately remove the worker to a "clean" area and discontinue personal sampling if a cassette or piece of tubing becomes loosened, dislodged, or is pulled off of the respirator or any other part of the sampling train during sampling.

Particle Size Sample Collection

A PIXE nine stage cascade impactor (aerodynamic cut-off diameter ranging from 16 to 0.06 micrometer) will be used to determine the size distribution of the particulates in specific areas where workers are working. This will be done in order to correct in-mask samples for lung retention. Impactor samples will be taken to coincide with the periods when WPF test samples are being collected. Therefore at least two impactor samples will be taken in the work area of each worker, one during the first half of the shift and one during the second half of the shift. The impactor sample will be collected at roughly shoulder level of the workers.

The impaction stages will be treated to minimize particle bounce. Treatment will be with toluene cut Apiezon L grease or another material compatible with the analytical procedure chosen. To avoid impactor overloading the period of impactor sampling may be shorter than the actual period of WPF sample collection.

Fit Test Instructions and Test Procedures

A. Instructions to be Given to Each Test Subject

You will be asked to perform two different types of fit tests to determine if the respirator fits your face. Fit is important for the respirator to function properly. The type of fit test will depend on whether an elastomeric or disposable facepiece respirator is being fit tested. Each of you will have the opportunity to be fit tested in each type.

With the elastomeric facepiece respirators you will need to select a size from several sizes of the same brand to find the one which seems to feel and fit the most comfortable. To select the most comfortable size facepiece you will need to try each size on. After selecting a size that feels comfortable you will be trained in how to don and adjust the respirator per manufacturer's instructions (negative/positive pressure fit checks will be done at this time according to instructions). You will be allowed to wear the respirator for awhile to make sure it does not hurt or pinch your face.

Elastomeric facepieces will be fit tested using a quantitative fit test. For this test you will step into a large plastic tent that contains a corn oil aerosol. You will need to attach your respirator to a sampling line inside the tent. During the test the test operator will ask you to: 1) move you head side-to-side and up and down; 2) do normal and deep breathing; and 3) recite the alphabet. Each test will take roughly 20-30 minutes to complete. You will need to have at least three fit tests since we are evaluating your ability to be fit tested with three different brands of elastomeric respirators.

Disposable facepieces will be fit tested using a qualitative test procedure. This fit test procedure uses a saccharin mist which is sweet to the taste. You will place a small hood over your head and determine if you can taste the saccharin mist. Then you will put the respirator on and conduct the fit test. During the test the test operator will ask you to move your head side-to-side and up and down, do normal and deep breathing, and recite the alphabet. If you taste the sweetness of the mist during the fit test the respirator does not fit well enough. It is important that you tell us if you notice the sweet taste. No penalty will occur to you if you tell us that you can. Each test will take roughly 15-20 minutes to complete. You will need to have at least two qualitative fit tests since we are evaluating your ability to be fit tested with two different brands of disposable dust respirators or one brand of disposable fume respirator.

If you have questions, at any time, please ask. I will try to answer them.

B. Fit Testing

The fit tests used to assess what respirator a person will use in the study is an important aspect of the overall effort. The assigned person/respirator interface is the main component of respirator wear being measured (along with the person/ respirator interaction over time). The fit tests used, the pass/fail criteria, and the training given will all have some affect on the outcome of the study. To control these aspects and minimize any undue operator bias, specific fit test criteria will be followed. An explanation of the test and training for respirator donning will be standardized as indicated in Section A. using manufacturers' training materials. The fit test order (i.e. which fit test is given first) will be randomized for each individual.

The quantitative qualitative fit test will be used on the elastomeric facepiece respirators equipped with high efficiency filters. A fit factor of 100 or above will constitute a pass. A portable fit test instrument using corn oil mist will be used.

The qualitative saccharin test will be used on the 3M 9920, and 8710 and the Gerson disposables. A failure will constitute a definite tasting of saccharin and a pass, no taste of saccharin. If a person appears to be uncertain whether saccharin was tasted, the test will be repeated. On repeat testing either a definite or an unsure indication of tasting will constitute a failure.

The qualitative and quantitative test protocols that will be used in the study are detailed in Appendix B of the NIOSH Publication <u>Guide to Industrial Respiratory.</u>[12]

<u>Determination of Worker Workrate</u>

A subjective determination of workload will be made by a research team member for each worker sampled. This determination will be arrived at by observing the work activities of the worker and classifying the work according to the categories of light, moderate, heavy, or very heavy as delineated by Smith and Ramsey [13]. The average workload will be recorded for each worker.

Environmental Data Collection

Recordings of ambient temperature, barometric pressure, and relative humidity will be made in the work areas of each worker participant during each WPF sample period.

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