U.S. Environmental Protection Agency
Common Sense Initiative
Metal Finishing Subcommittee
CLEANER - CHEAPER - SMARTER

In Cooperation With

The Nationial Institute of Standards and Technology
Manufacturing Extension Partnership

HARD CHROME POLLUTION PREVENTION DEMONSTRATION PROJECT

- INTERIM REPORT -

November 27, 1996

<u>PURPOSE:</u> TO ASSIST HARD CHROME METAL FINISHING OPERATORS COST-EFFECTIVELY COMPLY WITH, OR DO BETTER THAN, EPA'S CHROMIUM EMISSIONS MACT STANDARD

Notice

The U. S. Environmental Protection Agency through its Office of Research and Development partially funded, managed, and collaborated in the research described here under Assistance Agreement Number DW-13936163 to the National Institute of Standards and Technology Manufacturing Extension Partnership. This report has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of companies, trade names or commercial products does not constitute endorsement or recommendation for use.

Abstract

The EPA Common Sense Initiative (CSI) is a cooperative effort of government, industry, environmental, and other stakeholders groups to find “cleaner, cheaper, smarter” approaches to environmental management in industrial sectors. The CSI Metal Finishing Subcommittee endorsed and provided technical oversight for the Hard Chrome Pollution Prevention Demonstration Project. The purpose of the Project is to assist hard chrome metal platers to cost-effectively comply with, or do better than, EPA’s Chromium Emissions MACT Standard.

In this Project, five chromium emission prevention/control devices were tested that cover the spectrum of prevention/control techniques currently in use in small- and large-sized hard chrome metal plating shops. The Project found that two-stage composite mesh pad-style mist eliminators and chemical mist suppressants were effective in limiting chromium emissions to the levels, or better than the levels, specified in the MACT Standard--0.030 milligrams per dry standard cubic meter of air (mg/dscm) for small facilities with existing tanks and 0.015 mg/dscm for small facilities with new tanks or large facilities with existing or new tanks.

The Project found that these pollution prevention methods reduced the exposure of workers to chromium mists from electroplating tanks to 25% or less of the original exposure. The Project identified solutions for some previously unreported issues in the measurement procedures that may be used for determining compliance with the Chromium Emissions MACT Standard.

The techniques presented in this report cover most of the important prevention/control options available to a hard chrome metal plater. The techniques were selected by the Project staff with input from management of the participating electroplating companies, and reviewed by an EPA-selected peer panel composed of representatives from industry, equipment and chemical suppliers, and academia.

Acknowledgments

This project originated as a result of an interagency agreement between the Environmental Protection Agency (EPA) Office of Research and Development (ORD) and the National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership (MEP) to conduct a demonstration project of pollution prevention technologies that would assist typical metal finishers to achieve improved environmental and economic results.

These two groups then joined with the EPA Office of Pollution Prevention and Toxics (OPPT) Design for the Environment (DfE) Program, the Department of Energy (DOE) Office of Industrial Technologies (OIT), industry (American Electroplaters & Surface Finishers Society, Inc., Metal Finishers Suppliers Association, and National Association of Metal Finishers), and other parties in a Technology Reinvestment Project (TRP) called the Energy, Environment, and Manufacturing (EEM) Project. The EEM Project is one of the most significant collaborations of these three Federal agencies with the private sector for environmental, energy, and economic benefits.

When EPA's Common Sense Initiative (CSI) was created, it seemed natural that the Metal Finishing Subcommittee would endorse this project as one that the Subcommittee's Research and Technology Work Group would oversee. The result of the Work Group's and Subcommittee's deliberations was that the demonstration portion of the EEM project focused on evaluating the effectiveness and cost of pollution prevention techniques in helping typical hard chrome metal finishers comply with or do better than the EPA-promulgated Chromium Emissions MACT Standard.

In addition, endorsement of the project by the CSI Metal Finishing Subcommittee resulted in extensive peer review by industry, environmental, and academic experts of the selection of the chrome plating facilities for the demonstration, the before and after testing procedures, and the selection of the techniques to be evaluated. The owners and managers of the selected facilities participated fully in the selection of the

technologies to be evaluated. They and the appropriate vendors participated throughout the demonstration.

The Hard Chrome Pollution Prevention Demo Project was managed by two NIST Manufacturing Technology Centers--specifically, by Ken Saulter at the Industrial Technology Institute (ITI) in Ann Arbor, Michigan, and Larry Boyd at CAMP in Cleveland, Ohio. The project team included James Hensley and Christine Branson at ITI and Lisa D'Agostino and A. Gus Eskamani at CAMP. This interim report was primarily written by James Hensley. Brian Sweeney of NIST-MEP provided crucial oversight of the project and liaison among the project managers, NIST and EPA. Joe Breen of OPPT/DfE made available critical analytical capabilities.

The CSI Metal Finishing Subcommittee Research and Technology Work Group is co-chaired by Brian Manty of Concurrent Technologies Corporation (past president of the American Electroplaters and Surface Finishers Society) and Tim Oppelt, Director of the ORD National Risk Management Research Laboratory (NRMRL). Dave Ferguson of NRMRL is the EPA Project Officer for the project. Paul Shapiro, ORD CSI Coordinator and Co-Lead of the Metal Finishing Sector, provided guidance for the overall project.

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I. Introduction

A. Objectives

The impetus for this project is to assist hard chromium metal finishers to cost effectively meet or do better than the chromium air emission limits which all hard chromium electroplating shops must meet under the Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards (OAQPS)-promulgated 1995 National Emission Standards for Chromium Emissions from Hard and Decorative Chromium Electroplating and Chromium Anodizing Tanks ("Chromium Emissions MACT Standard" or "the Standard"). This Hard Chrome Pollution Prevention Demonstration Project ("Chrome Demo" or "Project") investigated pollution prevention methods that small- and large- size hard chromium electroplating facilities can use to meet the Standard.

The objectives of this project were to:

1. Demonstrate a real-world baseline of typical electroplating source emission prevention/control techniques;
2. Determine if the EPA-mandated emission limits can be met under job shop working conditions;
3. Demonstrate low/lower cost emission prevention/control techniques that emphasize pollution prevention;
4. Demonstrate methods of reducing trivalent, hexavalent, and total chromium emissions into the environment.

B. Background

Hard chrome electroplating shops must meet the limitations on chromium emissions that are embodied in the Chromium Emissions MACT Standard. The shops must report their source outlet chromium emissions either on a total (hexavalent + trivalent) or hexavalent chromium basis. The facility has the option of selecting which form of chromium to report.

The Standard includes two designations for hard chromium electroplating facilities, based on the maximum cumulative potential rectifier capacity and when the sources (electroplating tanks) were installed. A facility is designated as "large" if the rectifier capacity for all hard chromium electroplating tanks equals or is greater than 60 million ampere-hours per year. A “small” facility is one where the rectifier capacity is less than 60 million ampere-hours per year. The electroplating tanks in a facility can be “new” or “existing”. A ‘new” tank is one installed or reconstructed after December 16, 1993. An “existing” tank is one installed on or before December 16, 1993. Emission limits are:

Table 1. EPA Chromium Emissions MACT Standards

	“Small” Facility	“Large” Facility
All existing tanks:	0.03 milligrams/dry standard cubic meter	0.015 milligrams/dry standard cubic meter
All new tanks:	0.015 milligrams/dry standard cubic meter	0.015 milligrams/dry standard cubic meter

The facility Standards are based on the prevention/control devices listed in Table 2.

Table 2. Prevention/Control Devices Used to Determine Standards

“Small” Facility:	Packed-Bed Scrubber with water addition to top of scrubber bed
“Large” Facility:	Multi-Stage Composite Mesh Pad-style Mist Eliminators

The Chrome Demo investigated pollution prevention methods and control techniques that small- and large-size hard chrome electroplating facilities can use to meet the Chromium Emissions MACT Standard. Both mechanical and chemical techniques were investigated. Mechanical methods are those that involve physical separation of the chromium mist produced under electroplating conditions from the air. The chemical method used in the project was chemical mist suppressants that contain fluorinated wetting agent(s) (chemical mist suppressants) that resulted in less chromium mist being generated at the tank.

The Project provides information to help small- and large- sized hard chrome electroplating shops meet the January 1997 deadline for the EPA Maximum Achievable Technology Standard (MACT) for chromium.

II. Description of Overall Project

The Chrome Demo Project was divided into four phases in which extensive use was make of peer review. An EPA-selected Peer Review Expert Panel reviewed and commented on project actions proposed by ITI and CAMP. The results of the Peer Panel review were presented for review and approval to the Research and Technology Work Group of the CSI Metal Finishing Subcommittee. Only after Work Group approval, were proposed actions implemented.

The four phases were:

1. Selecting representative prevention/control devices of hard chromium emission sources from a variety of small- and large- sized sites.
2. Baseline testing of the prevention/control devices to provide data for: a) comparison with post- modification testing results, and b) selection of devices which need to be modified to meet the Chrome MACT. (baseline)
3. Selecting and installing low-cost emission reduction techniques to the sources that did not meet the “large” facility 1995 Chrome MACT emission limit.
4. Testing and evaluation of the installed techniques. (Phase 4)

The peer review process covered such actions as:

- Selecting the prevention/control devices to test;
- Sampling protocols;
- Selecting the stack testing firm to use for Phases 2 and 4;
- Selecting the analytical laboratories to use for Phase 2 and 4;
- Selecting the prevention/control techniques to install.

All testing and sample analysis was done following accepted methodologies such as EPA Method 306, 306A, and 306B. In order to obtain data quality assurance and quality control (QA/QC), formal Quality Assurance Project Plans (QAPs) were developed with input of the stack testing firms for Phase 2 (baseline testing) and Phase 4. In addition, the QA/QC procedures described in EPA Method 306, 306A, and 306B were followed. The QAPs have data quality objectives for:

- Duplicate analysis of both inlet and outlet stack samples and impinger blanks;
- Duplicate sample percentage difference;
- Instrument calibration percentage difference;
- Analysis of Standard sample;
- Calibration and re-calibration of test and air sampling equipment;
- Spiked samples and blanks for hexavalent chromium samples;
- Serial dilution and/or spiking of samples and blanks for total chromium samples;

- Duplicate sampling for above-tank sampling.

The surface tension analysis followed the EPA's Method 306B and the ASTM Method D 1331-89 procedures and included in Phase 4, QA/QC checks with water done before and after each sampling series for both the CSC DuNouy Ring tensiometer and the Lurex 5 milliliter stalagmometer. This report was peer reviewed before release.

III. Estimated Capital and Annual Costs

Each prevention/control technique has both an initial cost (capital cost) and an operational cost (annual cost). The definitions used for capital and annual costs are covered in sections 7.2.1.1. and 7.2.1.2. on page 7-3 of volume I of the EPA's *Chromium Emissions from Chromium Electroplating and Chromic Acid Anodizing Operations--Background Information for Proposed Standards*, , EPA 453/R-93-030a, July 1993 (BIDs). Below in Tables 3 and 4 are estimated costs for the listed prevention/control techniques. Except for those noted, the costs are obtained from the estimates listed in Volume 1 and 2 of the EPA BIDs.

Table 3. Estimated Prevention/Control Techniques Capital Costs

PREVENTION/CONTROL TECHNIQUE	ESTIMATED CAPITAL COSTS*	
	NEW	EXISTING
CHEMICAL MIST SUPPRESSANT	NONE	NONE
PACKED-BED SCRUBBER	$39,400	$49,300
COMPOSITE MESH PAD	$29,200	$36,500
MESH PAD + HEPA FILTER**	$41,000	? due to situation
COMBO = PBS + CMP	$62,400	$78,000
ENCLOSURE (Merlin/Cr Dome)**	$500-900/ft ^{2}	$500-900/ft ^{2}
FIBER BED MIST ELIMINATOR	$123,200	$135,000

*EPA estimates for 1 tank and 1 prevention/control device with auxiliaries
** Estimates from vendors

Table 4. Estimated Prevention/Control Technique Annual Costs

PREVENTION/CONTROL TECHNIQUE	ESTIMATED ANNUAL COSTS*	
	NEW	EXISTING
CHEMICAL MIST SUPPRESSANT**	$606	$1,340
PACKED-BED SCRUBBER	$10,400	$11,900
COMPOSITE MESH PAD	$14,500	$16,000
COMBO = PBS + CMP	$18,300	$20,700
ENCLOSURE (Merlin/Cr Dome)	$300/yr	$300/yr
FIBER BED MIST ELIMINATOR	$31,100	$33,000

*EPA estimates for 1 tank (42 square feet) and 1 control device with auxiliaries (10,500 cfm)
** Based on $140/gallon, 5,000,000 amp-hr/year, 3625 amp-hour, 1,730 gallon baths, 0.25% volume chemical mist suppressant, additions of 2.5 fluid ounce/10,000 amp-hr

The dollar amounts in Tables 3 and 4 are estimates. Before making a decision based on costs from these tables, a electroplater should contact a number of vendors who can supply the techniques and provide current price quotes. For comparative purposes, the vendor quote needs to include the prevention/control device/technique, duct work, fan changes, control panels, and the cost of installation. Money can be saved by the electroplater doing the installation. The cost of electrical and plumbing work is not typically included in quotes from vendors.

Electroplaters should be aware that it may be necessary to obtain “permits to install” before any installation work can be done. The electroplater must contact the local permitting agency to obtain information about what (if any) permitting is necessary and the typical time necessary to obtained any needed permits.

IV. Conclusions

A. Meeting the MACT Standard

1. The chemical mist suppressants tested in the Chrome Demo Project, when used at electroplating bath surface tensions of 41 dynes per centimeter and lower and in combination with existing controls (blade-type mist eliminators and a packed-bed scrubber), had chromium emission that were less than the Chrome Emissions MACT limit of 0.015 mg/M^3 and the emissions were reduced to as little as 2.5% of the "large" facility emission limit.

2. The chemical mist suppressants as used in the Chrome Demo Project, in some instances, reduced control device inlet hexavalent and/or total chromium air concentrations to as low as 32.5% of 0.015 mg/M^3.

   NOTE: Chemical mist suppressants still have quality issues (concerns of pitting versus depth of chromium plating) and work practice safety issues (ignition) that need to be addressed when they are used. These issues were not investigated in the Chrome Demo Project. The mechanical devices typically do not have these issues.

3. Several tested devices (one-stage mesh pad mist eliminator, two-stage mesh pad dry mist eliminator, and three-stage mesh pad wet mist eliminator) tested in the Chrome Demo Project had outlet chromium emissions less than the Chrome MACT limits of 0.015 mg/M^3 even though they were not the EPA reference prevention/control device for that limit.

4. The add-on two-stage composite mesh pad style mist eliminator significantly reduced an existing blade-type mist eliminator's chromium emission by less than (32% of) the Chrome MACT standard of 0.015 mg/M^3 when used inline with the blade-type device. The add-on two-stage composite mesh

pad mist eliminator resulted in an outlet emissions of only 3.8% of the outlet emission of the blade-type mist eliminators.

5. The packed-bed scrubber did not meet the "small" facility EPA Chrome MACT limit of 0.030 mg/M ^{3} even though this device meets the criteria for the EPA reference prevention/control device for a "small" facility.

6. Polyballs, used with chemical mist suppressants tested in this project, lowered inlet chromium air concentrations significantly. For surface tension of 28 dynes per centimeter, the inlet chromium air concentrations were typically less than 1% of 0.015 mg/M^3.

B. Test Methods Comparison

1 306 and 306A sampling done during the Project, typically produced similar outlet concentrations, the differences were 0-6% of the 306 values.

2 There were no indications of a reduction in the three-stage mesh pad mist eliminator's ability to prevent/control chromium emissions based on comparison of early EPA 306A test work and the Project test results. These results did not indicate a decrease in the ability of the device to prevent/control chromium emissions over a four year period.

3 Prevention/control device percent (%) efficiency should not be used as a method for comparing prevention/control techniques and determining if the technique meets Chrome MACT emission limits. The techniques' percent efficiency is related to inlet and outlet air concentrations and not outlet air concentration only. Percent efficiency values for some controls when a chemical mist suppressant was used, were lower than the control efficiencies calculated in the baseline portion of the Chrome Demo Project. The baseline control percent efficiencies ranged from 92-99.96% and the Phase 4 control percent efficiencies ranged from 65.9-99.7%. Some

baseline devices had control percent efficiencies greater than Phase 4 techniques even though the baseline outlet chromium air concentrations were up to 858% greater than the Chrome MACT emission limits, and the Phase 4 techniques had outlet emission below the Chrome MACT limit of 0.015 mg/M^3.

4 Mg/Amp-Hr values are not useful in determining if a prevention/control technique meets the Chrome MACT emission limits. The calculated mg/amp-hr values for the prevention/control techniques used, show that only three conditions (see Table 21) met or were less than the 0.006 mg/amp-hr comparison value. Most Chrome Demo Project conditions and techniques that had chromium outlet values of 0.015 mg/M^3 or less had mg/amp-hr values from 0.022-0.0079 mg/amp-hr.

C. Outlet Hexavalent Chromium to Total Chromium Ratio

1. Hexavalent chromium outlet concentrations were typically lower than total chromium outlet concentrations. The typical difference seen was greater than the +/-10% the EPA reports in the preamble to the Chrome MACT. The Chrome Demo Project ratio of hexavalent to total chromium ranged from 20-107%. This was seen in the baseline outlet results from a single laboratory and in the Phase 4 outlet results from the split sampling and duplicate analysis from two separate laboratories. The differences seen in the project between hexavalent and total chromium averaged 14.0% for RTI and 29.6% for MRI. For the packed-bed scrubber, RTI averaged a 18.1 % difference between hexavalent and total chromium results and MRI averaged a 32% difference. For the blade-type mist eliminators, RTI averaged a 12% difference and MRI averaged a 18% difference.

2. Different analysis methods used by different laboratories can result in very similar results even if the ratio of hexavalent to total chromium are different for two laboratories. In the Chrome Demo Project, for the packed-bed

scrubber, the mean difference for the same chromium ionic form between the two laboratories averaged 7.7%. For the blade style devices, the average difference between the same chromium ionic was 7.9%. This indicates that while each lab may have a different bias on the individual measurements of hexavalent and total chromium done within the lab, the difference between the labs was low.

D. Above-Tank Emissions

1. The use of chemical mist suppressant resulted in the reduction of chromium air concentration above the electroplating tanks to as low as 0.9% of the air concentration without chemical mist suppressant. The use of both polyballs and chemical mist suppressant was not synergistic; the above-tank concentration using both was similar to the above-tank concentration when chemical mist suppressant was used alone.

2. Polyballs, when used without chemical mist suppressants, did lower the chromium air concentrations above the electroplating tanks. The chromium air concentration was reduced to as low as 13% of the air concentration without polyballs.

E. Push-Pull Exhaust versus Pull-Pull Exhaust

1. The comparison of push-pull exhaust versus pull-pull exhaust for push-pull exhaust have more chromium capture, when based on the amount of chromium at the control inlet, gave mixed results. Push-pull ventilation tested in the baseline portion of the Chrome Demo Project indicated more effective capture. The amount of chromium at the inlet to the three-stage mesh pad mist eliminator (push-pull exhaust) was 182% higher than at the inlet of the blade style mist eliminator (tank 12) (pull-pull exhaust). These tanks had similar ampere-hour/hour (4% difference) and similar air flows (19% difference).

The push-pull exhaust ventilation installed in Phase 4 at the blade-type mist eliminator(tank 12) had inlet chromium concentration similar to the baseline Pull-Pull exhaust. The amount captured by the push-pull hood over the pull-pull hood was 5.4 % even though ampere-hour/hour of the push-pull exhaust test was 50.5% more than the pull-pull exhaust test.

2. Push-pull exhaust ventilation tanks did have reduced chromium air concentration above the electroplating tanks compared to tanks with similar ampere-hours/hour and exhaust air flow. Push-pull exhaust was used at the two-stage mesh pad mist eliminator and the blade style mist eliminator along with a two-stage composite mesh pad mist eliminator tanks. The chromium air concentration above these tanks was 69% less than the average above the tanks that used pull-pull exhaust, 1.11 mg/M^3 compared to 3.61 mg/ M^3.

F. Outlet Air Concentration Test Methods

1. Inductively Coupled Plasma emission spectrometry (ICP) analysis results from some laboratories that did not follow the quality assurance (QA) procedures described in this report had more bias than ICP results when the quality assurance procedures were used. The bias ranged from 5% to more than 100%.

2. Graphite Furnace Atomic Absorption Spectroscopy (GFAAS) analysis agreed well with full QA procedure ICP analysis when full QA procedures for ICP analysis were followed and the laboratory had lower detection limits than those listed in Appendix A to Part 63 of the Chrome MACT standard.

3. Ion Chromatography with Post Column Reactor (IC/PCR) analysis for hexavalent chromium results from baseline tests did not show the variation that draft and final baseline ICP analysis for total chromium did. If the analysis procedures listed in EPA Method 306 and Method 306A are

followed IC/PCR for hexavalent analysis and GFAAS for total chromium analysis would be the preferred tests.

G. Reduced-Cost Testing

1. Reduced-cost tests (EPA 306A or variations discussed in this report) should be done in order to obtain estimates of outlet air emissions for engineering purposes and to identify prevention/control technique needs.

2. IC/PCR analysis for reduced-cost test samples gave better agreement with full EPA 306 tests than ICP tests did. This is based on a limited number of data points. GFAAS analysis was not tested in reduced-cost tests nor was ICP analysis following the protocols for quality assurance (serial dilution and/or spikes).

H. Surface Tension Testing

1. Precision tensiometers (DuNouy ring type) should be used when measuring the surface tensions of electroplating baths when chemical mist suppressants are used as an emission prevention/control technique. The surface tension values of the Phase 4 chemical mist suppressant samples obtained using the stalagmometer method are typically a higher dynes per centimeter value than surface tension measurements done using a DuNouy Ring Tensiometer. The gap can be up to 22 dynes per centimeter.

V. Recommendations

1. No additional study of multi-stage composite mesh pad style mist eliminators is necessary, as this project's results support the EPA's reported results for this prevention/control technique.

2. Electroplaters who are concerned with the totality of chromium emissions should look at chemical mist suppressants as an emission prevention/control technique in addition to their existing mechanical prevention/control technique. Chemical mist suppressants can be used to control chromium emissions to both the worker environment and the public environment. Chemical prevention/control techniques reduce chromium emissions to the worker environment, whereas mechanical prevention/control techniques do not, due to where they are located in the exhaust system.

3. The work practices needed to successfully use chemical mist suppressants in hard chromium electroplating need to be examined as they were not addressed in this project.

4. Hard Chromium electroplaters considering the use of chemical mist suppressants must consult with the vendor to address the issue of applicability of the product for the plating operations.

5. Additional evaluation of chemical mist suppressants as used by a larger and more diverse population of hard chrome electroplaters over a longer time period is necessary to adequately characterize the effectiveness of these materials.

6. The difference in surface tension readings between the various EPA 306B methods used in the Chrome Demo Project bear further examination.

VI. Prevention/Control Device (Techniques) Description

Five in-place prevention/control devices were chosen for the Phase 2 portion of the Chrome Demo Project after EPA Peer Panel review of the proposed devices. A sixth device was added in the Phase 4 portion of the Chrome Demo Project. The devices chosen represent the range of common mechanical emission prevention/control devices and techniques.

The baseline mechanical prevention/control devices chosen along with a description of the connected electroplating tanks are:

- Blade-type mist eliminator at Tank 12;
    - One tank - 2880 liters (760 gallons) - 3.44 m^2 (37 ft^2)
- Blade-type mist eliminator at Tank 13;
    - One tank - 5938 liters (1569 gallons) - 7.4 m^2 (79.3 ft^2)
- Twin bed packed-bed scrubber;
    - Five tanks - 16,432 liters (4341 gallons) - 12.5 m^2 (135 ft^2)
- One-stage mesh pad mist eliminator;
    - One tank - 4043 liters (1068 gallons) - 3.44 m^2 (37 ft^2)
- Two-stage mesh pad mist eliminator;
    - One tank - 6568 liters (1735 gallons) - 1.86 m^2 (20 ft^2)
- Three-stage mesh pad mist eliminator.
    - One tank - 6522 liters (1723 gallons) - 1.86 m^2 (20 ft^2)

The devices selected had adequate room in the general vicinity of the emission sources (electroplating tanks) or on building roofs for add-on mechanical prevention/control techniques. The hard chromium electroplating done in the tanks represent the range of hard chromium electroplating commonly done in job shops. The age of all the controls is greater than six years old. Typically only one electroplating tank is connected to each prevention/control device. The packed-bed scrubber has 5 separate tanks connected to it through a common exhaust header. The freeboard of the tanks ranged from 9.1 centimeters (3.6 inches) to 30.7 centimeters (12.1 inches).

One device chosen was a packed-bed scrubber that is representative of the type of emission prevention/control on which the EPA based the “small” facility emission limit.

Also included was a three-stage mesh pad mist eliminator. This device is not necessarily representative of the type of emission prevention/control on which the EPA based the "large" facility emission limit. This tested control device has a continuous water wash-down during operation, instead of the EPA reference periodic wash-down. This device also had been tested in earlier EPA development of the 306A procedure. Testing this device allowed for comparison of emissions on a control over a four year period of time.

The baseline control systems are described below followed by the description of Phase 4 emission prevention/control techniques added to the existing baseline emission control system.

A. Blade-Type Mist Eliminator, (Tank 12):

1. Baseline

A blade-type (chevron) mist eliminator was selected for this study. The device is listed in tables as blade style (tank 12) or Tank 12. The device is connected to tank 12. The EPA's BID document states that this type of device is the most common emission control device. The device is similar to the prevention/control device on Tank 13.

a. Type of Plating:

The principal parts plated in this tank (and the dominant plating job done in this job shop) is large industrial steel rolls (3 feet long and longer with diameters of 3 inches and greater). The job shop typically plates assorted other parts in other tanks. The plating done in those tanks is either rack style or individual parts.

b. Device:

The device was designed by the site owner and built by an outside metal fabricator. The device more than 28 years old. The device consists of a box housing a single set of overlapping multi row V-shaped angle irons as the blade. The blade section is 68.6 centimeters (27 inches) tall, 91.4 centimeters (36 inches) wide, and 45.7 centimeters (18 inches) deep. The air flow through the device is horizontal. The fan is located before the device so that all "dirty" air has to pass through the fan. The duct work, fan and device are metal construction. It is believed that no protective coating was used on the inside of the duct or device. The device is not periodically cleaned.

In the Phase 4 test work, chemical mist suppressant was added to the electroplating tank. The prevention/control technique used combined chemical mist suppressant, the blade-type mist eliminator, and the two-stage composite mesh pad mist eliminator for two test series. One test series used the two-stage composite mesh pad mist eliminator combined with the blade-type mist eliminator as the prevention/control technique.

c. Tank:

The tank's surface area is 3.44 square meters (37 square feet). A single rectifier is used at the tank.

d. Exhaust system:

For the baseline testing, the control was connected to a pull-pull exhaust system. The exhaust hood on the tank is a dual-sided lateral style low-profile hood, see Figure 1. The two exhaust ducts from the hoods merge right before the fan. The system fan is located before the control. A horizontal exhaust stack that met the EPA Method 5 criteria was built for the testing program.

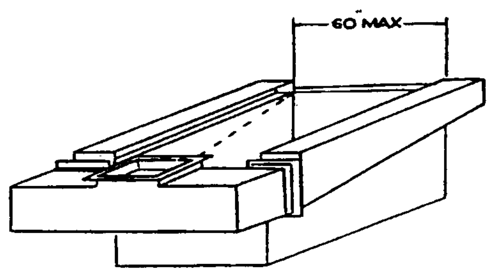

Figure 1. Dual Sided Lateral Exhaust Hood

e. Type of Facility:

The facility is an EPA "large" facility with 18 hard chromium electroplating tanks. A general layout diagram is shown in Figure 2.

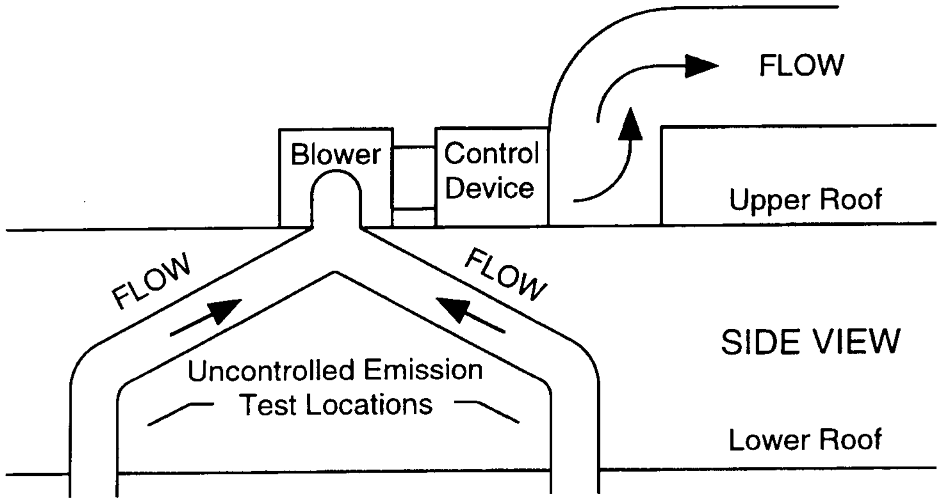

Figure 2. Blade-Type Baseline Layout (Tank 12)

2. Phase 4

The general layout of Tank 12 was modified in the Phase 4 portion of the Chrome Demo Project. The two-stage composite mesh pad mist eliminator (Spectra U-II by KCH Services, Inc. Forest City, NC) was added after the existing blade-type mist eliminator. The old fan was removed and a new fan (with a higher capacity and higher static pressure capability) was installed after the two-stage device. A push-pull exhaust hood replaced the existing pull-pull exhaust hood. The hood was replaced by a vertical style hood opposite the push air header, see figure 3. The existing ducts were used. A vertical stack that was included with the fan was used for the outlet tests. The baseline inlet test locations were used for the Phase 4 inlet testing. The Phase 4 layout is in Figure 4.

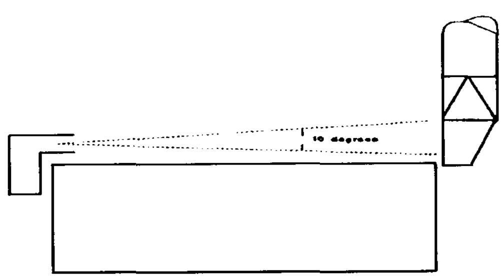

Figure 3. Push-Pull Exhaust Hood

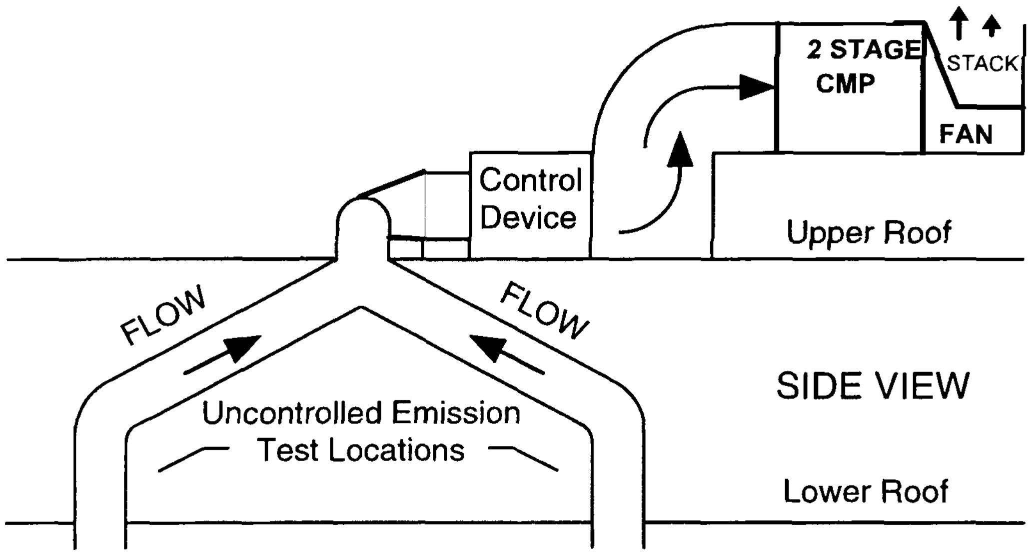

Figure 4. Blade-Type Phase 4 Layout (Tank 12)

B. Blade-Type Mist Eliminator, (Tank 13):

1. Baseline

This device is essentially similar to the blade-type mist eliminator at Tank 12. This control is on Tank 13 at the same facility as the blade-type, (tank 12). This device was included so that two types of chemical mist suppressants could be tested using the same part to be plated. The device is listed in tables as Blade (Tank 13) or Blade-Type (Tank 13). Tank 13 is connected to this prevention/control device.

a. Type of Plating:

This tank is used for industrial steel roll hard chromium plating as is Tank 12.

b. Device:

There are two blade-type mist eliminators in the system. The devices are constructed the same as the Tank 12 device.

c. Tank:

The tank's surface area is 7.4 square meters (79.3 square feet). A single rectifier is used at the tank.

d. Exhaust system:

The control is connected to a pull-pull exhaust system. Each control is connected to a separate dual-lateral exhaust hood. The exhaust hoods are U-shaped and surround one half of the tank. Each control has a system fan located before the control. A horizontal exhaust stack that met the EPA Method 5 criteria was built for the testing program.

e. Type of Facility:

The facility is an EPA "large" facility with 18 hard chromium electroplating tanks. A general layout diagram is shown in Figure 5; the actual system consists of two blade-type control devices each connected separately to individual pull-pull exhaust hoods.

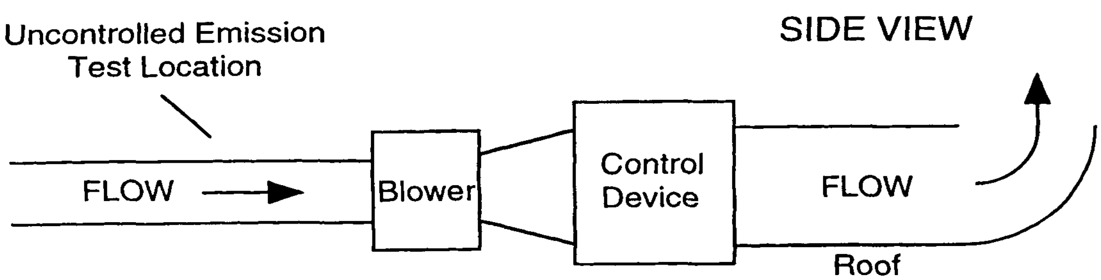

Figure 5. Blade-type Layout (Tank 13)

2. Phase 4

For the Phase 4 testing, no modifications were made to the device or exhaust system. Chemical mist suppressant at two surface tensions was combined with the existing blade style mist eliminators as the prevention/control technique tested. The same outlet and inlet test locations were used for all tests.

C. Packed-Bed Scrubber, (Tanks 3a-3e):

1. Baseline

This packed bed scrubber has 5 tanks ((Tanks 3a-3e) connected to it by a common exhaust duct. This packed-bed scrubber of the type on which the EPA based the “small” facility emission limit (0.030 mg/M^3). This device has water added to the top of the device. There are 20 hard chromium tanks at this facility connected to 4 prevention/control devices. The four separate prevention/control devices at this facility are two horizontal flow packed-bed scrubbers and two vertical flow packed-bed scrubbers. Multiple tanks are connected to each device. Device is referred to in tables paced bed scrubber.

a. Type of Plating:

The type of plating done in the tanks tested is aerospace/airline hard chromium plating. Typical job shop plating is done at the other hard chromium electroplating tanks at this facility.

b. Device:

The device is a horizontal air flow packed-bed scrubber built by Viron with an additional bed added at a subsequent date. Distilled water is used in the device. The beds are 30.5 centimeters deep and plastic tellerette packing is used for both beds. A blade style mist eliminator is located at the outlet end of the device. The blade section consists of a single set of wavy style blades. The device is approximately 15 years old. Polyballs are typically used in each tank connected to the prevention/control device. For the test, one tank’s polyballs were removed.

c. Tank:

There are five sources (tanks) connected to the device. The combined surface area of the five tanks is 12.54 square meters (135 square feet). Multiple rectifiers are used at each tank.

d. Exhaust System:

Each tank has a pull-pull exhaust system. A single dual-lateral exhaust hood is located at each tank. The exhaust ducts from each tank join together on the roof of the building to a 42-inch diameter exhaust duct which connects to the fan. The fan is located before the prevention/control device so all “dirty” air passes through the fan. A horizontal exhaust stack that met EPA Method 5 criteria was constructed and used for the entire testing program.

e. Type of Facility:

The facility is an EPA “large” facility. The general control system layout is shown in Figure 6.

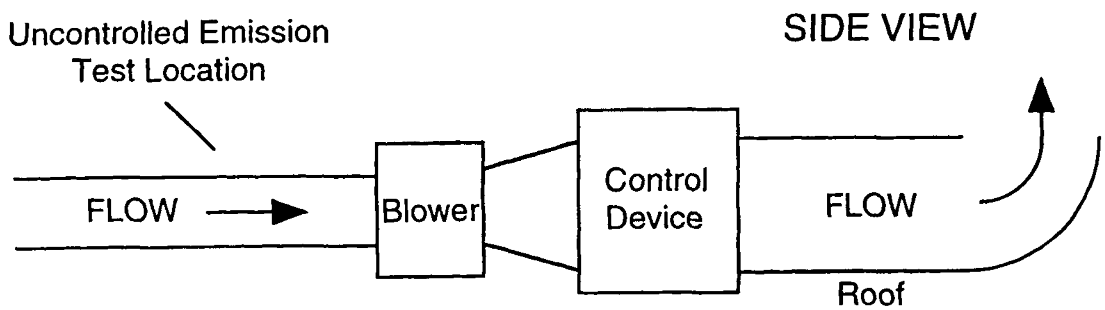

Figure 6. Packed-Bed Scrubber Layout

2. Phase 4

Chemical mist suppressant was the prevention/control technique added for the Phase 4 testing. The prevention/control technique used was chemical mist suppressant, polyballs, and the packed-bed scrubber. The same outlet and inlet test locations were used for the baseline and Phase 4 testing.

D. One-Stage Mesh Pad Mist Eliminator, (Tank 4):

1. Baseline

A one-stage mesh pad mist eliminator was selected for this study. Tank 4 is the tank connected to the one-stage mist eliminator.

a. Type of Plating:

Automotive parts plated on racks are the typical plating job.

b. Device:

The device is vertical flow unit built by the Heil Process Equipment Company. It is approximately 26 years old. A woven style single mesh pad, approximately 46 centimeters thick, is in the device. City water is sprayed into the air flow in the horizontal inlet duct and directed toward the electroplating tank. No rinse water is applied to the mesh pad. The pad is replaced periodically although there is no set timetable. The fan is located after the device. The device is inside the shop and the fan is located on the roof. The duct and device shell are metal construction.

c. Tank:

A single tank is connected to the device. The tank is 3.44 square meters (37 square feet). A single rectifier is connected to the tank.

d. Exhaust System:

A pull-pull exhaust system is used at this tank. The exhaust hood is a dual- lateral style. A single inlet located at the end of the tank connects the hood to the control device. An existing stack from the fan was used for the testing.

e. Type of Facility:

The facility is an EPA "large" facility but it is expected that with the installation of non-resettable amp hour meter, the shop would be a EPA "small" facility. A general layout of the system is shown in Figure 7.

2. Phase 4

No Phase 4 modifications have been done at this facility at the time of the preparation of this report. The current prevention/control device is to be replaced with a multi-stage mesh pad mist eliminator.

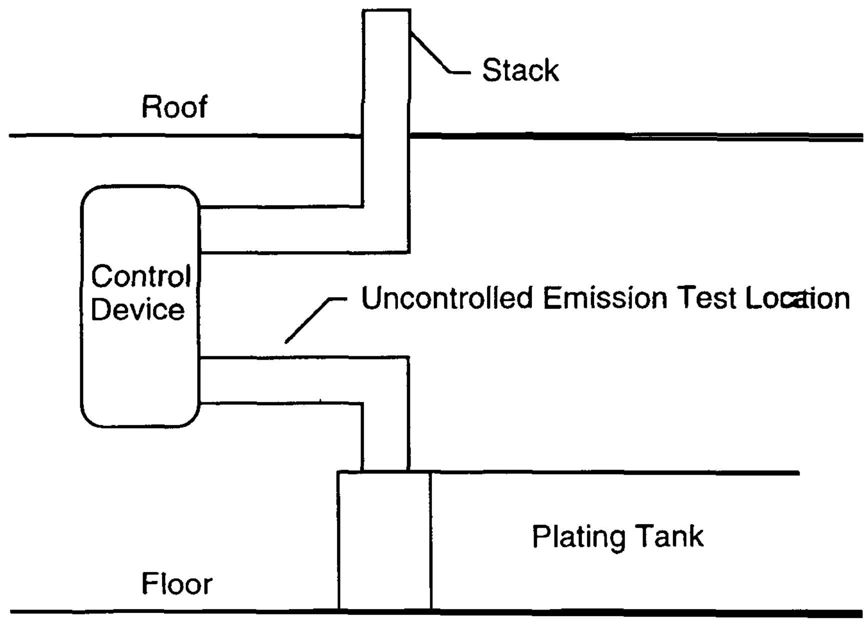

Figure 7. One-Stage Mesh Pad Mist Eliminator Layout

E. Two-Stage Mesh Pad Mist Eliminator, (Tank 5):

1. Baseline

The two-stage mesh pad mist eliminator was not expected to meet the EPA “large” facility emission limit. Tank 5 is connected to this device.

a. Type of Plating:

The facility does job shop plating where automotive and industrial rack plating is typical.

b. Device:

The device is seven years old. It is a two-stage horizontal air flow device built by ChromeTech, Inc. of Windsor, Ohio and is operated dry. The device does not use the originally incorporated recirculation deionized water spray in front of the 1st stage . The device, duct work, and fan are of plastic construction. The mesh pads are washed down in place daily and removed weekly and rinsed out.

c. Tank:

The device is connected to a single tank of 1.86 square meters (20 square feet). A single rectifier is used at the tank.

d. Exhaust System:

The push-pull exhaust system used consists of a low-profile hood opposite a push air header. The exhaust hood is C-shaped so exhaust air is removed from the side opposite the air header and the ends of the tank. A fan is located after the control device so it sees only "clean" air. The existing vertical stack was used for outlet testing.

e. Type of Facility:

The facility is an EPA "small" facility. There are three hard chromium electroplating tanks at the facility. A general layout of the system is shown in Figure 8.

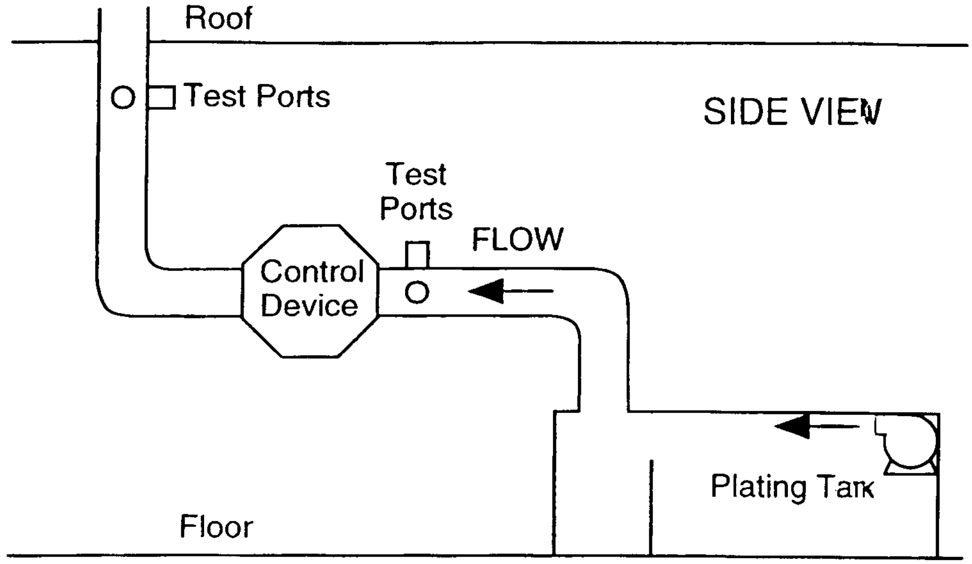

Figure 8. Two-Stage Dry Mesh Pad Mist Eliminator

2. Phase 4

No Phase 4 modifications are planned at this facility.

F. Three-Stage Mesh Pad Mist Eliminator, (Tank 6):

1. Baseline

This device was expected to met the Chrome MACT emission limit for the facility, but was included to test whether the device could meet the EPA "large" facility emission limit. In addition, the device was included to determine if there was any degradation in control effectiveness over a four year period. The device had been tested four years previously during the EPA development testing for the 306A procedure. Tank 6 is connected to this device.

a. Type of Plating:

The facility does job shop plating where automotive and industrial rack plating is typical.

b. Device:

The device is know as a Tri-Mesh unit. It was built by ChromeTech Inc. of Windsor Ohio and is six years old. There is a continuous wash-down in front of the first two mesh pads. Deionized water is recirculated to the pads from a tank under the device. The air flow is horizontal. The device, duct work and fan are constructed from plastic.

c. Tank:

The device is connected to a single tank of 1.86 square meters (20 square feet). A single rectifier is used at the tank.

d. Exhaust System:

A push-pull exhaust system used on this tank is a low-profile hood opposite a push air header. The exhaust hood is C-shaped so exhaust air is removed from the side opposite the air header and the ends of the tank. A fan is located after the prevention/control device so it sees only “clean” air. The existing vertical stack was used for outlet testing.

e. Type of Facility:

The facility is an EPA “small” facility. There are three hard chromium electroplating tanks at the facility. A general layout of the system is shown in Figure 9.

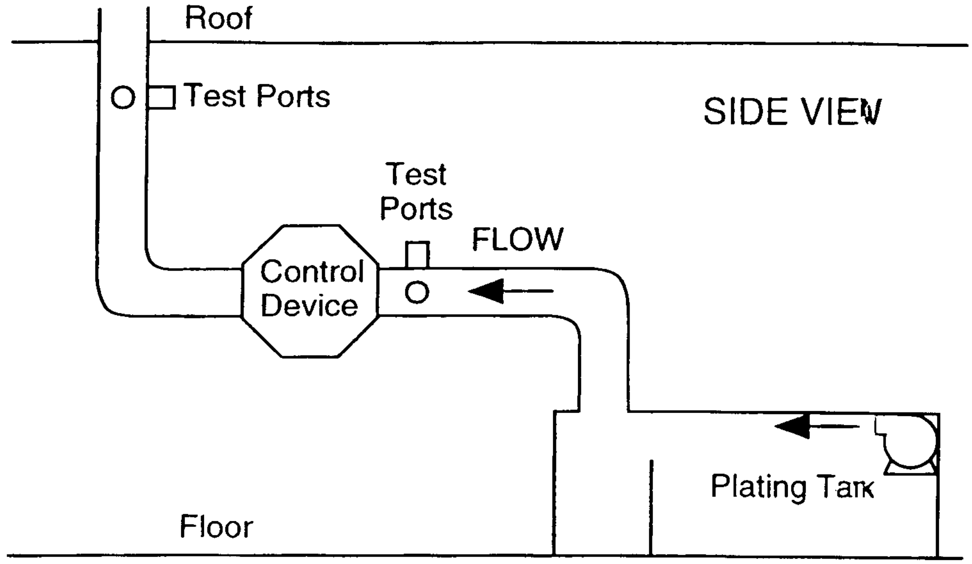

Figure 9. Three-Stage Wet Mesh Pad Mist Eliminator Layout

2. Phase 4

No Phase 4 modifications are planned at this facility.

VII. Procedure: Prevention/Control Technique Testing and Analysis

Sampling of the outlets and inlets of the six selected prevention/control devices was done following the EPA's Method 306. Several modifications were done in the Phase 4 testing. At the first two sampling runs at the Phase 4 packed-bed scrubber tests, a heated sampling probe was used. This was discontinued after the first two runs and was not done at the Tank 12 and 13 Phase 4 sampling tests or any other sampling runs. Another minor modification was done after consulting with Frank Clay of the EPA and Dr. Kate Luke of RTI. It was decided to filter the Phase 4 samples at the analysis labs and not in the field. The third minor modification was that both hexavalent and total chromium analysis were done on each inlet and outlet sample. The fourth minor modification was that at two of the prevention/control devices, concurrent EPA Method 306B sampling was performed.

Analysis of the inlet and outlet samples was done either by Inductively Couple Plasma emission spectrometry (ICP) or Graphite Furnace Atomic Absorption Spectroscopy (GFAAS) for total chromium depending on the individual laboratories detection limits for the methods. Hexavalent chromium was analyzed using Ion Chromatography with Post Column Reactor (IC/PCR).

The EPA's Method 306B was used for measurement of the electroplating baths' surface tension. Both stalagmometer and DuNouy Ring tensiometer (analysis followed the ASTM Method D 1331-89 procedures) were used. Chromium air concentrations above the electroplating tanks were analyzed using OSHA 125-G procedures for total chromium.

The density measurements of the electroplating baths in the baseline studies were done using ASTM Method D 1298. SW-846 Method 6010, ICP was used for multi-metals analysis of the electroplating baths. The industry standard titration method was used for determination of the hexavalent concentration in the electroplating bath samples. Chain of custody forms were completed for all samples submitted to laboratories for analysis.

The baseline prevention/control devices are:

1) Blade-type (tank 12)

2) Blade-type (tank 13)

3) Twin bed packed-bed wet scrubber
(similar to EPA “small” facility reference control device)

4) One-stage mesh pad wet mist eliminator

5) Two-stage mesh pad dry mist eliminator

6) Three-stage mesh pad wet mist eliminator
(similar to EPA “large” facility reference control device)

A baseline study of blade-type (tank 13) control device was done during the Phase 4 testing. The baseline control devices are ducted to either a single or multiple emission source(s) (electroplating tank).

After the Phase 2 (baseline) results were reported, only those prevention/control devices that had chromium outlet air emissions greater than the facility size emission limit for the facility were selected for Phases 3 and 4, post modification. The control devices selected for Phase 3 and 4 were blade-types (tank 12) and (tank 13), twin bed packed-bed scrubber, and the one-stage mesh pad wet mist eliminator. The work at the one-stage mesh pad mist eliminator is not expected to be completed until January of 1997 and is not reported in this interim report.

The “large” facility emission limit is 0.015 milligrams per cubic Meter (mg/M^3) and the “small” facility limit is 0.030 mg/M^3. The size designation is determined by a total available rectifier capacity calculation. A “large” facility has a total rectifier capacity of $\geq$ 60 Million Amp-Hr/year while a “small” facility has $<$ 60 Million Amp-Hr/year.

VIII. Results:

A. Ampere-Hours/Hour, Inlet Flow, Outlet Flow, and Freeboard

In order to have comparable results from the baseline and Phase 4 testing, it was attempted to have similar ampere-hour (Amp-Hr) values for the testing. For ease of comparison between the baseline and Phase 4 tests, the values reported are ampere-hour/hour (Amp-Hr/Hr) values. The stack sampling tests typically lasted 125 minutes.

The inlet and outlet air flows are reported in dry standard cubic feet per minute (cfm) and dry standard cubic meters per minute (M^3) calculated by the stack testing firms using data obtained during the testing. The values were expected to be similar for baseline and Phase 4 testing. The Phase 4 air flows for the blade-type (tank 12) is different from the baseline values as the fan was changed to increase the air flow. A new exhaust hood using a push-pull style replaced the baseline pull-pull style exhaust hood. This change was done in order to see the effects of a push-pull style system compared to a pull-pull system. The calculated values for air flow per tank surface area is reported so that comparisons can be made between tanks and to the OSHA minimum ventilation rate for open surface tanks. The OSHA open surface tank rate for hard chromium electroplating tanks is between 190 and 375 cfm per square foot.

Phase 4 tests at the packed-bed scrubber used a higher foaming version of the Lo-Mist chemical mist suppressant by Accurate Engineering Laboratories (Chicago, IL). The Phase 4 work done at the blade-type (tank 12) used Fumetrol 140 chemical mist suppressant by Atotech USA Inc. (Somerset, NJ) at two different addition concentrations.

The Phase 4 blade-type (tank 13) tests used a lower foaming version of the Lo-Mist chemical mist suppressant by Accurate Engineering Laboratories (Chicago, IL) at two addition concentrations. In the table above, “with two-stage CMP” refers to the tests series done using only the existing blade-type plus the add on two-stage composite mesh pad mist eliminator, Spectra U-II by KCH Services, Inc. (Forest City, NC). This device was placed inline after the existing blade-type. A new fan, which replaced the old fan, was installed after the Spectra U-II mist eliminator.

The freeboard values are the distance between the liquid surface and the bottom of the exhaust hood slot. The values are reported on Table 5.

Table 5. Baseline and Phase 4 Ampere-Hours/Hour, Inlet and Outlet Flow

	Tank 12	Tank 13+	Tanks 3a-3e	Tank 4	Tank 5	Tank 6
Baseline Amp-Hr/Hr	**2614**	**12,174**	**13,683**	**2636**	**2978**	**2512**
Phase 4 Amp-Hr/Hr	**===== =====**	**===== =====**	**===== =====**	**not done yet**	**no post test**	**no post test**
With two-stage CMP	**3933**	**===== =====**	**===== =====**	**===== =====**	**===== =====**	**===== =====**
@41 dynes/cm	**=====**	**11,158**	**=====**	**=====**	**=====**	**=====**
@23 dynes/cm	**=====**	**11,693**	**=====**	**=====**	**=====**	**=====**
@32 dynes/cm	**5357**	**=====**	**=====**	**=====**	**=====**	**=====**
@22 dynes/cm	**4207**	**=====**	**=====**	**=====**	**=====**	**=====**
@28 dynes/cm	**=====**	**=====**	**13,486**	**=====**	**=====**	**=====**
@24 dynes/cm	**=====**	**=====**	**18,126**	**=====**	**=====**	**=====**
Baseline Inlet M^3 (cfm)	**105 (3720)**	**242 (8531)**	**455 (16,056)**	**84 (2978)**	**117 (4144)**	**88 (3108)**
Phase 4 Inlet M^3 (cfm)	**149 (5259)**	**243 (8552)**	**492 (17,351)**	**not done yet**	**no post test**	**no post test**
Baseline Outlet M^3 (cfm)	**90 (3167)**	**287 (10,140)**	**441 (15,574)**	**86 (3049)**	**122 (4320)**	**137 (4838)**
Baseline Tank Ventilation Rate M^3/M^2 (cfm/ft^2)	**26.2 (85.6)**	**38.8 (127.9)**	**35.2 (115.4)**	**25.0 (82.4)**	**64.2 (216)**	**72.1 (241.9)**
Phase 4 Outlet M^3 (cfm)	**156 (5521)**	**282 (9976)**	**508 (17,934)**	**not done yet**	**no post test**	**no post test**
Phase 4 Tank Ventilation Rate M^3/M^2 (cfm/ft^2)	**45.3 (149.2)**	**38.1 (125.8)**	**40.5 (132.8)**	**not done yet**	**no post test**	**no post test**
Baseline Freeboard, cm (in)	**23.4 cm (9.2 in)**	**30 cm (11.8 in)**	**11.9 cm (4.7 in)**	**17.8 cm (7.0 in)**	**20.3 cm (8.0 in)**	**15.2 cm (6.0 in)**
New Phase 4 Freeboard, cm (in)	**27 cm (10.65 in)**	**===== =====**	**===== =====**	**not done yet**	**no post test**	**no post test**
High ST Phase 4 Freeboard, cm (in)	**22.3 cm (8.8 in)**	**30.7 cm (12.1 in)**	**9.1 cm (3.6 in)**	**===== =====**	**no post test**	**no post test**
Low ST Phase 4 Freeboard, cm (in)	**23.6 cm (9.3 in)**	**30.2 cm (11.9 in)**	**18.3 cm (7.2 in)**	**===== =====**	**no post test**	**no post test**

+ Draft RTI Laboratory Value
dy = dynes per centimeter

The 'xx dy' values in the Table 5 are the surface tensions in dynes per centimeter of the electroplating baths done by DuNouy Ring Tensiometer by Analytical Testing Laboratories (Keniworth, NJ).

B. Inlet Air Concentration

The control devices' inlet chromium air concentrations were sampled using the EPA's Method 306 procedures and analyzed for total and hexavalent forms of chromium. The baseline concentrations are those of the sources without any prevention/control technique used. The baseline stack sampling tests and analysis were done by Midwest Research Institute (Kansas City, MO). The same testing crew did all the sampling in a two-week period in October of 1995. The blade-type (tank 13) baseline sampling was performed by Pacific Environmental Services, Inc. (Mason, OH) during the Phase 4 portion of the Project. The value reported is from Research Triangle Institute (Research Triangle Park, NC). All values were determined by ICP analysis and are reported in Table 6.

All Phase 4 stack sampling was done by Pacific Environmental Services, Inc. The inlet and outlet samples were split and the splits were sent for total chromium and hexavalent chromium to both Midwest Research Institute (MRI) and Research Triangle Institute (RTI). Both Institutes used IC/PCR for hexavalent analysis. RTI used ICP for Phase 4 total chromium analysis as they have a lower minimum detection limit than is listed in section 2.2.1.1. of Appendix A to Part 63, Method 306. MRI used GFAAS for total chromium analysis as they did not have a minimum detection limit for ICP low enough to quantify the Phase 4 outlet and inlet samples. The baseline and Phase 4 inlet chromium air concentrations are listed in Tables 6 and 7.

Table 6. Baseline Inlet Chromium Air Concentration

	Tank 12	Tank 13	Tanks 3a-3e + Polyballs	Tank 4 + Polyballs	Tank 5	Tank 6	EPA*
Hexavalent mg/M^3	**5.3200**	**1.9544**	**0.653**	**4.8063**	**4.5686**	**11.5316**	**4.279**
Total mg/M^3	**5.5033**	**1.7158**	**0.589**	**5.1200**	**4.6733**	**11.2400**	**==== ====**

***** Background Information for Proposed Standard, Vol. I, page 3-31 EPA 453/R93-030a

Table 7. Phase 4 Inlet Chromium Air Concentration

Source	Modification at Tank	MRI mg/M^3 Hexavalent	RTI mg/M^3 Hexavalent	MRI mg/M^3 Total	RTI mg/M^3 Total
Tank 12	Push-Pull Hood	3.9218	3.9544	3.9822	3.7927
	Suppressant @ 32 dynes/cm	0.1763	0.1758	0.1748	0.1667
	Suppressant @ 22 dynes/cm	0.02677	0.0282	0.02837	0.0269
Tank 13	Suppressant @ 41 dynes/cm	0.04773	0.0472	0.05027	0.0517
	Suppressant @ 23 dynes/cm	0.00980	0.0075	0.01067	0.0083
Tank 3a-3e + ~95% Polyball	Suppressant @ 28 dynes/cm	0.00466	0.00488	0.00637	0.00610
	Suppressant @ 24 dynes/cm*	0.12044	0.12610	0.15064	0.13643
1-Stage Pad Mist Eliminator	None	Not Done Yet	Not Done Yet	Not Done Yet	Not Done Yet
2-Stage Pad Mist Eliminator	None	No Phase 4 test	No Phase 4 test	No Phase 4 test	No Phase 4 test
3-Stage Pad Mist Eliminator	None	No Phase 4 test	No Phase 4 test	No Phase 4 test	No Phase 4 test

* The measurements are high due to tank foam being sucked into exhaust duct

C. Outlet Air Concentration

The prevention/control device outlet stack sampling was performed using EPA Method 306 and 306A procedures. MRI did the baseline stack testing and analysis except for blade-type (tank 13). PES did Phase 4 stack testing and baseline on blade-type (tank 13). The outlet samples were split and MRI and RTI did independent analysis of outlet samples for hexavalent and total chromium, see Tables 8 and 9.

Table 8. Baseline Outlet Chromium Air Concentration, MRI Laboratory Results

	Blade-Type (Tank 12)	Blade-Type (Tank 13)	Packed-Bed Scrubber	One-Stage Mist Eliminator	Two-Stage Mist Eliminator	3-Stage Mist Eliminator
Hexavalent mg/M^3	0.1287	0.08757	0.0470	0.0114	0.0062	0.0030
Total mg/M^3	0.1427	0.08843	0.0699	0.0311	0.0168	0.0149

Table 9. Phase 4 Outlet Chromium Air Concentration

Baseline Device	Modification Technique	MRI mg/M^3 Hexavalent	RTI mg/M^3 Hexavalent	MRI mg/M^3 Total	RTI mg/M^3 Total
Blade (tank 12)	**Two-stage CMP**	**0.00531**	**0.00485**	**0.00496**	**0.00493**
	Suppressant @ 32 dynes/cm	**0.00086**	**0.00061**	**0.00078**	**0.00076**
	Suppressant @ 22 dynes/cm	**0.00042**	**0.00038**	**0.00070**	**0.00049**
Blade (tank 13)	**Suppressant @ 41 dynes/cm***	**0.01370**	**0.01610**	**0.01447**	**0.01500**
	Suppressant @ 23 dynes/cm	**0.00311**	**0.00207**	**0.00417**	**0.00245**
Packed-Bed Scrubber + PB	**Suppressant @ 28 dynes/cm**	**0.00143**	**0.00146**	**0.00243**	**0.00197**
	Suppressant @ 24 dynes/cm**	**0.00489**	**0.00483**	**0.00608**	**0.00560**
1-Stage Pad Mist Eliminator	**Not Done Yet**	Not Done Yet	Not Done Yet	Not Done Yet	Not Done Yet

* data point in this series is out of line with Total results and if deleted, mg/M^3=0.0131
** inlet concentration higher than 28 dyne/cm due to foam sucked into exhaust duct

D. EPA Methods 306 and 306A Outlets Air Concentration

In addition to Method 306, EPA Method 306A (the Mason jar method) was performed at the packed-bed scrubber and the three-stage Chemical mist eliminator. The three-stage mist eliminator had been tested by the EPA during the 306A method development trials. These results are included in this section. MRI performed the 306A inlet and outlet sampling concurrently with the 306 sampling done during the baseline sampling. MRI built up a 306A train. They used the Mason jars but used an older model stack testing control box. The box was run as the 306A method describes. The flow was adjusted to be approximately 0.75 cubic feet per minute of air flow. The 306A procedures listed in Appendix A to Part 63 were followed otherwise. The pump and gas meter in the meter box were of the type described in the 306A section 3.1.9 and 3.1.10. The results are in Table 10.

Table 10. 306 and 306A Outlet Chromium Air Concentration

	Hexavalent, mg/M^3			**Total, mg/M^3**	
Prevention/control	EPA 306	EPA 306A	Early EPA 306A*	EPA 306	EPA 306A

Device					
Packed-Bed Scrubber	**0.0470**	**0.0442**	**Not Done**	**0.070**	**0.070**
3-Stage Mist Eliminator	**0.0030**	**0.0047****	**0.011**	**0.0150**	**0.025**

*EPA Emission Test Report, ChromeTech Inc., Twinsburg Ohio, November 1993
** 1 data point in series is out of line with others, without that point, Hex =0.003 mg/M^3

E. Above-Tank Chromium Air Concentration

The above-tank chromium air concentration is the air concentration measured approximately 10 centimeters (4 inches) above the top of the electroplating tank exhaust hood or tank lip at three equidistant points (1/4, 1/2, and 3/4 of the length of the tank's long axis) along a line down the middle of the electroplating tank paralleling the long axis. Sampling was done for a 2-hour time period except for the first Phase 4 series for blade-type Tanks 12 and 13 where 1-hour sampling was used to loading of the cassettes. The sampling used personal sampling pumps connected to 37 millimeter diameter and 0.8 micrometer size mixed cellulose-ester filter cassettes. The filter cassettes were suspended so that the inlet was approximately 10 centimeters (4 inches) above the top of the exhaust hood slot. Typically, a dual lateral pull-pull exhaust hood was connected to the prevention/control devices tested. For the two- and three-stage mist eliminators however, a push-pull exhaust hood was connected to the prevention/control devices. The Table 11 and 12 results are given as total chromium.

Table 11. Baseline Above-Tank Total Chromium Air Concentration,
MRI Laboratory Results

Modification at Tank	Tank 12 mg/M^3	Tank 13+ mg/M^3	Tanks 3a-3e mg/M^3	Tank 4 mg/M^3	Tank 5 mg/M^3	Tank 6 mg/M^3
No Polyballs	**3.61**	**3.442**	**1.57**	ND	**1.01**	**5.31**
~65% Polyballs	ND	ND	ND	**14.6**	ND	ND
~90% Polyballs	ND	ND	ND	**4.1**	ND	ND
~95% Polyballs	ND	ND	**0.20**	ND	ND	ND

+ Draft LabCorp Laboratory Value
ND means not done

Table 12. Phase 4 Above-Tank Total Chromium Air Concentration, LabCorp Results

Modification at Tank	Tank 12 mg/M^3	Tank 13+ mg/M^3	Tanks 3a-3e mg/M^3	Tank 4 mg/M^3	Tank 5 mg/M^3	Tank 6 mg/M^3

Push-Pull hood & No Suppressant	**1.218**	Not Done	Not Done	Not Done	Not Done	Not Done
Suppressant @ 41 dynes/cm	Not Done	**0.196**	Not Done	Not Done	Not Done	Not Done
Suppressant @ 23 dynes/cm	Not Done	**<0.028**	Not Done	Not Done	Not Done	Not Done
Suppressant @ 32 dynes/cm	**<0.014**	Not Done	Not Done	Not Done	Not Done	Not Done
Suppressant @ 22 dynes/cm	**<0.17**	Not Done	Not Done	Not Done	Not Done	Not Done
Suppressant @ 28 dynes/cm + 95% PB	Not Done	Not Done	**<0.012**	Not Done	Not Done	Not Done
Suppressant @ 24 dynes/cm + 95% PB	Not Done	Not Done	**<0.008**	Not Done	Not Done	Not Done
Suppressant @ 28 dynes/cm + 0% PB	Not Done	Not Done	**<0.011**	Not Done	Not Done	Not Done
Suppressant @ 24 dynes/cm +0% PB	Not Done	Not Done	**<0.009**	Not Done	Not Done	Not Done

+ Draft report values

F. Surface Tension Measurement

An important measurement for the Chrome Demo Project is the surface tension of the electroplating bath. Surface tension can be thought of as a measure of the force needed to penetrate the liquid surface. The higher the surface tension, the more force is needed to break through the liquid-air interface.

The EPA has provided for several different methods for measuring surface tension. In the Project, the stalagmometer method and the DuNouy Ring tensiometer method were used. The DuNouy Ring tensiometer, (Fisher Model 20 Manual DuNouy Ring Tensiometer) was used for the baseline and for the Phase 4 work following the ASTM Method D 1331-89 procedure. Phase 4 surface tension measurements were done by Analytical Testing Laboratories (Keniworth, NJ) using a Fisher Model 21 SemiAutomatic DuNouy Ring tensiometer. In addition to the DuNouy Ring tensiometer testing by ATL, all Phase 4 bath samples were tested by stalagmometer by David York at Diamond Chrome Plating Inc. (Howell, MI) using a Lurex brand 5 milliliter stalagmometer.

Initial surface tension adjustments for the packed-bed scrubber Phase 4 work was done using the stalagmometer. Initial surface tension adjustment for the blade-type Tanks 12 and 13 work was done using a CSC Scientific Co. (Fairfax, VA) DuNouy ring tensiometer. A KSV Instruments (Monroe, CT) Sigma 703 DuNouy ring tensiometer was used in addition to the CSC device. The CSC designated values were values obtained by ITI personnel using the CSC tensiometer. The surface tension measurements are recorded in Tables 13 and 14.

Table 13. Baseline Corrected Surface Tension Measurement*

Tester	Tank 12 Dynes/Centimeter	Tank 13+ Dynes/Centimeter	Tanks 3a-3e Dynes/Centimeter
MRI	72.9	========== ==========	70.6 Tank 3-1 62.2 Tank 3-4
ATL+	67.2	69.2	========

***** MRI and ATL used DuNouy Ring Tensiometer
+ Draft ATL Laboratory Value

The values reported in Tables 13 and 14 are "corrected" values. The instruments used to measure surface tension indicate a relative value. This value has to be adjusted, i.e. corrected. The correction method depends on the instrument used to measure the surface tension. The tensiometer results have to be corrected by a F factor, typically 0.94, and for temperature. The temperature of the sample should be within a range of 28-22° Centigrade. For each degree above 25° Centigrade, add 0.14 to the reading after multiplying by 0.94 and for each degree below 25° Centigrade, subtract 0.14 after multiplying the instrument reading by 0.94. For the stalagmometer, the number of drops for 5 milliliters of electroplating bath solution is the value measured, the relative value. Using a formula supplied by the stalagmometer vendor, the number of drops measured, and the density of the electroplating bath, the corrected value is calculated.

Table 14. Phase 4 Corrected Surface Tension Measurements

	Blade-Type (Tank 12)+		Blade-Type (tank 13)+		Packed-Bed Scrubber	
Dynes/ Centimeter	DuNouy Ring Tensiometer	Stalag-mometer	DuNouy Ring Tensiometer	Stalag-mometer	DuNouy Ring Tensiometer	Stalag-mometer
High ST Series @ tank(s)	32 (ATL) 33 (CSC)	54	41 (ATL) 43 (CSC)	62	28 (ATL) 30 (CSC)	38
Low ST Series @ tank(s)	22 (ATL) 24 (CSC)	32	23 (ATL) 29 (CSC)	36	24 (ATL) 24 (CSC)	26

ST = Surface Tension
+ Draft report values

G. ICP Total Chromium Analysis

During the Chrome Demo Project, reduced-cost non-approved testing was done to get a estimate of expected Method 306 results. This was done for the five prevention/control devices tested in the Phase 2 portion. Blade-type (tank 13) baseline tests were not done in the Phase 2 portion. Only outlet emissions were measured. Clayton Environmental Consultants, Inc. (Detroit, MI), was used for the reduced-cost tests of the Michigan prevention/control devices and Envisage Environmental (Cleveland, OH) was used for the reduced-cost tests at the Ohio prevention/control devices. The analysis method used for the reduced-cost test samples was ICP. The results are in Table 15.

Table 15. Total Chromium Measurement Outlets

	Blade (Tank 12)+ mg/M^3	**Blade (Tank 13)+ mg/M^3**	**Packed-Bed Scrubber mg/M^3**	**One-Stage Mist Eliminator mg/M^3**	**Two-Stage Mist Eliminator mg/M^3**	**Three-Stage Mist Eliminator mg/M^3**
Reduced-Cost ICP Tests	**0.073***	**======**	**0.026***	**0.017****	**0.009****	**0.007****
Draft ICP Baseline	**0.113**	**======**	**0.038**	**0.012**	**0.008**	**0.0004**
Final ICP Baseline	**0.143**	**======**	**0.070**	**0.019**	**<0.008**	**<0.015**
Phase 4 RTI (ICP)	**two-stage 0.00493**	**Baseline 0.08843**	**0.0056**	Not Done Yet	No Phase 4	No Phase 4
Phase 4 MRI (GFAAS)	**two-stage 0.00496**	**Baseline 0.09493**	**0.0061**	Not Done Yet	No Phase 4	No Phase 4

* Clayton tests
** Envisage tests

In addition to the reduced-cost test results, Table 15 shows the MRI total chromium outlet results of ICP analysis of outlet samples from both the draft version of the MRI report and the final MRI report. The draft and final values differ as MRI reported a matrix interference in the draft baseline report and the samples were re-analyzed to correct for the matrix interference in the final baseline MRI report. The values obtained in the Phase 4 work is reported also in Table 15. Both ICP and GFAAS were used to analysis the Phase 4 samples.

Along with the total chromium analysis done in the reduced-cost tests, hexavalent chromium analysis was done for the Envisage samples. These results along with the final baseline MRI report hexavalent values are reported in Table 16.

Table 16. Comparison of Reduced-Cost Test and Final Report, Hexavalent Chromium

	One-Stage Mist Eliminator, mg/M^3	**Two-Stage Mist Eliminator, mg/M^3**	**Three-Stage Mist Eliminator, mg/M^3**
Reduced Cost Test	**0.01**	**0.006**	**ND***
Final Baseline	**0.0114**	**0.0062**	**0.0046**

* ND = None Detected

IX. Discussion

A. Sample Port

In the Project, inlet locations for all prevention/control devices except for the blade-type (tank 13) met the criteria for port location set forth in EPA Method 1. All outlet port locations met the criteria of Method 1. For all devices except for the add-on two-stage device (New) an outlet stack had to be constructed as the pre-existing outlets did not meet the Method 1.

B. Amp-Hr/hr and Inlet Chromium Air Concentrations:

It is commonly believed that inlet air concentrations are related to the Amp-Hr/Hour used by the bath. The baseline results in Tables 5 and 6, for the blade-type (tank 12), one-stage mist eliminator, and the two-stage mist eliminator, have a reverse relationship. With an increase in Amp-Hr/hr, there is a decrease in inlet emissions. The Amp-Hr/hr value of the three-stage mist eliminator is 92% of the average of the blade-type (tank 12), one-stage mist eliminator, and the two-stage mist eliminator and yet the inlet concentration of the three-stage mist eliminator is 235% more than the average total chromium concentration for the above devices, again a reverse relationship.

The project results indicate that the correspondence of Amp-Hr/Hour to emissions seems to be best for intrabath results and not with interbath results, although even the intrabath correlation is low. Correlation at the same device between different sampling dates does not show the correlation as between runs done on the same date. This can be seen by simple observation of Tables 5, 6, and 7. The inlet air concentration is much lower during the blade-type (tank 12) two-stage Device compared to the inlet concentration of the baseline testing (3.9544 to 5.3200) even though the Amp-Hr/hr is greater for the former (3933 to 2614). Also, looking at the baseline inlet air concentrations and Amp-Hr/hr for blade-type (tank 12) and blade-type (tank 13) shows no correlation or negative correlation. The Tank 13 has more Amp-Hr/hr and less inlet emissions than Tank 12 (12,174 to 2614 and 1.9544 to 5.3200). It seems that other factors have a greater effect on inlet concentrations than Amp-Hr/hr when comparing between devices. These may be factors such as air flow, capture efficiency of the exhaust hood, work practices, parts loading and type, and others not as yet known to the author.

C. Test Represenativeness

However, in order to make the tests as representative as possible, it was attempted to have the Phase 4 test Amp-Hr/hr be similar to the baseline tests. The Amp-Hr/hr of the Phase 4 tests were in the range of 92-205%, see Table 17.

Table 17. Percent (Phase 4 Amp-Hr/hr) / (Baseline Amp-Hr/hr)

Modification Technique	Blade-Type (Tank 12)	Blade-Type (Tank 13)	Packed-Bed Scrubber + Polyballs
Two-Stage CMP	**150**	**========**	**===============**
Chemical Mist Suppressant at High dyne/cm	**205**	**92**	**99**
Chemical Mist Suppressant at Low dyne/cm	**161**	**96**	**132**

From Table 17, no test was used less than 92% amp-hr/hr of the baseline tests. In several of the cases, the amp-hr/hr were higher due to processing loads of the parts in the electroplating baths. The amp-hr/hr are determined by the surface area of the parts in the bath. For Tank 12 and 13, the surface areas of the parts are used to figure amp settings for the rectifier. For the packed-bed scrubber, the rectifier setting is typically based on prior knowledge of build up rates for similar parts at a rectifier setting. The amp-hr/hr values were increased with expected greater control of chromium mist generation or prevention/control of chromium outlet emissions. This was done to get the best challenge for the prevention/control technique as possible.

D. Mg/M^3 is not always the Best Method of Comparing Prevention/Control Techniques

It is known that the amount of air flow will change the air concentration of a substance when the emission of the substance is constant. It is attempted to use the milligrams of chromium per minute at the inlet as a method of comparison. Even when the different air flows of the different devices are eliminated by converting the mg/M^3 concentration to milligrams chromium per minute, simple observation of Tables 19 and 5 shows a poor correlation between devices. At baseline, Tank 13 has 466% more Amp-Hr/hr than Tank 12 yet the amount of chromium measured at the inlet is less for Tank 13 than Tank 12. See Table 18 for inlet milligrams of chromium per minute.

Table 18. Inlet Milligrams of Hexavalent per Minute

Phase	**Blade-Type (Tank 12), mg/min**	**Blade-Type (Tank 13) mg/min**	**Packed-Bed Scrubber + Polyballs mg/min**
Phase 2: Baseline (Cr+6 inlet mg/M^3)	**559 (5.3200)**	**473 (1.9544)**	**297 (0.653)**
Phase 4: Push-Pull (Cr+6 inlet mg/M^3)	**589 (3.9544)**	**======== ========**	**============= =============**
Phase 4: High dyne/cm (Cr+6 inlet mg/M^3)	**26.2@ 32 dy/cm (0.1758)**	**11.5@41 dy/cm (0.0472)**	**2.4 @ 28 dy/cm**
Phase 4: Low dyne/cm (Cr+6 inlet mg/M^3)	**4.2 @ 22 dy/cm ((0.0282)**	**1.8@ 23 dy/cm (0.0075)**	**============ ============**
Inlet flow in M^3 Baseline	**105**	**242**	**455**
Inlet flow in M^3 Phase 4	**149**	**243**	**492**

Also, the packed-bed scrubber has 112% more Amp-HR/hr than Tank 13, yet the inlet chromium for the packed-bed scrubber is only 63% of that at the inlet of Tank 13, indicating the difficulty in comparing techniques used in different tanks.

The mg/M^3 measurement does not always indicate what is happening. In the case of chemical mist suppressant tests at Tanks 12 and 13, the inlet concentration of Tank 12 is 374% higher than the inlet chromium concentration for Tank 13. However when the inlet amount of chromium is calculated, the inlet amount of chromium for Tank 12 is only 230% more than Tank 13. The mg/M^3 values make the Lo-Mist chemical mist suppressant look better than the Fumetrol 140 than it actually is. One must be careful when comparing devices or techniques that are not used in the same tank.

A person must be very careful when comparing one prevention/control device to another even if the devices are very similar like the Tank 12 and Tank 13 blade-types. The outlet values between these similar devices show a different variation than expected when looking at outlet concentrations. The blade-type (tank 13) baseline outlet air concentrations are 63% lower than the baseline air concentrations of blade-type (tank 12). However when converted to milligrams (mg) of hexavalent chromium out per minute, the blade-type (tank 13) has 473 mg compared to 559 mg for blade-type (tank 12), a difference of only 15%. The blade-type (tank 13) used 283% more Amp-Hr/hrs than the blade-type (tank 12) and 181% more outlet air flow.

E. Freeboard: Effect

To keep the testing as representative as possible, the freeboards were kept similar for baseline and Phase 4. Freeboard between the devices varied from 9.1 cm to 30.7 cm. Previous work by Richard Bergland indicates that freeboard does have an effect on emissions. He stated that a freeboard of 15 cm will result in the lowest emissions and freeboards of either less or more than 15 cm would result in greater emissions. The Metal Finisher Foundation Report reported that freeboards varying from 15.2 to 30.5 cm did not have a significant effect on emissions. As the freeboards used during the Chrome Demo Project were in the range of the Metal Finishers Foundation study, it could be expected that the same effect would have shown up here.

In the baseline blade-type (tank 12), the freeboard varied from 7.4 to 10.3 cm. The Tank 12 baseline inlet concentrations increased with increased freeboard even when the run difference in Amp-Hr/hr was factored into the difference. The difference, at best only a 7% increase in emissions, can be attributed to the freeboard difference. These results support neither Bergland nor the Metal Finishers Foundation study results.

F. Freeboard: Effect of Chemical Mist Suppressant

It was noticed during the chemical mist suppressant tests, that use of the suppressant typically resulted in a foam blanket over the tank surface. The increase in freeboard typically noticed when no chemical mist suppressant was used, did not occur when the chemical mist suppressant was used. The foam layer reduces the evaporation losses. This can create problems if the evaporative losses from the electroplating tanks is used to dispose of process water. It is the evaporation of water that resulted in the increasing freeboard noted in the tests done without chemical mist suppressants.

During the Chrome Demo Project it was noticed that a foam layer in the electroplating tank results in increased cooling needs. The foam layer reduces the evaporative cooling for the tank.

G. Variation of Inlet and Outlet Flow during the Tests

The inlet and outlet flows of the Phase 4 blade-type (tank 12) increased due to the installation of a new fan. The baseline and Phase 4 inlet and outlet flows of the blade-type (tank 13) control devices were similar. For the packed-bed scrubber, the Phase 4 values are 8% greater inlet flow and a 15% greater outlet flow. There is no known reason for this difference. There were no changes to the fan. The fan had be replaced prior to the baseline tests. The building was not noticeably closed tighter during the baseline test series, as the outside air temperature for baseline and Phase 4 tests was above 65° F and overhead doors within the building were open during both tests. It was noticed that general roof ventilation fans were on during the Phase 4 tests and were not on during the baseline tests. This may indicate a make-up deficiency when general roof ventilation fans are not on.

It was noticed that the baseline inlet flow of the two-stage mist eliminator was 25% less than the three-stage mist eliminator. The outlet flows were similar with the two-stage being 12% higher when compared to the three-stage. It is believed that there was significant room air inleakage at the three-stage device and this accounted for the low inlet flow but the higher outlet flow. It was noticed that there were gaps around the mesh pad holder section of the three-stage device. Both devices used the same type exhaust fan, the same size fan motor and the same duct size. Both devices were built and installed by the same manufacturer.

In the EPA tests described in Volume II of the BID document for Plant G (Hard Chrome Specialists, Inc.), a similar difference in inlet and outlet flows were seen in approximately the same amounts. The same manufacturer produced the Plant G and two-stage control devices. In BID Volume II, it is stated that “The larger outlet flow resulted from an inadequate seal around the mesh pads which allowed ambient air to be drawn into the system.”

H. Inlet Chromium Concentration: Polyball Effect

The chromium inlet air concentration for most of the devices approximated the EPA average inlet chromium air concentration, see Table 6. All of the devices were in the range of those listed in Volume 1 of the EPA’s BID publication.

It is believed that the effect of the polyballs can be seen in the packed-bed scrubber inlet air concentration, as it is much lower than the others. The inlet concentration is 15% of the EPA average. This reduction from use of polyballs was seen during the baseline testing of the one-stage mist eliminator also. When the tank surface coverage of polyballs was increased from 65% to 90%, the inlet loading decreased 29%.

Table 19. Inlet Chromium Concentration with Polyballs

Modification at Tank	Tanks 3a-3e mg/M^3	Tank 4 mg/M^3
~65% Polyballs	ND	**6.33**
~90% Polyballs	ND	**4.52**
~95% Polyballs	**0.589**	ND

I. Inlet Chromium Concentration: Push-Pull Ventilation Effect

It is theorized that a push-pull exhaust system may be more effective in capturing source emissions than the typical dual lateral style exhaust hood. It was believed that the effect of the push-pull exhaust was seen in the three-stage mist eliminator when compared to the blade-types or the one-stage mist eliminator. The three-stage mist eliminator’s inlet chromium concentration was much higher than the blade-types or the one-stage mist eliminator. The principal differences were that the three-stage device used a push-pull exhaust system and had an air flow higher than the OSHA minimum ventilation rate.

The blade-types and one-stage used dual-lateral exhaust hoods and had air flows that were less than the OSHA minimum ventilation rate for open surface tanks. OSHA minimum ventilation rates are not typically an enforceable compliance issue if worker exposure is less than the OSHA Permissible Exposure Limit for an air contaminant. The effect of push-pull was not seen consistently in this project. The inlet loading of the three-stage mist eliminator was 200% of that of the two-stage mist eliminator even when the effect of the greater inlet flow of the two-stage is factored in. The parts loading and Amp-Hr/hr values of the two-stage and three-stage devices are similar and both devices use the same type of push-pull exhaust system from the same vendor.

The Phase 4 Tank 12 two-stage CMP test was expected to shed some light on this issue. A push-pull exhaust system was installed. The inlet loading of the Phase 4 Tank 12 two-stage CMP tests, see Table 18, did increase slightly. However, the Amp-Hr/hr of the Tank 12 two-stage CMP test was 50% greater than the baseline, so the increase may have been due to this.

J. Inlet Chromium Concentration: Chemical Mist Suppressant Effect

The inlet chromium concentrations show the effect of the chemical mist suppressant. The EPA’s BID documents have no comparable tests as all chemical mist suppressant tests in the BID were done at decorative chromium electroplating plants.

When chemical mist suppressant was used in the project, the inlet chromium air concentration decreased compared, to the baseline air concentration even when Amp-Hr/hrs were increased, see Tables 5 and 7. The inlet concentration decrease corresponds with the change in surface tension (dyne per centimeter) of the electroplating bath. Typically, as the surface tension decreased (to a lower dyne per centimeter value), the inlet chromium air concentration decreased. This did not happen with the 24 dynes per centimeter packed-bed scrubber test due to tank foam being sucked into the exhaust hood during this test.

The foam being sucked into the exhaust hood was due to the foam thickness increasing more than was expected. The foam layer increased from less than 2.5 centimeters (1 inch) for the 28 dynes per centimeter test series to more than 10 centimeters (4 inches) for the 24 dynes per centimeter test series. This was due to a facility management decision to override the suggestion of the chemical mist suppressant manufacturer and to request a higher foaming version of the chemical mist suppressant.

To correct this problem, the tanks had to be pumped to lower the tank levels and reduce the amount of foam being sucked into the exhaust duct. The average inlet chromium concentration for the 24 dyne run at the packed-bed scrubber does not show the entire picture. The individual runs of the 24 dyne series show a decrease in inlet concentration from run 1 to run 3 as expected. The decreasing amount of foam being sucked in due to the lower bath level (increased freeboard) resulted in the inlet concentration decreasing by 91% from the 1st run of the 24 dyne series, Run 1 = 0.2460 mg/M^3 and Run 3 = 0.0219 mg/M^3. Due to uncertainties during testing of the effect of foam on the inlet, time was not given to allow the foam to be eliminated from the system. It is expected that with time for the foam to have fully worked out of the system, the inlet concentration would be expected to be less than it was.

The inlet chromium air concentration decreased generally with the surface tension reduction and increased with higher surface tensions with both wetting agent chemical mist suppressants tested. The inlet reduction result of the Lo-Mist HC seems to be consistent with the surface tension. In both the packed-bed scrubber and blade-type (tank 13), Lo-Mist was used. At 23-28 dynes per centimeter surface tension, the inlet concentrations of these two prevention/control devices are similar even though their baseline inlet concentrations were an order of magnitude apart. For both the 23 and 28 dyne tests, the inlet chromium air concentrations were lower than the Chrome MACT emission limit for “large” facilities.

The inlet chromium air concentrations of blade-type (tank 12) tests using Fumetrol 140 were consistent with surface tension results. The inlet chromium concentration decreased as the surface tension of the electroplating bath was reduced. The inlet concentrations did not decrease to the same order of magnitude as the Lo-Mist HC tests.

The inlet air concentration was never less than the Chrome MACT “large” facility limit. It must be pointed out that at 22 dynes, the blade-type (tank 12) inlet chromium amount was only 2 milligrams more than the inlet concentrations at Tank 13 and the packed-bed scrubber where Lo-Mist was used. The air flow for Tank 13 and the packed-bed scrubber is 330% and 160% more than Tank 12. This clearly indicates the importance of ventilation rate in calculating air concentration. A person must be careful in making any judgments on the effectiveness of either chemical mist suppressants, as both wetting agent chemical mist suppressants were not used in the same tanks, and it is known that inlet concentrations vary from source to source. Direct comparisons of the effectiveness of the two chemical mist suppressants should not be made from the results of this project.

K. Outlet Chromium Concentration: Meeting the MACT

Three of the prevention/control devices tested met the “large” facility Chrome MACT limits when hexavalent results were used, one, two, and three-stage mist eliminators. The two and three-stage mist eliminators met the same limit when total chromium air concentrations were used. Based on the EPA’s information in the BID documents, it was believed that the one-stage and two-stage devices would not meet the Chrome MACT “large” facility emission limit. As the testing done in the Chrome Demo Project indicate that the EPA’s conclusions are not valid for all cases. The Project test results indicate that the outlet emissions of a prevention/control device can not be assumed to be larger than the Chrome MACT limits, even if the prevention/control device in question is not one of the devices the EPA suggested in the preamble to the Chrome MACT standard.

Also, the project results indicate that the reverse is also true. A device the EPA suggests may meet a Chrome MACT emission limit, may not meet the limit. In the case of the packed-bed scrubber, the device tested met the criteria for a well controlled packed-bed scrubber listed in 40 CFR Part 63 Section 630342(f) and in section H(2) of the preamble of the Chrome MACT standard. Yet the outlet concentration of the packed-bed scrubber was greater than the Chrome MACT limit for “small” facilities of 0.030 mg/M^3. A packed-bed scrubber is the reference device for the “small” facility limit.

L. Outlet Chromium Concentration: Meeting the MACT - Hex/TotalPercentages

The reason the three devices met the Chrome MACT limit when the hexavalent results are considered, and only two devices met the Chrome MACT limit when the total chromium results are considered, is the difference in reported values of outlet hexavalent and total chromium. For the one-stage device, the reported hexavalent value is only 37% of the reported total chromium value. The hexavalent-total percent ratio is much lower than the EPA suggested percentage of 90%. The percent difference between hexavalent results and total results also varies between the inlet and the outlet sampling locations. The inlets typically had a higher percent ratio between the hexavalent and total results. The percentage ratio of hexavalent to total chromium outlet emissions reported in the baseline testing ranged from 20-90.2% compared to 94-111% for the inlet chromium air concentrations.

The lower hexavalent-total ratio for the outlets compared to the inlet ratios continued in the Phase 4 testing. The RTI outlet ratios for the packed-bed scrubber ranged from 79-83% while the inlet ratios ranged from 81-88% and the MRI outlet ratios ranged from 57-75% and the inlet ratios ranged from 71-79%. For the blade-types, the RTI % ratios for outlets ranged from 85-103 % while the inlet ratios ranged from 101-106 %.   The MRI % ratios ranged from 89-98% for the inlets and 80-85% for the outlets.

The EPA, in its guidebook on how to comply with the Chrome MACT (EPA-453/B-95-001) and in section 4 and Appendix D of the BID documents, stated that the expected percent ratio between hexavalent and total chromium results would be up to 90%. In the results from the Chrome Demo Project, the inlet percent ratios are close to the EPA's stated ratio while the outlet ratios are generally much lower than the inlet ratios. One theory why the percent ratio at the project outlets is lower than the EPA's stated % ratio is that for some prevention/control devices, the hexavalent form is reduced to trivalent state inside the prevention/control devices. This theory is supported in Appendix D of the BID. The problem of lower ratios of hexavalent to total was also observed in one test. The explanation given in the EPA's BID, is that there is a reaction of the chromic acid mist with steel in the exhaust system. Additional support is gathered from an experiment mentioned in Appendix D of the BID. The Source Methods Standardization Branch of the Atmospheric Research and Exposure Assessment Laboratory of the EPA performed an experiment where a known concentration of weak chromic acid solution was split and one sample had a steel fitting placed in it. Subsequent analysis showed a hexavalent chromium decrease in the fitting sample compared to the sample with no fitting.

M. Outlet Chromium Concentration: Chemical Mist Suppressant Effect

The outlet air chromium concentrations, when wetting agent chemical mist suppressant was used, met the Chrome MACT limit of 0.015 mg/M^3 in each case in the Chrome Demo Project when the chemical mist suppressant was used with an in-place existing prevention/control device or with a add-on prevention/control device at an existing prevention/control device. The packed-bed scrubber, the blade-type (tank 12), and the blade-type (tank 13) tests at surface tensions less than 28 dynes per centimeter achieved inlet chromium concentrations of 0.015 mg/M^3 or less. This indicates that the wetting agent chemical mist suppressant at low surface tension values may produce chromium air concentrations that meet the Chrome MACT limit of 0.015 mg/M^3 no matter what prevention/control device is in place. At 41 dynes per centimeter, the outlet emissions of the blade-type (tank 13) with the blade-type prevention/control devices were able to meet the Chrome MACT limit judged against the total chromium test result.

Review of the EPA's BID and Technical Assessment of New Emission control Technologies Used in the Hard Chromium Electroplating Industry (EPA 453/R-93-031) shows that no tests at hard chromium electroplating facilities using a wetting agent chemical mist suppressant were reported. In the draft version of Emission Factor Documentation for AP-42, Section 12.20, several tests were done using a chemical mist suppressant. From the draft AP-42 list of references and the descriptions for the tests reported, none of the tests in the draft AP-42 were done using the chemical mist suppressants used in the Chrome Demo Project. In the draft AP-42, no surface tension values are reported. The Metal Finishers Foundation's Chromium Air Emissions Report was the source for many of the references for chemical mist suppressant reported in the draft AP-42.

A report was made available to this author in which Fumetrol 140 was tested at a hard chromium electroplating shop. The South Coast Air Quality Management District (SCAQMD) Method 205.1 modified with reduced sampling volume was used for hexavalent and total chromium measurements. In this test, SCAQMD approved the use of the 85% ratio of hexavalent to total chromium for inlet (uncontrolled) emission rates. The test points were located only before the inlet of the prevention/control device. The tank surface area was 2.3 M^2 (25 ft^2) and the Amp-Hr/hr were 1,500 and 5,000. The test results indicate that at surface tensions of 33 dynes per centimeter and below, the inlet air chromium concentrations were less than 0.015 mg/M^3. They ranged from 0.0021-0.011 mg/M^3. The outlet emissions were less than the Chrome MACT “large” facility emission limit. This data supports the results seen at the Chrome Demo Project’s Phase 4 chemical mist suppressant tests.

N. Outlet Chromium Concentration: two-stage Composite Mesh Pad Device Effect

It is expected that the add-on two-stage CMP device at the blade-type (tank 12) would produce outlet emissions that would be lower the Chrome MACT "large" facility emission limit. This combination resulted in outlet emissions that were only 33% of the EPA "large" facility emission limit and only 4% of the baseline emissions.

O. Other Methods of Comparing Prevention/control Devices Emissions

In addition to the Chrome MACT limits, other methods are used to compare the emissions of prevention/control devices. One method is the percent efficiency (% efficiency) of the prevention/control device, the California standard lists control percentages for three levels of emitted chromium. The other method is the mg/Amp-Hr rating of a prevention/control device which is used also in the California standard. The EPA did not recognize either of these methods when the Chrome MACT limits were promulgated. In addition, there is not an equivalency between the three methods, % efficiency, mg/Amp-Hr, and outlet air concentration limits. As can be seen when comparing Tables 8, 9 and Table 20, it does not follow that the prevention/control with the higher % efficiency will have the lower emissions. The equation for calculating percent efficiency is,

$$((\text{inlet mg/M}^3 - \text{outlet mg/M}^3) / \text{inlet mg/M}^3) \times 100 = \%\ \text{efficiency} \quad (1)$$

The danger of how the use of percent efficiency can lead to the wrong conclusion is seen in Table 20. The % efficiencies of the prevention/control techniques that use chemical mist suppressant in some cases are less than 98% yet the outlet concentrations are lower than the outlet concentrations of devices with % efficiencies greater than 99%. In particular, for the blade-type (tank 13), the % efficiencies calculated for chemical mist suppressant tests are 72% and less, yet the outlet concentrations when using chemical mist suppressant are more than 97% less than the baseline outlet concentration. Similar cases can be seen for the packed-bed scrubber and the blade-type (tank 12). A literal interpretation of Table 20 would suggest that using chemical mist suppressant results in higher emissions than using a blade-type prevention/control device alone and that is wrong.

Table 20. Baseline and Phase 4 Prevention/Control Devices/Technologies Percent Efficiencies

	Blade (Tank 12) %	Blade (Tank 13)+ %	Packed-Bed Scrubber + PB %	One-Stage Mist Eliminator %	Two-Stage Mist Eliminator %	Three-Stage Mist Eliminator %
Baseline	**95.7**	**95.5**	**92.0**	**99.7**	**99.8**	**99.96**
Two-stage CMP	**99.977**	===== =====	======== ========	======= =======	======= =======	======== ========
Suppressant @ 32 dynes/cm	**99.653**	===== =====	======== ========	======= =======	======= =======	======== ========
Suppressant @ 22 dynes/cm	**98.653**	===== =====	======== ========	======= =======	======= =======	======== ========
Suppressant @ 41 dynes/cm*	===== =====	**65.89**	======== ========	======= =======	======= =======	======== ========
Suppressant @ 23 dynes/cm	===== =====	**72.4**	======== ========	======= =======	======= =======	======== ========
Suppressant @ 28 dynes/cm	===== =====	=====	**70.08**	======= =======	======= =======	======== ========
Suppressant @ 24 dynes/cm	===== =====	=====	**96.17**	======= =======	======= =======	======== ========

PB means polyballs

The mg/Amp-Hr method is used in the California Standard on Airborne Toxic Control Measures Section 93102, Hexavalent Chromium Airborne Toxic Control Measures. In this standard, three limits are listed, with 0.006 mg hexavalent chromium per Ampere-Hour as the limit for the largest facilities. Prevention/control techniques that met the Chrome MACT emission limits may not met the 0.006 mg Cr+6/Amp-Hr California limit. As can be seen by inspection of Table 21 and Tables 5, 8, and 9, of the controls with outlet emissions of 0.015 mg/M^3 or less, only blade-type (tank 12) at 32 and 22 dynes per centimeter, blade-type (tank 13) at 23 dynes per centimeter and packed-bed scrubber at 28 dynes per centimeter met or were less than the 0.006 mg/amp-Hr standard. The packed-bed scrubber at 24 dynes per centimeter, blade-type (tank 12) New Device, and blade-type (tank 13) at 41 dynes per centimeter did not meet the 0.006 mg/Amp-Hr standard.

Table 21. Baseline and Phase 4 Control Devices/Technologies mg/Amp-Hr Rating

	Blade Tank 12 mg/amp-hr	Blade Tank 13+ mg/amp-hr	Packed-Bed Scrubber + PB mg/amp-hr	One-Stage Mist Eliminator mg/amp-hr	Two-Stage Mist Eliminator mg/amp-hr	Three-Stage Mist Eliminator mg/amp-hr
Baseline	**0.265**	**0.123**	**0.456**	**0.022**	**0.015**	**0.010**
Two-stage CMP	**0.0166**	===== =====	======= =======	======= =======	======= =======	======= =======
Suppressant @ 32 dynes/cm	**0.0011**	======= =======	======= =======	======= =======	======= =======	======= =======
Suppressant @ 22 dynes/cm	**0.0009**	======= =======	======= =======	======= =======	======= =======	======= =======
Suppressant @ 41 dynes/cm*	======= =======	**0.0247**	======= =======	======= =======	======= =======	======= =======
Suppressant @ 23 dynes/cm	======= =======	**0.003**	======= =======	======= =======	======= =======	======= =======
Suppressant @ 28 dynes/cm	======= =======	======= =======	**0.0034**	======= =======	======= =======	======= =======
Suppressant @ 24 dynes/cm	======= =======	======= =======	**0.0079**	======= =======	======= =======	======= =======

PB means polyballs

The results of the Chrome Demo Project support the arguments on current (Ampere-hour) loading the EPA used in the preamble to the Chrome MACT as to why compliance values in mg/Amp-Hr would not result in consistent results. The change in milligrams of chromium emitted may not correspond to the change in Amp-Hours. For the blade-type (tank 12), the 22 dynes per centimeter air concentration is 37% less than of the 32 dynes per centimeter test, yet the mg/Amp-Hr is of the 22 dynes per centimeter test is only 18% less than the 32 dynes per centimeter test. This situation is further seen in the results of the blade-type (tank 12) with two-stage CMP and the packed-bed scrubber at 24 dynes per centimeter. The air concentrations are very similar, 0.00483 mg/M^3 for the Packed-bed and 0.00485 mg/M^3 for Tank 12, yet the mg/Amp-Hr result for the Packed-bed is only 52% of the Tank 12 result due to the higher Amp-Hr/hr values for the Packed-bed. The Chrome Demo Project results indicate that meeting the California 0.006 mg/Amp-Hr standard will mean that a control will meet the Federal limit of 0.015 mg/M^3 but not the reverse.

P. 306 versus 306A Comparison

The Chrome Demo Project results of the two devices tested using both the EPA 306 and the 306A methods indicate that either method, when done correctly, can produce samples that are similar in chromium concentration. The 306 versus 306A comparison shows that in two instances, there was less than 6% difference. The two other results had a greater difference. However at the three-stage device, one data point of the series was out of line with the others. If it was excluded, then the difference at this comparison would have been less than 6%. All three runs tested for the 306 versus 306A comparison at the three-stage Device show that the 306A chromium concentrations are higher than the 306 concentration by an average of 165%. There is no explanation offered why this difference exists for this run series other than sampling probe contamination.

Q. Effect of Age on Three-Stage Mesh Pad Mist Eliminator

The comparison to the early 306A indicates that the three-stage mist eliminator has held up well. The control does not show an increase in emissions as might be expected of the control that is over six years old, and when sampling is done more than four years apart.

R. Above-Tank Chromium Emissions

In this Project, the above-tank emissions are those emissions above the top of the exhaust hood slots that are assumed to be not captured by the exhaust hood. It is known that hexavalent chromium is present in hard chromium electroplating shop air. OSHA has a Permissible Exposure Limit for chromic acid of 0.1 milligram per cubic meter of air. This equates to 0.052 milligrams of hexavalent chromium per cubic meter of air. An objective of the Chrome Demo Project is to look at ways of reducing the worker exposure to chromium. Several methods to reduce above-tank emissions were looked into: 1) polyballs, 2) improved ventilation, and 3) chemical mist suppressants.

S. Above-Tank Chromium Emissions: Polyballs

The polyballs used in the Chrome Demo Project were 1-3/8 inch polypropylene plastic balls. These balls float on the surface of the electroplating tanks. In the packed-bed scrubber tanks, four tanks were covered (+95% coverage) and one was not. The above-tank emissions were collected above one of the tanks with polyballs (Tank 3-1) and the tank without polyballs (Tank 3-4). The Amp-Hr/hr loading of these tanks was similar even though different parts were in the tanks. In the one-stage mist eliminator tank, two levels of polyball coverage were used. The first two test runs used ~60% polyball coverage and the last test run used ~90% coverage. The parts load and Amp-Hr/hr load were similar for all three runs at the one-stage site.

The polyballs were effective in reducing the above-tank emissions as measured in this project. The reduction in above-tank emissions was 82% at the packed-bed scrubber and 72% at the one-stage tank. In prevention/control device testing, as is stated in section 3 of the EPA's BID document, different conditions at different sites may result in different emissions. The polyballs were not as effective in reducing the inlet emissions at the one-stage device as at the packed-bed scrubber. The one-stage inlet emissions were the same for test runs 1 and 2 yet the above-tank emissions decreased by 72%. The outlet emissions were very similar for the two runs.

When chemical mist suppressant was used, above-tank emissions above-tanks with and without polyballs were essentially the same, see Table 12. The polyballs did not have a definite effect when used with the chemical mist suppressant.

The results at the packed-bed scrubber device support the work reported in the Metal Finishers Foundation's Chromium Air Emission Report. In this report, inlet air concentrations were 82% less with polyballs than without polyballs. In the EPA's BID document, polyballs were reported to result in a 78% decrease in inlet emissions with only a 30% decrease in outlet emissions when polyballs were used. The packed-bed scrubber was not tested without polyballs, but the inlet concentration is about 85% less than the EPA average inlet concentration and the average value seen in the project. The inlet concentration of the Packed-bed is similar to the inlet concentration with polyballs reported in the EPA's Plant G tests in the BID document.

T. Above-Tank Chromium Emissions: Push-Pull Ventilation Effect

Further mixed indications on the effect of better ventilation that might result from the use of a push-pull exhaust system are seen in the above-tank emission results. While the push-pull three-stage inlet results showed a higher chromium air concentration than for the pull-pull lateral exhaust systems, the two-stage push-pull test did not, see table 6. The blade-type (tank 12) two-stage composite mesh pad mist eliminator test did not show an increase in inlet emissions over the baseline even with an increase in the Amp-Hr/hr value. The above-tank chromium air concentration when the combination technique of the blade-type device and the two-stage CMP device do show a decrease. The above-tank air concentrations of the two-stage show values that are less than those typically seen during the Chrome Demo Project when a lateral exhaust systems are used.

The high above-tank concentration values for the three-stage may be due to placement of filter cassette inlet. For the three-stage, the cassette inlet was placed such that it may have been below the air stream coming from the push header. This would mean that the inlet was not above the top of the slot but below the slot. The expected result would be a higher above-tank air concentration. Again, as for the inlet values, the above-tank chromium concentrations gave a mixed message as to the improvement that a push-pull exhaust system may have over a typical lateral exhaust system in decreasing worker exposure to chromium.

U. Above-Tank Chromium Emissions: Chemical Mist Suppressant Effect

The above-tank results indicate that a chemical mist suppressant does reduce worker exposure to chromium. In all cases of the chemical mist suppressant, the above-tank air concentration ranged from 0.4-6% of the baseline above-tank air concentrations. Chemical mist suppressants were more effective in reducing above-tank chromium air concentration than were polyballs.

V. Surface Tension Measurement

EPA Method 306B allows several methods for measuring the surface tension of an electroplating bath. In the Chrome Demo Project, two methods (stalagmometer and DuNouy Ring tensiometers) were used. The stalagmometer gave consistently higher surface tension readings than did a DuNouy Ring tensiometer. The difference varied with the concentration of chemical mist suppressant. It was greatest (22 dynes per centimeter) at the higher surface tensions and decreased (to 2 dynes per centimeter) at the lowest surface tensions. Surface tensions are related to the concentration of the chemical mist suppressant in the electroplating bath. Higher concentrations of chemical mist suppressant result in lower surface tensions.

In order to understand this situation, the surface tension of several different fluids were measured. Checks of the stalagmometer and CSC brand DuNouy Ring tensiometer were made using fluids such as water, methanol, 25% methanol and water and 10% acetone and water. The CRC Handbook of Chemistry and Physics, 65th ed. reported surface tensions of the test fluids covered the range of surface tensions used in the Project. The CRC values are: water = 71 dynes per centimeter, 10% acetone = 49 dynes per centimeter, 25% methanol = 46 dynes per centimeter and 100% methanol = 22 dynes per centimeter. With these fluids, the measured difference between the stalagmometer and the CSC tensiometer were 1-5 dynes per centimeter. The largest difference was with the 46 and 49 dynes per centimeter fluids.

When a solution of hydrocarbon surfactant and water was tested, a similar difference in surface tension values between the stalagmometer and DuNouy Ring tensiometer was seen. The difference between the devices measurement was ~22 dynes per centimeter at tensiometer measured surface tensions of 45 dynes per centimeter and the difference decreased to ~4 dynes per centimeter at 22 dynes per centimeter.

The difference in the measured surface tensions for the 306B methods tested seems to be due to an inherent difference in the basic mechanism used by each surface tension measuring device. It is expected, based on the work done in this project, that solutions containing chemical mist suppressants will give higher readings when tested with a stalagmometer than when tested using a DuNouy Ring tensiometer.

The Chrome MACT standard in the 306B section states that ASTM 1331-89 must be followed when using a precision tensiometer. The ASTM method cited in the Chrome MACT Method 306B is for surfactant containing aqueous solutions, and mentions only a DuNouy Ring or Plate tensiometer and does not mention a stalagmometer.

Using a stalagmometer will not result in lack of compliance. The surface tension as measured with a stalagmometer will always be higher than the DuNouy reading. The higher stalagmometer values will result in adding more chemical mist suppressant than is actually needed to get the desired dynes per centimeter value.

W. Reduced-Cost Testing

The issue of what a hard chromium electroplater is going to do to meet the Chrome MACT is crucial. Without information, an electroplater is generally going to take the conservative and possibly more expensive route. With baseline information on the outlet concentrations, a vendor can make recommendations that can result in savings over recommendations made without this information. This was seen in the Chrome Demo Project where the installation of a two-stage Composite Mesh Pad device could be evaluated when knowing the outlet emission of the existing control.

The cost of generating the needed information is an issue. The EPA estimates that a Method 306 emissions test by an outside testing firm will cost approximately $5,000 per sample location. In the Project, reduced-cost testing was done. The reduced-cost test, done by an outside testing firm, cost approximately $1,500 per location. In addition, the use of 306A sampling may result in reduced-costs.

The reduced-cost testing for the Project was done by both Clayton and Envisage using modified sampling procedures. The Clayton reduced-cost tests used a modified sampling method which used five traverse points and a membrane filter in a cassette as the catch mechanism. Each test run (three runs total per Michigan device) was for 60 minutes. The Envisage reduced-cost tests used a modified Method 306 procedure. Only one run was done at each prevention/control device and the runs were only 60 minutes long. Impingers were used to collect the sample. These test methods are not replacements for the EPA 306 or 306A testing and cannot be used as compliance testing for reporting purposes.

The results of the reduced-cost tests, when judged by the hexavalent results, were useful. The Ohio results show a very good correspondence to the baseline results, >95%. The total chromium results did not correspond as well. The total chromium Clayton reduced-cost test results ranged from 49-63% of the final report baseline results. The total chromium Envisage reduced-cost test results ranged from 0-53% of the final report baseline results. The reduced-cost tests were analyzed by ICP and that may be the problem. If the reduced-cost test samples had been analyzed by GFAAS, the results may have been closer to the final report baseline results.

The Envisage reduced-cost test samples were also analyzed by the IC/PCR method for hexavalent chromium concentration, see Table 16. The baseline hexavalent results differ from the reduced-cost results by less than 1%. This indicates that IC/PCR would be an appropriate analysis for reduced-cost test samples. The GFAAS analysis method was not done for the reduced-cost test samples or the baseline samples and no conclusions can be drawn on the comparability of this method.

X. ICP Test Difficulties

The Chrome Demo Project baseline testing indicated that some laboratories may have difficulty in reporting “true” values when following the ICP procedure as described in the Chrome MACT standard. Baseline testing analysis strongly indicates a matrix interference with the 0.1 Normal sodium hydroxide solution required by the 306 and 306A methods. Sodium bicarbonate was not used in this project.

The baseline testing indicates that tests done without serial dilution or spike recovery results checking may very well give a low result for total chromium. The reduced-cost results and the draft baseline (see Table 11) differ from the final baseline numbers. The more a prevention/control technique's outlet chromium air concentration differs from 0.015 mg/M^3, the more bias the ICP method gave. In the Envisage results, when the outlet concentrations reported approach the Chrome MACT limit of 0.015 mg/M^3, there is a smaller difference between the reduced-cost ICP and the final report baseline ICP values.

The reduced-cost test and the Project test results also indicate that different laboratories may report different chromium air concentration values for a prevention/control device. The Envisage ICP reduced-cost test results for the three-stage mist eliminator are closer to the final baseline report values than are the draft baseline report values. The Clayton ICP reduced-cost test results are further from the final baseline report values than are the draft baseline report values.

This is not to say that ICP should not be used. In the Phase 4 tests, RTI uses ICP while MRI uses GFAAS. The results are very similar. The ratio of MRI values divided by RTI values ranged from 84-125%. This indicates that ICP can give good results, but without a serial dilution or spike recovery quality assurance program, as was done at RTI for the Phase 4 samples and at MRI for the final report baseline samples, any ICP result should be treated as unreliable. The larger the ICP value is from 0.015 mg/M^3, the more unreliable the value may be.

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APPENDIX A: SUMMARY OF BASELINE METHOD 306 CHROME DEMO TESTS

BASELINE METHOD 306 TEST CONDITIONS				TEST PARAMETERS			TEST CHROMIUM CONCENTRATION				
							INLET		OUTLET		
DEVICE	RUN	POLY-BALLs	SURFACE TENSION	AMP - Hr/hr	OUTLET AIR FLOW	RUN TIME	HEX	TOTAL	HEX	TOTAL	ABOVE TANK
BASELINE TESTS	#	Percentage	Dynes/Cm		dscm	minute	mg/M^3	mg/M^3	mg/M^3	mg/M^3	mg/M^3
Blade Mist	1	0	67.2	2,685	78	120	2.23	2.23	0.115	0.128	1.7018
Eliminator,	2	0		2,527	97	120	3.25	3.52	0.139	0.159	6.0502
(Tank 12)	3	0		2,630	94	120	2.5	5.31	0.132	0.141	4.1136
Blade Mist	1	0	69.2	13,625	274	125	2.892	2.7249	0.110	0.1210	3.873
Eliminator,	2	0		11,496	297	125	0.9968	1.0088	0.0650	0.08030	2.537
(Tank 13)	3	0		11,400	290	125	1.0801	1.0572	0.0717	0.08350	3.900
Packed-bed	1	95	70.6	14,840	454	125	0.430	0.487	0.0490	0.0860	
Scrubber,		0 (Tank 4)									1.5210
(Tanks 3a-3e)		95(Tank 1)									0.0724
	2	95		13,911	439	125	1.0004	0.689	0.0480	0.0652	
		0 (Tank 4)									1.1825
		95(Tank 1)									0.2921
	3	95		12,299	430	125	0.530	0.590	0.044	0.0584	
		0 (Tank 4)									1.8753
		95(Tank 1)									0.2923
One-Stage Mist	1	65	Not Reported	3,232	87	125	5.8846	6.330	0.0133	0.0554	20.7645
Eliminator,	2	90		2,353	86	125	3.9349	4.500	0.0108	0.0222	6.0664
(Tank 4)	3	90		2,324	86	125	4.5993	4.530	0.0102	0.0157	6.3028
Two-Stage Mist	1	0	Not Reported	2,690	123	120	1.2932	1.190	0.0049	0.0162	1.3308
Eliminator,	2	0		2,598	124	120	5.8476	6.020	0.0040	0.0150	0.8914
(Tank 5)	3	0		3,646	120	120	6.5651	6.810	0.0097	0.0192	0.8142
Three-Stage Mist	1	0	Not Reported	2,176	135	120	8.1134	9.020	0.0028	0.0169	9.9924
Eliminator,	2	0		2,354	137	120	14.8243	13.700	0.0030	0.0190	3.3605
(Tank 6)	3	0		3,005	139	120	11.6571	11.000	0.0032	0.0087	2.6966

APPENDIX B. SUMMARY OF BASELINE METHOD 306A CHROME DEMO PROJECT TESTS

BASELINE METHOD 306A TEST CONDITIONS				TEST PARAMETERS			TEST CHROMIUM CONCENTRATION				
							INLET		OUTLET		
DEVICE	RUN	POLY-BALLs	SURFACE TENSION	AMP - Hr/hr	OUTLET AIR FLOW	RUN TIME	HEX	TOTAL	HEX	TOTAL	ABOVE TANK
Baseline Tests	#	Percentage	Dynes/Cm		dscm	minute	mg/M^3	mg/M^3	mg/M^3	mg/M^3	mg/M^3
Packed-bed	1	95	70.6	14,840	454	125	0.430	0.487	0.0460	0.06575	SAME
Scrubber,	2	95		13,911	439	125	1.0004	0.689	0.0469	0.080	AS
(Tanks 3a-3e)	3	95		12,299	430	125	0.530	0.590	0.0396	0.0624	VALUES
Three-Stage Mist	1	0	Not Reported	2,176	135	120	8.1134	9.020	0.0025	0.0172	IN
Eliminator,	2	0		2,354	137	120	14.8243	13.700	0.0041	0.0342	APPENDIX
(Tank 6)	3	0		3,005	139	120	11.6571	11.000	0.0076	0.0245	A

APPENDIX C. SUMMARY OF PHASE 4 METHOD 306 CHROME DEMO PROJECT TESTS, RTI

PHASE 4 METHOD 306 TEST CONDITIONS				TEST PARAMETERS			RTI TEST CHROMIUM CONCENTRATION				
							INLET		OUTLET		
DEVICE	RUN	POLY-BALLs	SURFACE TENSION	AMP Hr/hr	OUTLET AIR FLOW	RUN TIME	HEX	TOTAL	HEX	TOTAL	ABOVE TANK
PHASE 4 TESTS	#	Percentage	Dynes/Cm		dscm	minute	mg/M^3	mg/M^3	mg/M^3	mg/M^3	mg/M^3
Tank 12, Baseline +	1	0	67.2	3950	156	120	0.6025	0.5757	0.00466	0.00538	1.285
Push-Pull Hood +	2	0	NOT DONE	3950	158	120	5.4520	5.2654	0.0049	0.00423	1.200
two-stage CMP ME	3	0	NOT DONE	3900	157	120	5.8954	5.6197	0.0050	0.00517	1.170
As Above +	4	0	30.8	5271	157	120	0.3929	0.3746	0.0008	0.00132	0.015
Chemical Mist Suppressant	5	0	32.5	5400	157	120	0.0961	0.0892	0.0009	0.00067	0.015
at 32 dyne/cm avg	6	0	32.0	5400	157	120	0.0417	0.0388	0.0001	0.00028	0.012
As Above +	7	0	22.0	5400	157	120	0.0493	0.0464	0.0005	0.00053	0.021
Chemical Mist Suppressant	8	0	22.0	3121	155	120	0.0239	0.0233	0.0004	0.00040	0.018
at 22 dyne/cm avg	9	0	23.2	4100	157	120	0.0111	0.0106	0.0003	0.00053	0.013
Tank 13, Baseline +	4	0	44.2	11350	274	120	0.0675	0.0703	0.0134	0.01680	0.173
Chemical Mist Suppressant	5	0	39.8	11025	294	120	0.0395	0.0410	0.0128	0.01530	0.270
@ 41 dynes/cm	6	0	39.5	11100	291	120	0.0363	0.0396	0.0221	0.01290	0.146
Tank 13, Baseline +	7	0	24.0	11680	289	120	0.0112	0.0118	0.0020	0.00326	0.015
Chemical Mist Suppressant	8	0	22.5	11600	284	120	0.0072	0.0073	0.0033	0.00313	0.025
@ 23 dynes/cm	9	0	23.0	11800	267	120	0.0112	0.0129	0.0023	0.00261	0.045
Packed-bed	1	95	27.4	14,028	484	127	0.0066	0.0087	0.0025	0.0033	
Scrubber Baseline		0 (Tank 4)	26.9								0.012
(Tanks 3a-3e) +		95(Tank 1)	27.8								0.019
Chemical Mist Suppressant	2	95	29.3	13,353	526	127	0.0035	0.0042	0.0007	0.0007	
@ 28 dynes/cm		0 (Tank 4)	25.5								0.009
		95(Tank 1)	33.1								0.009
	3	95	26.5	12,896	559	126	0.0045	0.0053	0.0012	0.0019	
		0 (Tank 4)	26.5								0.012
		95(Tank 1)	26.5								0.006

APPENDIX C. SUMMARY OF PHASE 4 METHOD 306 CHROME DEMO PROJECT TESTS, RTI

PHASE 4 METHOD 306 TEST CONDITIONS				TEST PARAMETERS			RTI TEST CHROMIUM CONCENTRATION				
							INLET		OUTLET		
DEVICE	RUN	POLY-BALLs	SURFACE TENSION	AMP - Hr/hr	OUTLET AIR FLOW	RUN TIME	HEX	TOTAL	HEX	TOTAL	ABOVE TANK
PHASE 4 TESTS	#	Percentage	Dynes/Cm		dscm	minute	mg/M^3	mg/M^3	mg/M^3	mg/M^3	mg/M^3
Packed-bed Scrubber Baseline (Tanks 3a-3e) + Chemical Mist Suppressant @ 24 dynes/cm	4	95	23.9	18,116	503	127	0.2317	0.2460	0.01023	0.0113	
		0 (Tank 4)	22.8								0.012
		95(Tank 1)	25.0								0.016
	5	95	24.2	17,999	487	126	0.1297	0.1412	0.00212	0.0030	
		0 (Tank 4)	22.8								0.008
		95(Tank 1)	25.5								0.005
	6	95	24.3	18,263	488	126	0.0170	0.0219	0.00218	0.0025	
		0 (Tank 4)	23.6								0.006
		95(Tank 1)	25.0								0.003

APPENDIX D. SUMMARY OF PHASE 4 METHOD 306 CHROME DEMO PROJECT TESTS, MRI

PHASE 4 METHOD 306 TEST CONDITIONS				TEST PARAMETERS			MRI TEST CHROMIUM CONCENTRATION				
							INLET		OUTLET		
DEVICE	RUN	POLY-BALLs	SURFACE TENSION	AMP Hr/hr	OUTLET AIR FLOW	RUN TIME	HEX	TOTAL	HEX	TOTAL	ABOVE TANK
PHASE 4 TESTS	#	Percentage	Dynes/Cm		dscm	minute	mg/M^3	mg/M^3	mg/M^3	mg/M^3	mg/M^3
Tank 12, Baseline +	1	0	67.2	3950	156	120	0.5811	0.6016	0.00532	0.00477	1.285
Push-Pull Hood +	2	0	NOT DONE	3950	158	120	5.3313	5.4879	0.0054	0.00505	1.200
two-stage CMP ME	3	0	NOT DONE	3900	157	120	5.8531	5.8570	0.0053	0.00507	1.170
As Above +	4	0	30.8	5271	157	120	0.3958	0.3824	0.0008	0.00115	0.015
Chemical Mist Suppressant	5	0	32.5	5400	157	120	0.0939	0.0983	0.0010	0.00013	0.015
@ 32 dyne/cm avg	6	0	32.0	5400	157	120	0.0392	0.0436	0.0007	0.00106	0.012
As Above +	7	0	22.0	5400	157	120	0.0461	0.0508	0.0005	0.00087	0.021
Chemical Mist Suppressant	8	0	22.0	3121	155	120	0.0238	0.0242	0.0004	0.00067	0.018
at 22 dyne/cm avg	9	0	23.2	4100	157	120	0.0104	0.0101	0.0003	0.00056	0.013
Tank 13, Baseline +	4	0	44.2	11350	274	120	0.0655	0.0740	0.0142	0.0145	0.173
Chemical Mist Suppressant	5	0	39.8	11025	294	120	0.0395	0.0443	0.0147	0.01580	0.270
@ 41 dynes/cm	6	0	39.5	11100	291	120	0.0382	0.0419	0.0122	0.01310	0.146
Tank 13, Baseline +	7	0	24.0	11680	289	120	0.0119	0.0120	0.0023	0.00282	0.015
Chemical Mist Suppressant	8	0	22.5	11600	284	120	0.0077	0.0089	0.0045	0.00619	0.025
@ 23 dynes/cm	9	0	23.0	11800	267	120	0.0098	0.0141	0.0025	0.00350	0.045
Packed-bed	1	95	27.4	14,028	484	127	0.00663	0.00836	0.00246	0.00401	
Scrubber Baseline		0 (Tank 4)	26.9								0.012
(Tanks 3a-3e) +		95(Tank 1)	27.8								0.019
Chemical Mist Suppressant	2	95	29.3	13,353	526	127	0.00295	0.00465	0.00071	0.00136	
@ 28 dynes/cm		0 (Tank 4)	25.5								0.009
		95(Tank 1)	33.1								0.009
	3	95	26.5	12,896	559	126	0.00441	0.00609	0.00113	0.00192	
		0 (Tank 4)	26.5								0.012
		95(Tank 1)	26.5								0.006

APPENDIX D. SUMMARY OF PHASE 4 METHOD 306 CHROME DEMO PROJECT TESTS, MRI

PHASE 4 METHOD 306 TEST CONDITIONS				TEST PARAMETERS			MRI TEST CHROMIUM CONCENTRATION				
							INLET		OUTLET		
DEVICE	RUN	POLY-BALLs	SURFACE TENSION	AMP - Hr/hr	OUTLET AIR FLOW	RUN TIME	HEX	TOTAL	HEX	TOTAL	ABOVE TANK
PHASE 4 TESTS	#	Percentage	Dynes/Cm		dscm	minute	mg/M^3	mg/M^3	mg/M^3	mg/M^3	mg/M^3
Packed-bed Scrubber Baseline (Tanks 3a-3e) + Chemical Mist Suppressant @ 24 dynes/cm	4	95	23.9	18,116	503	127	0.21649	0.27776	0.01040	0.01197	
		0 (Tank 4)	22.8								0.012
		95(Tank 1)	25.0								0.016
	5	95	24.2	17,999	487	126	0.12624	0.14981	0.00207	0.00310	
		0 (Tank 4)	22.8								0.008
		95(Tank 1)	25.5								0.005
	6	95	24.3	18,263	488	126	0.01859	0.02434	0.00220	0.00316	
		0 (Tank 4)	23.6								0.006
		95(Tank 1)	25.0								0.003

APPENDIX E: GLOSSARY OF TERMS

Add-on control device: Equipment installed in the ventilation system of the chromium electroplating and anodizing tanks for the purposes of collecting and containing chromium emissions from the tank(s).

Air prevention/control technique: Any method, such as an add-on air pollution control device or a chemical mist (fume) suppressant, which is used to reduce chromium emissions from chromium electroplating and chromium anodizing tanks.

Chemical mist suppressant: Any chemical agent that reduces or suppresses fumes or mists at the of an electroplating or anodizing bath. Another term for chemical mist suppressant is fume suppressant.

Chromic acid: The common name for chromium anhydride (CrO_3).

Chromium anodizing: The electrolytic process by which an oxide layer is produced on the of a base metal for functional purposes (e.g., corrosion resistance or electrical) using a chromic acid solution.

Chromium electroplating or chromium anodizing tank: The receptacle or container in which hard or decorative chromium plating or anodizing occurs.

Composite mesh-pad system: An add-on air pollution control device typically consisting of several mesh-pad stages. The purpose of the first stage is to remove large particles. Smaller particles are removed in the second stage, which consists of the composite mesh pad. A final stage may remove any re-entrained particles not collected by the composite mesh pad.

Decorative chromium electroplating: The process by which a thin layer of chromium, (typically 0.003 to 2.5 microns) is electrodeposited on a base metal, plastic, or undercoating to provide a bright surface with wear and tarnish resistance. This chromium process can be hexavalent or trivalent. Typical current density applied during this process ranges from 50 to 220 Amperes per square foot for total plating times ranging between 0.5 to 5 minutes.

Electroplating or anodizing bath: The electrolytic solution used as the conducting medium in which current is accompanied by movement of metal ions for the purposes of electroplating metal out of the solution onto a work-piece or for oxidizing the base material.

Emission limitation: The concentration of chromium allowed to be emitted expressed in milligrams per dry cubic meter (mg/dscm), or the allowable surface tension expressed in dynes per centimeter (dynes/cm).

Existing tank: The startup date of the tank occurred before the proposed regulation. (December 16, 1993.)

Facility: The major or area source at which chromium electroplating or chromium anodizing is performed.

Facility size determination: A large facility may be considered small:

- *If records show that the previous annual actual rectifier capacity is less than 60 million ampere-hr/yr, by using non-resettable ampere-hr meters,*

- *Keeping monthly records of ampere-hr usage; or*

- *By accepting a federally enforceable limit on the potential rectifier capacity through the Title V Renewable Operating Permit Program and maintaining monthly records.*

Fiber-bed mist eliminator: An add-on air pollution control device that removes contaminants from a gas stream through the mechanisms of inertial impaction and Brownian diffusion.

Foam blanket: The type of fume suppressant that generates a layer of foam across the surface of a solution when current is applied to that solution. Foam blanket additives do not normally reduce surface tension of the solution.

Hard chromium electroplating: A process by which a thick layer of chromium (typically 1.3 to 760 microns) is electro-deposited on a base material to provide a surface with functional properties such as wear resistance, a low coefficient of friction, hardness and corrosion resistance. Hard chromium electroplating process is performed at current densities typically ranging from 150 to 600 ampere per square foot for total plating times ranging from 20 minutes to 36 hours depending upon the desired plate thickness.

Hazardous air pollutant:. Title III of the CAAA identifies 189 substances as hazardous air pollutants (HAPs). Under Title III, sources that emit one or more HAPs may be required to comply with Maximum Achievable Control Technology (MACI) standards. These standards will be based upon the best demonstrated control technology or practices used by the regulated industry.

Hard chromium: The form of chromium in a valence state of +6.

Large, hard chromium electroplating facility: A facility that performs hard chromium electroplating and has a maximum cumulative potential rectifier capacity greater than or equal to 60 million ampere-hours per year (amp-hr/yr).

Maximum Achievable Control Technology (MACT): Emission limitations based on the best demonstrated control technology or practices to be applied to major sources emitting one or more of the federally listed hazardous air pollutants.

Maximum cumulative potential rectifier capacity: The summation of the total installed rectifier capacity at a hard chromium electroplating facility, expressed in amperes, multiplied by the maximum potential operating schedule of 8,400 hours per year and 0.7, which assumes that electrodes are energized 70 percent of the total operating time.

Modification: Any physical change in, or change to method of operation of a source that is expected to reduce the actual emissions of any hazardous air pollutant emitted by such sources.

National Ambient Air Quality Standards(NAAQS): Air quality standards established by EPA that apply to outside air throughout the country.

National Emission Standards for Hazardous Air Pollutants (NESHAPs): Emission standards set by EPA for air contaminants not covered by NAAQS that may cause an increase in deaths, serious irreversible or incapacitating illness.

New tank: The startup date of the tank occurred after the proposed date December 16, 1993. Tanks that were installed after the proposed date (December 16, 1993) but before the standard's effective date (January 25, 1995) are subject to the same requirements as those with a startup after January 25, 1995. See 6 3.6(b)(3)&(4).

Operating parameter value: A minimum or maximum value established for a control device or process parameter that, if achieved by itself or in combination with one or more other operating parameter values, determines that an owner or operator is in continual compliance with the applicable emission limitation or standard.

Owner or Operator: Any person who owns, leases, operates, controls, or supervises a stationary source.

Packed-bed scrubber:. An add-on air pollution control device consisting of a single or double packed-bed that contains packing media on which the chromic acid droplets impinge. The packed-bed section of the scrubber is followed by a mist eliminator to remove any water entrained from the packed-bed section. When using this type control method, fresh water must be added from the top in order to meet the standard.

Reconstructed: The replacement of tank components, which were replaced to an extent that the fixed capital cost of the new components exceeded 50% of the fixed capital cost that would be required to construct a comparable new source, and it is technologically and economically feasible for the tank to meet the requirements of the final rule.

Rectifier: A device that converts alternating current into direct current by permitting a considerable flow of current in one direction.

Research or laboratory facility: Any stationary source whose primary purpose is to conduct research and development into new processes and products. Operated under the close supervision of technically trained personnel, this facility is not engaged in the manufacture of products for commercial sale in commerce.

Small, hard chromium plating facility: A facility that performs hard chromium electroplating and has a maximum cumulative potential rectifier capacity less than 60 million amp-hr/yr.

Stalagmometer: A device used to measure the surface tension.

Stationary source: Any building, structure, facility, or installation that emits or may emit any air pollutant.

Surface tension: The property, due to molecular forces, which exists in the surface film of all liquids and tends to prevent liquid from spreading.

Tank operation: The time in which current and/or voltage is being applied to a chromium electroplating tank or a chromium anodizing tank.

Tensiometer: A device used to measure the surface tension of a solution.

Trivalent chromium: The form of chromium in a valence state of +3.

Trivalent chromium process: The process used for electro-deposition of a thin layer of chromium onto a base material using a trivalent chromium solution instead of a chromic acid solution.

Wetting agent: A component in a chemical mist suppressant that reduces the surface tension of a liquid.

APPENDIX F: ABBREVIATIONS USED IN THIS DOCUMENT

ACGIH	= American Conference of Governmental Industrial Hygienists
AESF	= The American Electroplaters and Surface Finisher's Society, Inc.
A/ft2	= ampere per square foot
Amp	= ampere
Amp-Hr	= ampere-hour
ASTM	= The American Society of Testing and Materials
ATL	= Analytical Testing Laboratories
BIDs	= USEPA Background Information Documents
CAA	= Clean Air Act
cfm	= cubic feet per minute
CFR	= Code of Federal Regulations
cm	= centimeter
CMP	= Composite Mesh Pad
$Cr0_3$	= chromium anhydride, commonly known as chromic acid
CRC	= Chemical Rubber Corporation
CSC	= CSC Scientific Company
CSI	= Common Sense Initiative
°C	= degrees Celsius
°F	= degrees Fahrenheit
DfE	= Design for the Environment
dscf	= dry standard cubic foot
dscm	= dry standard cubic meter
dy	= dynes
EPA	= Environmental Protection Agency (US)
ft	= foot
ft^2	= square foot
ft^3	= cubic foot
g	= gram
gal	= gallon
GFAAS	= Graphite Furnace Atomic Absorption Spectroscopy
gr	= grain
HAP	= Hazardous Air Pollutant
Project	= The Hard Chrome Pollution Prevention Demonstration Project
hex	= hexavalent
hp	= horsepower
hr	= hour
IC/PCR	= Ion Chromatography with Post Column Reactor
ICP	= Inductively Couple Plasma emission spectrometry
in.	= inch

in. w.c.	= inches of water column
$in.^2$	= square inch
ITI	= Industrial Technology Institute
kg	= kilogram
kPa	= kilopascal
KSV	= KSV Instruments
kW	= kilowatt-hour
L	= liter
lb	= pound
lbf/ft	= pound force per foot
m	= meter
m^2	= square meter
m^3	= cubic meters
MACT	= Maximum Achievable Control Technology
MDEQ	= Michigan Department of Environmental Quality
MEP	= Manufacturing Extension Partnership
MFSA	= The Metal Finishing Suppliers Association
mg	= milligram
min	= minute
MRI	= Midwest Research Institute
MW	= megawatt
NAMF	= The National Association of Metal Finishers
NESHAP	= 1995 Chromium National Emission Standards for Hazardous Air Pollutants
NIST	= National Institute of Standards and Technology
NRMRL	= National Risk Management Research Laboratory
OAQS	= Office of Air Quality planning and Standards
OIT	= Office of Industrial Technologies
ORD	= Office of Research and Development
OSHA	= Occupational Safety and Health Administration
P2	= Pollution Prevention
PBS	= Packed-Bed Scrubber
PEL	= Permissible Exposure Limit
PES	= Pacific Environmental Services, Inc.
QA/QC	= Quality Assurance and Quality Control
QAPs	= Quality Assurance Project Plans
RTI	= Research Triangle Institute
SCAQMD	= The South Coast Air Quality Management District
SW-846	= Standard Methods for Environmental Testing
US DOE	= United States Department of Energy
US EPA	= United States Environmental Protection Agency

APPENDIX G: EPA OFFICE OF AIR QUALITY PLANNING & STANDARDS (OAQPS) CHROME MACT BOOKLET

EPA'S NEW REGULATION CONTROLLING AIR EMISSIONS FROM CHROMIUM ELECTROPLATING AND ANODIZING TANKS

In November 1994, the U. S. Environmental Protection Agency (EPA) issued national regulations to control air emissions of chromium from chromium electroplating and anodizing tanks. The regulation appeared in the January 25, 1995 edition of the Federal Register [volume 60, beginning on page 4948]. The regulation affects all facilities performing hard and decorative chromium electroplating and chromium anodizing, regardless of size. Over 5,000 facilities are affected nationwide.

Why is EPA regulating electroplating and anodizing tanks?

The Clean Air Act (CAA), as amended in 1990, directs EPA to regulate emissions of 189 toxic chemicals, including chromium compounds, from a wide range of industrial sources. EPA is regulating emissions of chromium from electroplating and anodizing tanks to meet the requirements of the CAA. The hexavalent form of chromium is highly toxic and strongly suspected of causing lung cancer. Less is known about the cancer risk of the trivalent form of chromium, but it can accumulate in the lungs and may decrease lung function after continuous exposure.

Hard chromium electroplating operations deposit a thick layer of chromium directly on a base metal to provide wear and corrosion resistance, low friction, and hardness (for hydraulic cylinders, industrial rolls, etc.). Decorative chromium electroplating operations deposit a thin layer of chromium on a base metal, plastic, or undercoating to provide a bright finish and wear and tarnish resistance (for bicycles, auto trim, tools, etc.). Chromium anodizing operations form a chromium oxide layer on aluminum to provide corrosion and wear resistance (for aircraft parts, architectural structures, etc.). Except for the trichrome decorative process, which uses the trivalent form of chromium, all other electroplating processes use the hexavalent form of chromium.

Chromium electroplating and anodizing tanks are one of the largest sources of chromium emissions. Over 5,000 facilities with chromium electroplating and/or anodizing tanks exist in the United States; many are located in small shops (using one plating tank) that are within close proximity to residential areas. EPA estimates that full compliance with its new regulation will result in a reduction of about 173 tons of chromium emitted into the air annually, or about a 99 percent reduction from today's levels.

How does the new EPA regulation affect you?

The regulation affects all facilities that use chromium electroplating or anodizing tanks, regardless of size. How you are affected depends on the size and type of shop (hard, decorative, or anodizing) you have and the technique that you use to reduce emissions. Decorative chromium electroplating operations must be in compliance with the regulation by January 25, 1996. Hard chromium electroplating and chromium anodizing operations must comply by January 25, 1997. In general, the regulation requires:

- ✓ Emission limits
- ✓ Work practice standards
- ✓ Initial testing
- ✓ Ongoing monitoring
- ✓ Recordkeeping
- ✓ Reporting

These requirements are summarized below. Also, EPA has published a guidebook entitled "A Guidebook on How to Comply with the Chromium Electroplating and Anodizing National Emission Standards for Hazardous Air Pollutants" (EPA-453/B-95-001) that provides a more detailed explanation of the regulation. (See the back of this pamphlet for information on how to obtain a copy.)

Emission Limits

The regulation specifies emission limits (expressed as concentration of chromium in milligrams per dry standard cubic meter [mg/dscm] of exhaust air) that can typically be achieved by the use of a certain technique to reduce emissions (such as a control device or fume suppressant). The emission reduction technique that corresponds to the emission limit is shown in the following table. However, you may use another technique, as long as the level of emission reduction is the same or better.

Work Practice Standards

The regulation specifies work practice standards, which include:

- ✓ Preparation of an operation and maintenance plan.
- ✓ Quarterly inspections of control devices, ductwork, and monitoring equipment.
- ✓ Periodic washdown of composite mesh-pad systems.
- ✓ Fresh water additions to the top of packed-bed scrubbers.

Affected tanks	Emission limit	Emission reduction technique
Hard Chromium Plating Tanks		
Small, existing tanks[a]	0.03 mg/dscm	packed-bed scrubber (PBS)
All other tanks[b]	0.015 mg/dscm	composite mesh-pad (CMP) system
Decorative Chromium Plating Tanks Using a Chromic Acid Bath		
All tanks[b]	0.01 mg/dscm or 45 dynes/cm	Fume suppressants (FS) FS that contains wetting agent
Decorative Chromium Plating Tanks Using a Trivalent Chromium Bath		
All tanks[b]	Only subject to recordkeeping and reporting	
Chromium Anodizing Tanks		
All tanks[b]	0.01 mg/dscm or 45 dynes/cm	FS FS that contains wetting agent

[a]Small means tanks having a maximum potential rectifier capacity of less than 60 million ampere-hours per year. Existing means installed before 12/16/93.
[b]Includes new tanks.

Initial Testing

A one-time test is required by July 23, 1996 for decorative chromium platers and by July 24, 1997 for hard chromium platers and chromium anodizers to demonstrate that you are meeting the emission limit for your type of operation. During testing, you are required to establish operating parameters (e.g., pressure drop or foam thickness) that correspond to compliance with the emission limit. Sources that meet the following criteria do not have to perform initial testing: (1) decorative chromium plating tanks or chromium anodizing tanks that use a wetting agent and limit the surface tension of the bath to 45 dynes per centimeter (dynes/cm), or (2) decorative chromium plating tanks that use a trivalent chromium bath. The regulation contains test methods for measuring the chromium concentration discharged to the atmosphere (EPA Reference Methods 306 and 306A) and for measuring the surface tension of the bath (EPA Reference Method 306B).

EPA has produced a videotape on stack sampling and monitoring entitled "Construction and Operation of the EPA Method 306A Sampling Train and Practical Suggestions for Monitoring of Electroplating and Anodizing Facilities" that is available to you for a nominal fee by calling North Carolina State University at (919) 515-4659.

Ongoing Monitoring

Continuous compliance with the regulation is demonstrated through ongoing monitoring of the operating parameters established during initial testing. The monitoring requirements vary depending on the type of emission reduction technique that you use.

Emission reduction technique	What to monitor	How often
CMP	Pressure drop across unit	Once per day
PBS	Inlet velocity pressure & pressure drop across unit	Once per day
CMP/PBS	Pressure drop across unit	Once per day
Fiber-bed mist eliminator (FBME)	Pressure drop across FBME & across upstream unit	Once per day
Wetting agent	Surface tension of bath	Once every 4 hours[a,b]
Foam blanket	Foam thickness	Once per hour[a]

[a]The time between monitoring may be increased gradually if the emission limit is not exceeded.
[b]Does not apply to trivalent chromium baths with wetting agents.

Sample monitoring checklists are included in the EPA guidebook on how to comply with this rule.

Recordkeeping

The regulation requires that sources keep records to document compliance with the regulation. Records include inspection records, equipment maintenance records, records of malfunctions and exceedances, performance test results, and monitoring data. All records must be kept for 5 years. If you operate a decorative chromium plating tank that uses a trivalent chromium bath, you only need to keep records of bath component purchases.

Sample recordkeeping forms are included in the EPA guidebook on how to comply with this rule.

APPENDIX G: EPA OFFICE OF AIR QUALITY PLANNING & STANDARDS (OAQPS) CHROME MACT BOOKLET

Reporting

The extent and frequency of reporting depends on the type and size of your source.

Requirement	Date
All Tanks	
Initial notification	7/24/95
Decorative Chromium Plating Tanks Using a Chromic Acid Bath	
Compliance deadline	1/25/96
Testing deadline	7/23/96
Notification of performance test	≥60 days before test
Notification of compliance status	≤90 days after test or 2/24/96 if no test is required
Notification of test results	≤90 days after test
Decorative Chromium Plating Tanks Using a Trivalent Chromium Bath	
Notification of compliance status	2/24/96
Notification of process change	≤30 days after change
Hard Chromium Plating and Chromium Anodizing Tanks	
Compliance deadline	1/25/97
Testing deadline	7/24/97
Notification of performance test	≥60 days before test
Notification of compliance status	≤90 days after test or 2/24/97 if no test is required
Notification of test results	≤90 days after test

Note: ≥ means "at least"; ≤ means "no more than."

In addition, major sources (emitting 10 tons per year or more of chromium or 25 tons per year or more of a combination of hazardous air pollutants) must submit semiannual reports that contain information on the compliance status of the source. Check with the EPA Regional Office for your State or territory to see if reports should be sent to the Regional Office or to the delegated State authority. All other sources must complete a compliance status report annually and keep the report onsite.

Sample reporting forms are included in the EPA guidebook on how to comply with this rule.

What pollution prevention options exist?

There are several pollution prevention options in this regulation. Source reduction techniques include: (1) the use of fume suppressants to inhibit chromium emissions at the source (i.e. the bath), and (2) the use of a trivalent chromium bath instead of a hexavalent chromium (chromic acid) bath to lower total chromium emissions and lower chromium concentrations in process wastewaters (thus, less sludge generated). In addition, each of the add-on emission reduction techniques has a recycling element; they allow for recycling of all collected chromium and/or reductions in the total wastewater treatment burden of a facility.

How does the new federal EPA regulation relate to State or local requirements?

State or local requirements that may have affected you prior to the new EPA regulation continue to apply. The new EPA regulation is the minimum emission reduction that is required nationally. Some State and local agencies do require stricter limits. In addition, the format of some State requirements may differ from EPA's regulation. Testing will always give you the chromium concentration in mg/dscm; other formats, such as percent control or mg/ampere-hour, may be derived from mg/dscm.

All sources affected by this regulation must apply for an operating permit under Title V of the CAA. A sample General Permit is included in EPA's guidebook on how to comply with this rule. Contact your State or local air pollution control agency or your State Small Business Assistance Program for more information on permitting.

How much will it cost?

The cost of compliance will vary considerably from facility to facility. The average price to purchase a packed-bed scrubber (PBS) or a composite mesh-pad (CMP) system ranges from $27,000 to $186,000 depending on the size of your operation. Ongoing annual costs related to upkeep of these emission reduction devices range from $10,000 to $45,000 for a PBS and $14,000 to $84,000 for a CMP system. Ongoing annual fume suppressant costs range from $1,000 to $17,000. The initial compliance test will cost about $1,150 per stack if you perform the test inhouse or $4,500 per stack if you use a contractor. The ongoing annual costs for monitoring, recordkeeping, and reporting are $2,300 per facility on average. You will also be charged a permit fee by your State or local agency.

Whom can you contact for additional information?

For more information on this regulation, EPA's testing videotape, or EPA's guidebook on how to comply with this rule, please call your State or local air pollution control agency; your local, regional, or national metal finishers trade association; your State Small Business Assistance Program; or your State Small Business Ombudsman. Contact EPA's Control Technology Center (CTC) Hotline at (919) 541-0800 to get information on your State small business program contacts. A copy of the regulation can be obtained from the *Federal Register* (January 25, 1995) or the EPA's Technology Transfer Network (TTN). The TTN can be accessed via modem by dialing (919) 541-5742. Call (919) 541-5384 for TTN assistance.

The EPA is divided into 10 geographic regions. You may also call the Regional Office where your State or territory resides for more information.

Region	States	Telephone No.
1	CT, ME, MA, NH, RI, & VT	(617) 565-2734
2	NJ, NY, Puerto Rico, & Virgin Islands	(212) 264-6676
3	DE, MD, PA, VA, WV, & District of Columbia	(215) 597-3237
4	AL, FL, GA, KY, MS, NC, SC, & TN	(404) 347-2864
5	IL, IN, MI, WI, MN, & OH	(312) 886-6793
6	AR, LA, NM, OK, & TX	(214) 665-7225
7	IA, KS, MO, & NE	(913) 551-7097
8	CO, MT, ND, SD, UT, & WY	(303) 293-1886
9	AZ, CA, HI, NV, American Samoa, & Guam	(415) 744-1143
10	AK, ID, WA, & OR	(206) 553-1949

The information in this pamphlet is intended for general reference only; it is not a full and complete statement of the technical or legal requirements associated with the regulation.

United States Environmental Protection Agency
EPA-453/F-95-001
January 1995
Office of Air Quality Planning & Standards (MD-10)

EPA

New Regulation Controlling Air Emissions from Chromium Electroplating and Anodizing Tanks