DEPARTMENT OF THE AIR FORCE
ARMSTRONG LABORATORY (AFMC)
BROOKS AIR FORCE BASE, TEXAS

30 May 97

MEMORANDUM FOR HQ ACC/SGPO/LGM

FROM: AL/OEMI
2402 E Drive
Brooks AFB TX 78235

SUBJECT: Consultative Letter, AL/OE-CL-1997-0128, Chromate Exposures During Modified Aircraft Corrosion Control Operations, Shaw AFB, SC

1. INTRODUCTION: HQ ACC requested the Industrial Hygiene (IH) Branch of Armstrong Laboratory evaluate the effectiveness of aircraft painting inserts in controlling chromate exposures during aircraft corrosion control operations. The IH Branch performed chromate exposure assessments at Shaw, Cannon, and Holloman Air Force Bases [1-3]. Chromate exposures measured at each base were elevated during all phases of the corrosion control process, especially during priming. In order to reduce these exposures, the IH Branch, in collaboration with the Air Force Corrosion Program Office, developed changes to current corrosion practices. These new workplace practices were tested at Shaw AFB, the initial test base designated by HQ ACC, with the assistance of Structural Maintenance personnel. The IH Branch and Corrosion Program Office jointly performed the reevaluation 7-9 April 1997.

2. SURVEY PROCEDURES

a. *Description of Operation*: Corrosion Control personnel (20 EMS/LGMFS) scuff sand, prime, and paint F-16 aircraft in Building 1511, an aircraft hangar with a JBI Incorporated aircraft paint insert installed. The insert is a crossdraft ventilation system providing air movement from the front of the plane to the rear. Personnel scuff sand the aircraft surface with a rotary vacuum assisted pneumatic sander, remove residual dust, and then wipe down the surface with isopropyl alcohol. Two workers then prime the aircraft with an epoxy primer and paint it with a polyurethane enamel. Detail and finish work are done after the enamel cures.

b. *Source of Exposure*: The epoxy primer contains strontium chromate as a corrosion inhibitor. During the application of the primer with a compressed air spray gun, paint droplets become airborne and may be transported into the worker's breathing zone. Additionally, sanding of the aircraft releases chromates from previous surface priming operations. Exposures to chromates have been linked to occupational diseases such as dermatitis, nasal irritation, and lung cancer [4]. Strontium chromate is a suspected human carcinogen [5]. The current Air Force Occupational Exposure Limit (OEL) for strontium chromate is 0.5 $\mu g/m^3$ as an eight-hour time-weighted average (TWA, measured as chromium, Cr) [5,6]. OSHA regulates chromate exposures with a Permissible Exposure Limit (PEL) of 100 $\mu g/m^3$ as a ceiling limit (measured as chromium trioxide, CrO_3) [7].

c. *Survey Personnel*:

Major Gary Carlton, AL/OEMI

Table 1. Maximum Worker Exposures to Strontium Chromate During Modified Corrosion Procedures

Corrosion Procedure	Measured Exposure ($\mu g/m^3$)		Factor Over OSHA PEL[1]	Factor Over AF OEL[2]
	Task (as CrO_3)	8-hr TWA (as Cr)		
Sanding	7.3	1.0	--	2.0
Vacuum Plane	0.6	0.1	--	--
Vacuum Floor	3.7	0.2	--	--
Wipe Down	7.9	0.3	--	--
Priming	165.9	5.6	1.6	11.2
Painting	13.3	0.7	--	1.4

[1] 100 $\mu g/m^3$ (as CrO_3)
[2] 0.5 $\mu g/m^3$ (as Cr)

b. *Aircraft Insert Ventilation*: A ventilation survey was performed in the painting insert. Air flows on the right side of the aircraft ranged from 50-115 feet per minute (fpm) while those on the left side ranged from 25-60 fpm. The Industrial Ventilation Manual recommends a minimum capture velocity of 100 fpm [10]. An investigation revealed louvers on two of the three exhaust stacks leading from the insert were partially closed. It appears they either were installed improperly or were broken, leading to their partial closure when the ventilation system is on. The louver condition may be responsible for the flow variability. The booth was operating under negative pressure as designed, with exhaust ducts removing more air than the supply ducts provide.

c. *Sander Ventilation Units*:

(1) The DCM unit is a pneumatic rotary sander with a 5-inch diameter sanding head containing five holes through which air is drawn. Particulates captured by this air flow pass through the hose into the HEPA vacuum unit. The sander and vacuum are designed and manufactured as a small, portable unit. 15 feet of hose separates the sanding head from the vacuum unit. The compressed air pressure at the wall was set to 90 psi. Average capture velocities measured at the face of the sander ranged from 1750 to 2420 fpm with an average capture velocity of 1950 fpm. Total air flow through the unit was 13.3 cubic feet per minute (cfm). For the vacuuming procedures, the sanding head was removed and replaced by a 5-foot wand with a circular opening. The air velocity measured at this opening exceeded 3000 fpm. For future comparisons with other vacuum units, we weighed the dust collected by the DCM unit during aircraft sanding and vacuuming of the aircraft and floor. The unit collected approximately one-half pound of dust during the sanding procedure and vacuumed over 5 pounds of dust from the aircraft and floor.

(2) Workers remarked that the Tiger Vac units currently in use at Shaw, have inadequate suction to effectively remove dusts. During this survey, we found two of the Tiger Vac systems were full of dust and debris. This could have had some impact on the effectiveness of the sanders. Workers also remarked that the Tiger Vac units are large and rather cumbersome to use. Hoses of all the sanders were in good repair.

d. *Respiratory Protection*:

(1) Personnel wore full-face air purifying respirators with high-efficiency particulate/organic vapor (HEPA/OV) cartridges during surface preparation and dust removal procedures. Full-face pressure-demand supplied air respirators were worn during priming and painting.

(2) The previous surveys indicated respiratory protection in use did not provide adequate protection [1-3]. The assigned protection factor (APF) for a respirator is the minimum expected workplace level of respiratory protection that a properly functioning respirator provides. The APF must be greater than the hazard ratio (HR), defined as the concentration in the workplace divided by the exposure limit. Hazard ratios were calculated from the measured task exposures, which most closely approximate workplace concentrations, and the Air Force OEL of 0.5 g/m^3. APFs are from AFOSH Standard 48-1 [11]. If the hazard ratio exceeds the APF, the respirator in use is inadequate to protect the health of workers. Table 2 shows hazard ratios found during this survey. During all of the modified procedures, the respirator used provided adequate protection.

Table 2. Respirator APFs and Hazard Ratios During Modified Corrosion Procedures

Corrosion Procedure	Task Exposure ($\mu g/m^3$, as Cr)	Respirator Assigned Protection Factor (APF)	Hazard Ratio	HR > APF?
Sanding	3.8	50	7.6	No
Vacuum Plane	0.3	50	0.6	No
Vacuum Floor	1.9	50	3.8	No
Wipe Down	4.1	1000	8.2	No
Priming	86.3	1000	173	No
Painting	6.9	1000	14	No

e. *Work Practices*:

(1) During this survey, workers used the DeVilbiss Model 531 high-volume low-pressure (HVLP) spray gun to apply primer and paint. The HVLP gun is designed to operate at air cap pressure less than those of a conventional spray gun. Compressed air pressure was measured at the wall, at the pressure pot, and at the air cap to ensure the spray gun manufacturer's guidelines were followed. For the priming operation the compressed air pressure at the wall was 100 pounds per square inch (psig), 30 psig at the pressure pot, and 5 psig at the air cap. For the painting operation, 100 psig was measured at the wall, 30 psig at the pressure pot, and 30 psig at the air cap. The higher air cap pressure during painting was necessary to obtain an acceptable finish on the aircraft. This higher pressure, however, defeated the purpose of using an HVLP gun, which is to reduce air cap pressures and minimize overspray generation.

(2) Personnel wore cloth coveralls, a paint sock, and reusable nitrile rubber gloves during sanding, wipe down, priming, and painting. During HEPA vacuuming of the aircraft and floor, workers wore cloth coveralls and a paint sock. No gloves were worn during the vacuuming operations. The workers removed their coveralls in a locker area before entering the break area to ensure contaminated dust was not carried into office areas and the break room.

5. DISCUSSION

a. This survey ends the evaluation of the aircraft painting inserts in ACC. As demonstrated by the results, the modified work practices tested at Shaw significantly reduced worker exposures to chromates. Table 3 shows a comparison of maximum worker exposures before and after the modifications. Although exposures measured during sanding, priming, and painting still exceed the AF OEL, a significant reduction in measured chromate levels was obtained during each of the procedures. Specifically, task exposures were reduced 79% during sanding, 98% during dust removal, and 86% during priming.

Table 3. Comparison of Maximum Worker Exposures Before and After Modified Procedures

Corrosion Procedure	Task Exposure (µg/m³)			8-hr TWA Exposure (µg/m³)		
	Before	After	% Decrease	Before	After	% Decrease
Sanding	18.1	3.8*	79	8.7	1.0*	89
Dust Removal	245	4.1	98	12.3	0.3	98
Priming	625	86.3	86	75.5	5.6	93
Painting	5.3	6.9	-	1.3	0.7	47

* Worker using the DCM Vacuum Unit

b. Table 4 compares hazard ratios before and after the modified corrosion procedures. Note the large reduction in priming hazard ratio. With the modified priming procedures, workers are now adequately protected with supplied air respirators.

Table 4. Comparison of Hazard Ratios Before and After Modified Procedures

Corrosion Procedure	Hazard Ratio	
	Before	After
Sanding	36	7.6
Dust Removal	490	8.2
Priming	1250	173
Painting	11	14

c. Table 5 compares exposures of the worker using the DCM sander and those using the Tiger Vac system. Overall, exposures to workers using the Tiger Vac system were higher. The worker using the DCM sander actually performed more aggressive sanding than the other workers, covered more surface area, and accessed the primer coat more often. The Tiger Vac worker with the lowest exposure spent approximately 50% of the time on the top surface of the aircraft, where exposures tend to be lower because gravity pulls the sanding dust away from the worker's breathing zone. The DCM worker indicated the smaller 5-inch sanding disc was more convenient because it allowed better access to small areas. The smaller sanding head may have played some role in reducing the exposure. The DCM sanding and vacuum unit did not provide recommended air flows as listed in the Industrial Ventilation Manual [10]. It did, however, provide comparable capture velocities to the Tiger Vac units.

d. The HEPA vacuum reduced exposures during dust removal. The workers' use of compressed air to blow down the aircraft and the floor in the initial survey caused excessive exposures. The HEPA vacuum was acceptable to the workers and removed dust adequately. For future aircraft vacuuming efforts, however, a different attachment with a brush is recommended.

e. Chromate exposures were elevated during the initial survey partly due to high application rates of primer onto the aircraft surface. During this reevaluation the primer application rate was reduced. Priming

Table 5. Comparison of Pneumatic Sanders

Vacuum Unit	Task Time (min)	Task Exposure ($\mu g/m^3$)
DCM	124	3.83
Tiger Vac (1)	132	5.97
Tiger Vac (2)	134	15.7
Tiger Vac (3)	100	7.84
Tiger Vac (4)	163	2.51

time was lengthened and the priming operation broken into two parts, with a break in-between. Having only one person apply primer to the aircraft at a time prevented workers from inadvertently exposing others.

f. Manufacturers of HVLP spray guns claim the lower air cap pressures result in a higher transfer efficiency than a conventional gun. During the priming procedure the manufacturer's specifications were met, and this most likely helped to reduce overspray generation and chromate exposures.

g. This survey indicates chromate exposures can be reduced with relatively simple modifications. The work practice changes we feel have the most impact for reducing exposures during each of the corrosion control operations, based upon sampling results obtained during this survey, are summarized in Attachment 2.

6. RECOMMENDATIONS

a. HQ ACC/LGM should implement the work practices changes in Atch 2 at all ACC Corrosion Control shops. These techniques will reduce chromate exposures and protect worker health with minimal mission impact.

b. Bioenvironmental Engineering should perform exposure monitoring at their individual bases after the corrosion procedures are modified to verify adequacy of available respiratory protection.

c. WL/MLS-OL should incorporate these work practices and the reasoning behind them into T.O. 1-1-8 [12]. The inclusion of these changes in the T.O. will standardize procedures and techniques throughout the Air Force and ensure all Air Force Corrosion Control personnel have access to this information.

7. We appreciate the cooperation and support received from all personnel in the Corrosion Control Office at Shaw AFB during this survey. If you have any questions concerning this report, please contact the IH Branch at DSN 240-6137.

//signed//
GARY N. CARLTON, Maj, USAF, BSC
Chief, Industrial Hygiene Branch

3 Atch
1. Individual Exposure Data
2. Workplace Practice Recommendations
3. References

cc: 20 EMS/CC
20 EMS/LGMF
20 AMDS/SGPB w/add atchs
WL/MLS-OL

Attachment 1 - Individual Chromate Exposure Data

Process	Worker	Task Time (min)	Task Exposure (mg/m^3)	8-hr TWA Exposure (mg/m^3)
Sanding	[redacted]	124 132 134 100 163	3.83 5.97 15.7 7.84 2.51	0.99 1.64 4.38 1.63 0.85
Vacuuming Aircraft	[redacted]	103	0.27	0.06
Vacuuming Floor	[redacted]	46	1.89	0.18
Wipe Down	[redacted]	34 34 30	4.08 2.43 0.82	0.29 0.17 0.05
Priming	[redacted]	23 31	79.5 86.3	3.81 5.57
Painting	[redacted]	48 53	6.88 1.53	0.69 0.17

Attachment 2 - Workplace Practice Recommendations

1. Surface Preparation: Ensure the vacuum assisted sander in use provides adequate air flow. Make sure the air hoses are in proper repair, limit the length of the hoses, and frequently remove collected dust from the HEPA vacuum units. Hold the sander flush against the work surface as often as possible. Do not sand above, below, or directly adjacent to other workers to avoid propelling dust into their breathing zone.

2. Dust Removal: Use HEPA vacuums to remove dust from the aircraft surface and the paint facility floor after surface preparation.

3. Priming:

a. Only one individual should spray primer in the facility at a time.

b. Start priming on the portion of the aircraft closest to the exhaust end of the insert and move toward the supply end. This will ensure the worker moves away from the direction of the paint droplet cloud.

c. Workers should prime with the air flow to their side or back.

d. Adjust compressed air pressures at the wall, pressure pot, and gun to keep air cap pressures below 10 psig for HVLP spray guns.

e. Apply only the minimum amount of primer required onto the aircraft, producing a very translucent coating.

4. Painting: Avoid spraying directly at another worker. Begin painting at opposite ends or areas of the aircraft if possible. Workers should stay away from the paint droplet cloud and always paint with their backs or sides to the air flow.

5. Miscellaneous Factors:

a. Routinely evaluate aircraft painting inserts or other hangar ventilation systems. Ensure painting facilities remain under negative pressure and exhaust fans and make-up air systems operate properly.

b. Control the spread of contaminated dusts by removing contaminated coveralls before exiting work areas and designating separate break room areas.

Attachment 3 - References

1. AL/OEM Consultative Letter, *Chromate Exposures During Aircraft Corrosion Control Operations, Shaw AFB, SC*, AL/OE-CL-1997-0031, 4 Feb 97.

2. AL/OEM Consultative Letter, *Chromate Exposures During Aircraft Corrosion Control Operations, Cannon AFB, NM*, AL/OE-CL-1997-0042, 10 Mar 97.

3. AL/OEM Consultative Letter, *Chromate Exposures During Aircraft Corrosion Control Operations, Holloman AFB, NM*, AL/OE-CL-1997-0043, 10 Mar 97.

4. R.A. Goyer, "Toxic Effects of Metals," in *Casarett and Doull's Toxicology, The Basic Science of Poisons*, 5th edition, C.D. Klaassen, M.O. Amdur, J. Doull, editors, McGraw-Hill, Inc., New York NY (1996).

5. American Conference of Governmental Industrial Hygienists, *Threshold Limit Values for Chemical Substances and Physical Agents*, ACGIH, Cincinnati, OH (1996).

6. AFOSH Standard 48-8, *Controlling Exposures to Hazardous Materials*, 1 December 1995.

7. 29 CFR 1910.1000, *Air Contaminants.*

8. National Institute for Occupational Safety and Health, *NIOSH Manual of Analytical Methods*, 4th edition, NIOSH, Cincinnati, OH (1994).

9. Stokinger, H.E., "The Metals," in *Patty's Industrial Hygiene and Toxicology, Vol II, Part C*, G.D. Clayton and F.E. Clayton, editors, John Wiley & Sons, Inc., New York NY (1994).

10. American Conference of Governmental Industrial Hygienists, *Industrial Ventilation, A Manual of Recommended Practice*, 22nd edition, ACGIH, Cincinnati, OH (1995).

11. AFOSH Standard 48-1, *Respiratory Protection Program*, 25 February 1994.

12. T.O. 1-1-8, *Application and Removal of Organic Coatings, Aerospace and Non-Aerospace Equipment.*