PUBLIC MEETING AGENDA

December 9-10, 2004
9:00 a.m./8:30 a.m.

Agenda Items to be heard;
04-11-1, 04-11-2, 04-11-3
04-11-4, 04-11-5, 04-11-6

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ELECTRONIC BOARD BOOK

LOCATION:
Air Resources Board
Central Valley Auditorium, Second Floor
1001 I Street
Sacramento, California 95814

California Environmental Protection Agency

Air Resources Board

PUBLIC MEETING AGENDA

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04-11-1 Report to the Board on a Health Update - Traffic-Related Air Pollution Near Busy Roads: The East Bay Children's Respiratory Health Study

The Office of Environmental Health Hazard Assessment (OEHHA) recently conducted a school-based cross-sectional epidemiological study to examine the associations between proximity to traffic and respiratory health among children living and attending schools at varying distances from high-traffic roadways in Alameda County, CA. Most of these children are nonwhite and of lower socioeconomic status. Outdoor concentrations of nitrogen oxides (NOx), nitric oxide (NO), and black carbon (BC) measured at neighborhood schools were used as surrogates for children's overall exposure to traffic pollutants. The study found associations between traffic pollution and increased asthma and bronchitis symptoms. This study is one of the first in the U.S. to examine the relationships between measured traffic-related pollutants and respiratory symptoms in children.

04-11-2 Report to the Board on the In-Vehicle Exposures: Implications for Exposure Assessment

Exposure to vehicle-related pollutants—both near-traffic and inside vehicles—are beginning to be linked to health outcomes, such as the recent study associating driving time with increased risk of heart attack. An overview of in-vehicle measurements and exposures for California will be presented. These measurements show that time in vehicles (about 6% a day on average) results in a major fraction of a person's total daily exposure, ranging from about 15% for benzene, to 30 to 55% for diesel PM, and even higher for ultrafine particles.

04-11-3 Public Hearing to Consider a Proposed of the Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying

Staff will propose a new Airborne Toxic Control Measure (ATCM) to reduce emissions of hexavalent chromium and nickel from thermal spraying operations. This ATCM establishes emission standards for hexavalent chromium and nickel for thermal spraying operations at stationary sources that use materials containing chromium or nickel. The ATCM also requires monitoring, recordkeeping, and reporting.

TO SUBMIT WRITTEN COMMENTS ON AN AGENDA ITEM IN ADVANCE OF THE MEETING:

CONTACT THE CLERK OF THE BOARD, 1001 I Street, 23rd Floor, Sacramento, CA 95814 **(916) 322-5594**
FAX: (916) 322-3928
ARB Homepage: www.arb.ca.gov

To request special accommodation or language needs, please contact the following:

- TTY/TDD/Speech-to-Speech users may dial 7-1-1 for the California Relay Service.
- Assistance for Disability-related accommodations, please go to http://www.arb.ca.gov/html/ada/ada.htm or contact the Air Resources Board ADA Coordinator, at (916) 323-4916.
- Assistance in a language other than English, please go to http://www.arb.ca.gov/as/eeo/languageaccess.htm or contact the Air Resources Board Bilingual Coordinator, at (916) 324-5049.

SMOKING IS NOT PERMITTED AT MEETINGS OF THE CALIFORNIA AIR RESOURCES BOARD

04-11-4 Public Hearing to Consider Amendments to the California Off-Road Emissions Regulation for Compression-Ignition Engines and Equipment

Staff is proposing to amend California's existing off-road compression-ignition (diesel) engine regulations to harmonize with the U.S. EPA requirements as set forth on June 29, 2004. The standards proposed for the Tier 4 engines, which begin with the 2008 model year, represent aftertreatment-based levels to reduce engine out NOx and PM emissions by 90 percent. The proposed Tier 4 standards are equivalent to the California 2007 on-road heavy-duty engine standards. The staff's proposal also supplements the federal rule by requiring more descriptive labeling and certification requirements to improve the implementation of the regulations

04-11-5 Public Meeting to Update the Board on the Heavy-Duty Diesel Engine Voluntary Software Upgrade (Chip Reflash) Program Update

Staff will present data on the status and sustainability of a voluntary program to reflash (reprogram the electronic controls of) 1993-1999 model year heavy-duty diesel trucks. The Board will evaluate whether to continue the voluntary program or to direct staff to implement a mandatory program by filing the regulation approved by the Board in March 2004.

04-11-6 Public Meeting to Update the Board on Air Quality

ARB staff will make a presentation on the progress that has been achieved in reducing exposure to unhealthy air and meeting State and federal standards. The presentation will cover ozone, particulate matter, and toxic air contaminants, and will look at how 2004 air quality compares to previous years.

OPEN SESSION TO PROVIDE AN OPPORTUNITY FOR MEMBERS OF THE PUBLIC TO ADDRESS THE BOARD ON SUBJECT MATTERS WITHIN THE JURISDICTION OF THE BOARD.

Although no formal Board action may be taken, the Board is allowing an opportunity to interested members of the public to address the Board on items of interest that are within the Board's jurisdiction, but that do not specifically appear on the agenda. Each person will be allowed a maximum of five minutes to ensure that everyone has a chance to speak.

THOSE ITEMS ABOVE THAT ARE NOT COMPLETED ON DECEMBER 9 WILL BE HEARD BEGINNING AT 8:30 A.M. ON DECEMBER 10.

THE AGENDA ITEMS LISTED ABOVE MAY BE CONSIDERED IN A DIFFERENT ORDER AT THE BOARD MEETING.

California Environmental Protection Agency

Air Resources Board

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TITLE 17. CALIFORNIA AIR RESOURCES BOARD

NOTICE OF PUBLIC HEARING TO CONSIDER ADOPTION OF AN AIRBORNE TOXIC CONTROL MEASURE TO REDUCE EMISSIONS OF HEXAVALENT CHROMIUM AND NICKEL FROM THERMAL SPRAYING

The Air Resources Board (the Board or ARB) will conduct a public hearing at the time and place noted below to consider adoption of a regulation to reduce emissions of hexavalent chromium and nickel from thermal spraying.

DATE: December 9, 2004

TIME: 9:00 a.m.

PLACE: California Environmental Protection Agency
Air Resources Board
1001 I Street
Central Valley Auditorium, Second Floor
Sacramento, CA 95814

This item will be considered at a two-day meeting of the Board, which will commence at 9:00 a.m., on Thursday, December 9, 2004, and may continue at 8:30 a.m., December 10, 2004. This item may not be considered until December 10, 2004. Please consult the agenda for the meeting, which will be available at least 10 days before December 9, 2004, to determine the day on which this item will be considered.

If you have a disability-related accommodation need, please go to http://www.arb.ca.gov/html/ada/ada.htm for assistance or contact the ADA Coordinator at (916) 323-4916. If you are a person who needs assistance in a language other than English, please contact the Bilingual Coordinator at (916) 324-5049. TTY/TDD/Speech-to-Speech users may dial 7-1-1 for the California Relay Service.

INFORMATIVE DIGEST OF PROPOSED ACTION AND POLICY STATEMENT OVERVIEW

Sections Affected: Proposed adoption of new section 93102.5, title 17, California Code of Regulations (CCR).

Background:

The California Toxic Air Contaminant Identification and Control Program (Program), established under California law by Assembly Bill 1807 (Stats. 1983, Ch. 1047) and set forth in Health and Safety Code (HSC) sections 39650–39675 (as amended), requires the ARB to identify and control toxic air contaminants (TAC) in California. Following the identification of a substance as a TAC, Health and Safety Code section 39665 requires the ARB, with participation of the air pollution control and air quality management districts (districts), and in consultation with affected sources and interested parties, to prepare a report on the need and appropriate degree of regulation for that substance. Health and Safety Code section 39665(b) requires that this "needs assessment" address, among other things, the technological feasibility of proposed airborne toxic control measures (ATCM) and the availability, suitability, and relative efficacy of substitute products or processes of a less hazardous nature.

Once the ARB has evaluated the need for and appropriate degree of regulation of a TAC, Health and Safety Code section 39666 requires the ARB to adopt regulations to achieve the maximum feasible reduction in public exposure to TACs.

The Board identified hexavalent chromium and nickel as TACs in 1986 and 1991, respectively. Both hexavalent chromium and nickel were determined to be human carcinogens without an identifiable threshold exposure level below which no significant adverse health effects are anticipated. Nickel was also deemed to have acute health impacts. Because hexavalent chromium and nickel do not have Board-specified threshold exposure levels, HSC section 39666 requires that the proposed ATCM be designed to reduce emissions to the lowest achievable level through the application of the best available control technology (BACT) or a more effective control method, in consideration of cost, risk, environmental impacts, and other specified factors.

Description of the Proposed Regulatory Action:

Thermal spraying (or metal spraying) is a process in which materials are heated to a molten or nearly molten condition and are sprayed onto a surface to form a coating. The proposed ATCM applies to thermal spraying operations at any stationary source that uses materials containing chromium, chromium compounds, nickel, or nickel compounds. The proposed ATCM requires the use of BACT in consideration of risk and cost, and also establishes hourly emissions limits for nickel for existing, modified, and new facilities. The proposed ATCM also establishes recordkeeping, monitoring, and reporting requirements. However, the proposed ATCM does not regulate the sale or composition of thermal spraying materials. It also does not apply to portable thermal spraying operations that are temporary (not more than 30 consecutive days at the same location) and are used for offsite field applications.

If a facility does not use materials that contain chromium, chromium compounds, nickel, or nickel compounds, it is not subject to the proposed ATCM. If a facility has very low emission levels (e.g., less than 0.001 pounds per year of hexavalent chromium), it may qualify for an exemption from installing additional controls. However, the facility must still comply with the permitting, recordkeeping, monitoring, and reporting requirements.

The proposed ATCM specifies that facilities with relatively high emission rates must meet the highest control efficiency requirements, while facilities with much lower emission rates must meet slightly lower control efficiency requirements. Emissions are determined by using ARB's calculation methods specified in Appendix 1 of the proposed ATCM, or by using source test data that has been approved by the local air district. The proposed ATCM specifies the test methods to be used when conducting an emissions source test.

All existing facilities must comply with the proposed ATCM by January 1, 2006. New and modified thermal spraying operations must comply upon initial startup.

Existing thermal spraying operations are defined as those operations in existence as of January 1, 2005. These operations must use air pollution control devices that meet minimum control efficiency levels, ranging from 90 percent to 99.97 percent. The efficiency requirements are established in consideration of health risks and cost. These facilities must also use an enclosure and a ventilation system that complies with designated operating standards. In addition, recordkeeping and regular monitoring are required to ensure the proper operation of the ventilation system and control devices. An existing thermal spraying facility may be exempt from the minimum control efficiency requirements of the proposed ATCM if it is located at least 1,640 feet from the nearest sensitive receptor and emits no more than 0.5 pound per year of hexavalent chromium. This exemption is contingent upon the facility's submission of a permit application and annual reports of hexavalent chromium and nickel emissions. This exemption is also contingent upon a site-specific analysis of public health impacts conducted by the air district. The air district will verify annually that the facility continues to meet the necessary requirements for an exemption.

All existing thermal spraying operations must submit an emissions inventory by October 1, 2005, and obtain a permit from their local air district if they do not have one.

Modified thermal spraying operations are defined as those operations that undergo a modification after January 1, 2005. Modified thermal spraying operations must use an air pollution control device that can achieve 99.97 percent control efficiency down to 0.3 microns (e.g., a high efficiency particulate abatement or HEPA filter). If a facility already has a HEPA filter, no additional upgrades are required after a modification.

New thermal spraying operations are defined as those operations that have an initial startup after January 1, 2005. No person may operate a new thermal spraying operation unless it is located outside of an area that is zoned for residential or mixed use and is located at least 500 feet from the boundary of any area that is zoned for residential or mixed use. In addition, new thermal spraying operations must use an air pollution control device that meets at least 99.97 percent control efficiency down to 0.3 microns (e.g., a HEPA filter). Existing facilities that add new permit units are not considered to be "new facilities." All new facilities must undergo a site-specific evaluation by the local air district to ensure that they do not present a public health risk.

COMPARABLE FEDERAL REGULATIONS

There are no comparable federal regulations that apply to thermal spraying operations that use materials containing chromium, chromium compounds, nickel, or nickel compounds.

AVAILABILITY OF DOCUMENTS AND CONTACT PERSONS

The ARB staff has prepared a Staff Report: Initial Statement of Reasons (ISOR) for the Proposed Regulatory Action, which includes the full text of the proposed regulatory language, a summary of the economic and environmental impacts of the proposal, and supporting technical documentation. The report is entitled: "Staff Report: Initial Statement of Reasons for the Proposed Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying."

Copies of the ISOR and the full text of the proposed regulatory language may be accessed on the ARB's web site listed below, or may be obtained from the Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental Services Center, 1st Floor, Sacramento, CA 95814, (916) 322-2990 at least 45 days prior to the scheduled hearing on December 9, 2004.

Upon its completion, the Final Statement of Reasons (FSOR) will be available and copies may be requested from the agency contact persons in this notice, or may be accessed on the ARB's web site listed below.

Inquiries concerning the substance of the proposed regulation may be directed to the designated agency contact persons, Monique Davis, Air Resources Engineer, at (916) 324-8182 or Jose Gomez, Manager, Technical Development Section, at (916) 324-8033.

Further, the agency representative and designated back-up contact persons to whom nonsubstantive inquiries concerning the proposed administrative action may be directed are Artavia Edwards, Manager, Board Administration & Regulatory Coordination Unit, (916) 322-6070, or Amy Whiting, Regulations Coordinator, (916) 322-6533. The Board has compiled a record for this rulemaking action, which includes all the information upon which the proposal is based. This material is available for inspection upon request to the contact persons.

This notice, the ISOR and all subsequent regulatory documents, including the FSOR, when completed, are available on the ARB Internet site for this rulemaking at http://www.arb.ca.gov/regact/thermspr/thermalspr.htm.

<u>COSTS TO PUBLIC AGENCIES AND TO BUSINESSES AND PERSONS AFFECTED</u>

The determinations of the ARB's Executive Officer concerning the costs or savings necessarily incurred by public agencies and private persons and businesses in reasonable compliance with the proposed regulations are presented below.

The ARB's Executive Officer has determined that the proposed regulatory action will not create costs or savings, as defined in Government Code sections 11346.5(a)(5) and 11346.5(a)(6), to any state agency or in federal funding to the state, costs or mandate to any school district whether or not reimbursable by the state pursuant to part 7 (commencing with section 17500), division 4, title 2 of the Government Code, or other nondiscretionary savings to State or local agencies.

The proposed regulatory action will impose a mandate upon and create costs to some local government agencies. One local agency that performs thermal spraying will be minimally impacted because it will incur costs of approximately $600 per year to conduct monitoring, recordkeeping, and reporting. These costs are not state mandated costs that are required to be reimbursed pursuant to part 7 (commencing with section 17500), division 4, title 2 of the Government Code and section 6 of article XIII B of the California Constitution, because the proposed regulations apply generally to all thermal spraying operations in the State and do not impose unique requirements on local government agencies.

The proposed regulatory action will also impose a mandate upon and create costs to local air pollution control and air quality management districts (the "districts"). However, these costs to the districts are recoverable by fees that are within the districts' authority to assess (see Health and Safety Code sections 42311 and 40510). Therefore, the proposed regulatory action imposes no costs on local agencies that are required to be reimbursed by the State pursuant to part 7 (commencing with section 17500), Division 4, Title 2 of the Government Code, and does not impose a mandate on local agencies that is required to be reimbursed pursuant to Section 6 of Article XIII B of the California Constitution.

In developing this regulatory proposal, the ARB staff evaluated the potential economic impacts on representative private persons and businesses. The proposed ATCM is expected to impact 37 thermal spraying facilities; 34 are businesses, two are federal government facilities, and one is a local government facility. Twenty-six of the 34 businesses have fewer than 100 employees and are considered small businesses. Twenty-four of the 37 affected facilities already have HEPA filters or other control devices that are expected to qualify as BACT. Since these 24 facilities already have adequate control, they will not have to upgrade their systems but they may experience impacts which include obtaining or modifying permits, improving their ventilation system monitoring, and maintaining additional records. One thermal spraying facility is operated by a local public agency. The impact on this local agency is expected to be minor, since the facility is already permitted and has already installed a HEPA filter.

Nine facilities may qualify for an exemption from additional controls under subsection (c)(1)(E). These facilities must still comply with the permitting, recordkeeping and reporting requirements.

The Executive Officer has made an initial determination that the proposed regulatory action will not have a significant statewide adverse economic impact directly affecting businesses, including the ability of California businesses to compete with businesses in other states, or on representative private persons.

In accordance with Government Code section 11346.3, the Executive Officer has determined that the proposed regulatory action will have minimal or no impacts on the creation or elimination of jobs within the State of California, the creation of new businesses or elimination of existing businesses within the State of California, or the expansion of businesses currently doing business within the State of California. A detailed assessment of the economic impacts of the proposed regulatory action can be found in the ISOR.

As discussed in the ISOR, most affected businesses will be able to absorb the costs of the proposed ATCM with no significant adverse impacts on their profitability. However, four facilities subject to control requirements could be adversely impacted because they would need to upgrade or install new control devices if they elect to continue thermal spraying operations. As discussed in the ISOR, three of these facilities are expected to cease thermal spraying operations rather than complying with the proposed ATCM because thermal spraying generates less than five percent of their gross annual revenue. The fourth facility, however, is expected to install controls since it is a large dedicated thermal spraying operation. This facility would experience a significant adverse economic impact on its profitability, and the Executive Officer has therefore determined that the proposed regulatory action will have a significant adverse economic impact on this one business.

The Executive Officer has also determined, pursuant to title 1, CCR, section 4, that the proposed regulatory action will affect small businesses.

In accordance with Government Code sections 11346.3(c) and 11346.5(a)(11), the Executive Officer has found that the reporting requirement of the regulation which apply to businesses are necessary for the health, safety, and welfare of the people of the State of California.

Before taking final action on the proposed regulatory action, the ARB must determine that no reasonable alternative considered by the agency or that has otherwise been identified and brought to the attention of the agency would be more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons than the proposed action.

SUBMITTAL OF COMMENTS

The public may present comments relating to this matter orally or in writing at the hearing, and in writing or by e-mail before the hearing. To be considered by the Board, written submissions not physically submitted at the hearing must be received **no later than 12:00 noon, December 8, 2004**, and addressed to the following:

Postal mail is to be sent to:

Clerk of the Board
Air Resources Board
1001 I Street, 23rd Floor
Sacramento, CA 95814

Electronic mail is to be sent to: **thermspr@listserv.arb.ca.gov,** and received at the ARB **no later than 12:00 noon, December 8, 2004.**

Facsimile transmissions are to be transmitted to the Clerk of the Board at (916) 322-3928 and received at the ARB **no later than 12:00 noon, December 8, 2004.**

The Board requests but does not require that 30 copies of any written statement be submitted and that all written statements be filed at least 10 days prior to the hearing so that ARB staff and Board Members have time to fully consider each comment. The ARB encourages members of the public to bring any suggestions for modification of the proposed regulatory action to the attention of staff in advance of the hearing.

STATUTORY AUTHORITY AND REFERENCES

This regulatory action is proposed under that authority granted in Health and Safety Code sections 39600, 39601, 39650, 39658, 39659, 39666, and 41511. This action is proposed to implement, interpret and make specific Health and Safety Code sections 39650, 39658, 39659, 39666, and 41511.

HEARING PROCEDURES

The public hearing will be conducted in accordance with the California Administrative Procedure Act, title 2, division 3, part 1, chapter 3.5 (commencing with section 11340) of the Government Code.

Following the public hearing, the Board may adopt the regulatory language as originally proposed, or with nonsubstantial or grammatical modifications. The Board may also adopt the proposed regulatory language with other modifications if the text as modified is sufficiently related to the originally proposed text that the public was adequately placed on notice that the regulatory language as modified could result from the proposed regulatory action. In the event that such modifications are made, the full regulatory text, with the modifications clearly indicated, will be made available to the public, for written comment, at least 15 days before it is adopted.

The public may request a copy of the modified regulatory text from the ARB's Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental Services Center, 1st Floor, Sacramento, CA 95814, (916) 322-2990.

CALIFORNIA AIR RESOURCES BOARD

Catherine Witherspoon
Executive Officer

Date: 10/12/04

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs see our Web –site at www.arb.ca.gov.

California Environmental Protection Agency
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING

AIRBORNE TOXIC CONTROL MEASURE TO REDUCE EMISSIONS OF HEXAVALENT CHROMIUM AND NICKEL FROM THERMAL SPRAYING

Stationary Source Division
Measures Assessment Branch

October 2004

State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING

Public Hearing to Consider

ADOPTION OF THE PROPOSED AIRBORNE TOXIC CONTROL MEASURE TO REDUCE EMISSIONS OF HEXAVALENT CHROMIUM AND NICKEL FROM THERMAL SPRAYING

To be considered by the Air Resources Board on December 9, 2004, at:

California Environmental Protection Agency
Headquarters Building
1001 "I" Street
Sacramento, California

Stationary Source Division:
Peter D. Venturini, Chief
Robert D. Barham, Assistant Chief
Measures Assessment Branch:
Barbara Fry, Chief
Technical Development Section:
Jose Gomez, Manager

State of California
AIR RESOURCES BOARD

PROPOSED AIRBORNE TOXIC CONTROL MEASURE TO REDUCE EMISSIONS OF HEXAVALENT CHROMIUM AND NICKEL FROM THERMAL SPRAYING

Contributing Authors

Monique Davis, P.E. (Lead)
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Nancy Adams
Marcia Jorgensen
Reza Mahdavi, Ph.d.
Tony Servin, P.E.
Lynna Negri

Legal Counsel

Robert Jenne, Esq., Office of Legal Affairs

Acknowledgements

We wish to acknowledge the participation and assistance of:

International Thermal Spraying Association and its members

We would also like to acknowledge the participation and assistance of air pollution control and air quality management districts. In particular, we would like to thank the following district representatives that participated in the ARB/District Working Group:

Randy Frazier, Bay Area Air Quality Management District
Dave Valler, Feather River Air Quality Management District
Jason Davis, North Coast Unified Air Quality Management District
Dave Byrnes, San Diego County Air Pollution Control District
Esteban Gutierrez, San Joaquin Valley Air Pollution Control District
Robert Gottschalk, South Coast Air Quality Management District
Terri Thomas, Ventura County Air Pollution Control District

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ACRONYMS

AB	Assembly Bill
APC	Air Pollution Control
APCD	Air Pollution Control District
AQMD	Air Quality Management District
ARB	Air Resources Board
ASM	American Society for Metals
ATCM	Airborne Toxic Control Measure
AWS	American Welding Society
BAAQMD	Bay Area Air Quality Management District
BACT	Best Available Control Technology
BL	Barrio Logan
Cal/OSHA	California Occupational Safety and Health Administration
CAPCOA	California Air Pollution Control Officers' Association
CAS	Chemical Abstract Service
CATEF	California Air Toxic Emission Factors
CCR	California Code of Regulations
C.E.	Control Efficiency
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CRF	Capital Recovery Factor
HAP	Hazardous Air Pollutant
HCAT	Hard Chrome Alternatives Team
HEPA	High Efficiency Particulate Abatement
HRA	Health Risk Assessment
HSC	Health and Safety Code
HVOF	High Velocity Oxy-Fuel
ISOR	Initial Statement of Reasons
ITSA	International Thermal Spraying Association
MW	Molecular Weight
NEC	Not Elsewhere Classified
NESHAP	National Emission Standards for Hazardous Air Pollutant
NIOSH	National Institute for Occupational Safety and Health
OEHHA	Office of Environmental Health Hazard Assessment
OSHA	Occupational Safety and Health Administration
PD	Protected Data
PEL	Permissible Exposure Limit
PM	Particulate Matter
PM_{10}	Particulate Matter with an aerodynamic diameter less than or equal to 10 microns
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter less than or equal to 2.5 microns
PTA	Plasma Transferred Arc
REL	Reference Exposure Level

ACRONYMS

SCC	Source Classification Code
SCAQMD	South Coast Air Quality Management District
SDAPCD	San Diego County Air Pollution Control District
SFO	San Francisco Airport
SIC	Standard Industrial Classification
SRP	Scientific Review Panel
SWA	Sales-Weighted Average
TAC	Toxic Air Contaminant
T-BACT	Best Available Control Technology for Toxics
T.E.	Transfer Efficiency
TSP	Total Suspended Particulate
ug	Microgram
ug/m3	Micrograms per Cubic Meter
U.S. EPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

I. INTRODUCTION

This executive summary presents the Air Resources Board (ARB/Board) staff's *Proposed Airborne Toxic Control Measure (proposed ATCM) to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying*. The proposed ATCM would require thermal spraying facilities that use materials containing chromium or nickel to have the best available control technology (BACT) and obtain an air permit, if they have not already done so. The proposed ATCM would not specifically eliminate the use of materials containing chromium or nickel and it would not require these materials to be reformulated. If approved by the Board, the proposed ATCM will be sent to the air pollution control and air quality management districts (air districts) to be implemented and enforced. The local air districts may implement the proposed ATCM as approved by the Board, or adopt an alternative rule that is at least as stringent as the proposed ATCM.

II. BACKGROUND

1. What is thermal spraying?

Thermal spraying (or metal spraying) is a process in which materials are heated to a molten or nearly molten condition and are sprayed onto a surface to form a coating. Materials can be heated by combustion of fuel gases (similar to welding) or by using electricity. Thermal spraying includes processes such as flame spraying, plasma spraying, high velocity oxyfuel (HVOF) spraying, and twin wire electric arc spraying. Thermal spraying can be used in a wide variety of industries for numerous applications. In addition, thermal metal spraying can be a replacement for some hard chromium electroplating processes. Some thermal spraying materials contain chromium and nickel compounds and the use of these materials can create emissions of hexavalent chromium and nickel.

2. Why is the staff proposing an ATCM for thermal spraying?

There are potential serious health risks associated with thermal spraying, as there are with hard chromium electroplating. As a result, the Board directed staff to investigate the health risks associated with thermal spraying activities, and to propose an ATCM if warranted.

The ARB identified hexavalent chromium and nickel as toxic air contaminants (TAC) in 1986 and 1991, respectively. The ARB identifies and controls TACs under the authority of the California Toxic Air Contaminant Identification and Control Program (Air Toxics Program) established by Assembly Bill 1807 (AB 1807) and set forth in Health and Safety Code (HSC) sections 39650 through 39675. Both hexavalent chromium and nickel were determined to be human carcinogens without an identifiable threshold exposure level below which no significant adverse health effects are anticipated. Nickel was also deemed to have acute health impacts.

Hexavalent chromium is a very potent carcinogen relative to other TACs. For example, hexavalent chromium is second only to dioxins in terms of carcinogenic potency, and is 24,000 times more potent than perchloroethylene and 5,000 times more potent than benzene. Although nickel is a much less potent carcinogen than hexavalent chromium, short-term exposure to relatively low concentrations of nickel can result in acute health impacts.

The Board has adopted three ATCMs for hexavalent chromium. These are the chrome plating and chromic acid anodizing ATCM in 1988, an ATCM prohibiting the use of hexavalent chromium in cooling towers in 1989, and an ATCM prohibiting the use of hexavalent chromium in motor vehicle coatings in 2001. None of these ATCMs address hexavalent chromium emissions from thermal spraying. The chrome plating ATCM is currently being updated, and is scheduled for Board consideration in 2005.

There are currently no federal or local air district rules that specifically regulate thermal spraying operations. Some districts have permitted these operations and through the permits have required controls. Other districts have not required such permits. Therefore, no uniform method of regulating thermal spraying operations currently exists statewide.

3. What actions did staff take to consult with interested parties?

As part of our outreach program, staff made extensive contacts with air districts, industry and facility representatives as well as other affected parties through public workshops, meetings, telephone calls, and mail-outs. Major outreach activities included:

- Forming an ARB/District Working Group and conducting three conference calls with group members;
- Forming an ARB/Industry Working Group and conducting four conference calls with group members;
- Creating an ARB Thermal Spraying website and maintaining a List-Server to automatically update interested parties about proposed ATCM developments;
- Providing copies of draft surveys to working group members to obtain their input and recommendations;
- Conducting a survey by mail and e-mail for 42 thermal spraying material manufacturers in the United States and Canada;
- Conducting a survey by phone, FAX, and e-mail for facilities in California identified as potentially conducting thermal spraying operations;
- Preparing and making available for review, on ARB's website, the survey reports for the manufacturers survey and the facility survey;

- Making a presentation at the International Thermal Spray Association's regional meeting on April 2, 2004, in San Diego;
- Mailing workshop notices and posting workshop materials on ARB's website;
- Conducting three public workshops which allowed for participation by phone;
- Conducting site visits to three thermal spraying operations to better understand the thermal spraying processes and facility layouts; and
- Preparing fact sheets regarding the development of the proposed ATCM and making them available to industry associations, potentially affected facilities, and the public.

4. How does this proposed ATCM relate to ARB's goals on community health and environmental justice?

The ARB is committed to evaluating community impacts of proposed regulations, including environmental justice concerns. It is ARB's goal to reduce or eliminate any disproportionate impacts of air pollution on low-income areas and ethnically diverse populations so that all individuals in California can live, work, and play in a healthful environment. The proposed ACTM will reduce exposure to hexavalent chromium and nickel in California communities with affected facilities, including those with low-income and ethnically diverse populations.

To address environmental justice and general concerns about the public's exposure to hexavalent chromium emissions, the proposed ATCM establishes criteria for the operation of new thermal spraying facilities that use materials containing chromium or nickel. New facilities would be required to install High Efficiency Particulate Abatement (HEPA) filters (or equivalent), and could not operate in, or within 500 feet of, the boundary of a residential or mixed use zone. In addition, new facilities would be required to undergo a site-specific analysis to ensure adequate protection of public health. We believe these criteria are necessary for new thermal spraying facilities because hexavalent chromium is a potent carcinogen, and short-term exposure to nickel causes acute health impacts.

III. EMISSIONS AND POTENTIAL HEALTH IMPACTS

1. How much hexavalent chromium and nickel is emitted from thermal spraying facilities?

Thirty-seven of the 51 thermal spraying facilities in California use materials that contain chromium or nickel. We used ARB survey data to estimate the range of statewide emissions of hexavalent chromium and nickel from these thermal spraying facilities. The actual emissions estimate (the lower end of the range) is based on actual material usage reported by individual thermal spraying facilities. The maximum potential emissions estimate is based on the results of our 2003 manufacturer survey, which reflects total material sales during 2002. According to our 2003 manufacturer survey, 90 tons of thermal spraying materials containing chromium or nickel were sold or distributed in California during 2002.

Actual emissions of hexavalent chromium are estimated to be 9.4 pounds (based on 2003 facility data) and the maximum potential emissions are estimated to be 66 pounds (based on 2002 material sales data.) Actual emissions of nickel are estimated to be 105 pounds (based on 2003 facility data) and the maximum potential emissions are estimated to be 740 pounds (based on 2002 material sales data). The difference between the estimates of actual emissions and maximum potential emissions may be due to the following factors: 1) materials sold in one year may be used over multiple years; 2) some materials sold to California distributors may be redistributed out of State; and 3) some businesses that conduct thermal spraying may not have been captured by the ARB facility survey. Consequently, actual and maximum potential emissions represent the range of estimated emissions from thermal spraying. Table ES-1 provides a summary, by air district, of the estimated actual emissions of hexavalent chromium and nickel from thermal spraying facilities in 2003. These data were used to estimate the potential cancer risk for each thermal spraying facility in California.

Table ES-1: Estimated Actual Emissions of Hexavalent Chromium and Nickel*

District	No. of Affected Facilities	Hexavalent Chromium Emissions (lbs/yr)	Nickel Emissions (lbs/yr)
Bay Area AQMD	6	1.5	22.2
Feather River AQMD	1	0.04	0.3
South Coast AQMD	18	7.6	70.1
San Diego County APCD	7	0.3	6.4
San Joaquin Valley APCD	3	0	6.0
Ventura County APCD	2	0	0.01
Total	37	**9.4**	**105**

**Based on 2003 emissions data reported by facilities in the 2004 ARB Thermal Spraying Facility Survey.*

2. What are the potential health impacts from exposure to hexavalent chromium and nickel emissions from thermal spraying facilities?

Exposure to hexavalent chromium and nickel may result in increased cancer risks and health risks from other non-cancer impacts, such as respiratory irritation, nasal and skin ulcerations, allergic sensitization, asthma complications, and birth defects. To assess potential health impacts, we evaluated health risks for the thermal spraying facilities identified in our facility survey. First, we conducted air dispersion modeling using data from four actual thermal spraying facilities that represented a range of operating conditions. We then used the results of that modeling and facility-specific actual emissions data to estimate health risks for thermal spraying businesses throughout the State.

The methods used in this risk assessment are consistent with the Tier 1 analysis presented in the Office of Environmental Health Hazard Assessment (OEHHA) Air Toxics "Hot Spots" Program Risk Assessment Guidelines, the Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. The air dispersion models that were used have been approved by the U.S. Environmental Protection Agency, and are recommended by ARB for use in risk assessments.

Estimated potential cancer risks from hexavalent chromium and nickel exposure ranged from less than one per million up to approximately 300 per million for most facilities, with one facility having a potential cancer risk of 2,800 per million. For more than half of the 51 thermal spraying facilities in California, our analysis indicated potential cancer risks of less than one per million for near-source receptors where the maximum concentrations are expected to occur.

We are working with the South Coast Air Quality Management District (SCAQMD) to address the impacts from the facility with a potential cancer risk of 2,800 per million as soon as possible, and in advance to adoption and implementation of the proposed ATCM. The SCAQMD has notified this facility that it is subject to the AB 2588 program requirements, and must perform a health risk assessment. The facility will be conducting a source test to quantify their emissions for use in the health risk assessment.

We also evaluated non-cancer health impacts, including acute impacts from short-term exposure to nickel and chronic impacts from long-term exposure to hexavalent chromium and nickel. The primary non-cancer health impacts from thermal spraying are potential acute impacts from short-term exposure to nickel emissions. The potential for acute or chronic non-cancer health impacts is expressed in terms of a hazard quotient for a single TAC or a hazard index for multiple TACs. Typically, a hazard quotient or hazard index greater than one is considered unacceptable. Our analysis indicated that nickel emissions from thermal spraying facilities could result in an acute hazard quotient greater than one. Our evaluation of acute health impacts only included nickel, because hexavalent chromium does not have an established acute reference exposure level.

Our analysis also indicated that long-term exposure to hexavalent chromium and nickel emissions from a small number of high use thermal spraying facilities could result in a chronic hazard index greater than one. All but a few facilities are expected to have chronic hazard indices less than one. The highest estimated chronic hazard index for a specific facility was approximately two.

IV. SUMMARY OF THE PROPOSED AIRBORNE TOXIC CONTROL MEASURE

1. Who must comply with the proposed ATCM?

The proposed ATCM applies only to thermal spraying facilities in California that use materials containing chromium, chromium compounds, nickel, or nickel compounds. The proposed ATCM does not apply to portable thermal spraying operations that are used for 30 or less consecutive days for field applications at offsite locations.

2. What does the proposed ATCM require?

The proposed ATCM establishes emission standards that reflect the use of best available control technology (BACT). The proposed ATCM applies only to thermal spraying facilities in California that use materials containing chromium, chromium compounds, nickel, or nickel compounds. The proposed ATCM does not regulate the sale or composition of thermal spraying materials.

The proposed ATCM specifies control efficiency requirements for point sources and volume sources. The requirements increase in stringency with increasing emissions. Emissions must be determined by the calculation methods specified in the proposed ATCM or by using source test data that has been approved by the local air district. The proposed ATCM specifies the test methods to be used when conducting an emissions source test.

The proposed ATCM establishes requirements for new and modified thermal spraying operations that are more stringent than the requirements for existing operations. January 1, 2005, is the cutoff date in the proposed ATCM for distinguishing between existing operations, and new and modified operations. For example, a facility is considered "new" if it begins initial operations on or after January 1, 2005. A facility is considered "modified" if it undergoes a physical modification on or after January 1, 2005, that requires an application for an authority to construct and/or a permit to operate. We are proposing this cutoff date for two reasons. First, we want to minimize the potential for existing facilities to modify their operations prior to the ATCM's effective date in order to avoid the more stringent requirements for modified operations. Secondly, we want to minimize the potential that companies considering construction of a new thermal spraying facility will begin initial operations before the ATCM's effective date in order to avoid the more stringent requirements that apply to new operations. The January 1, 2005, cutoff date will also provide such companies adequate notice of the ATCM requirements before they undertake the expense of construction.

The air districts must implement and enforce the proposed ATCM or adopt an equally effective measure. The earliest the air districts could enforce the proposed ATCM for new facilities would be when the Office of Administrative Law approves it. The effective date for existing facilities to comply with the proposed ATCM is January 1, 2006.

a. What are the requirements for existing facilities?

Existing facilities are defined as those in existence before January 1, 2005. These facilities must use air pollution control devices that meet control efficiencies ranging from 90 percent to 99.97 percent. The control efficiency requirements increase in stringency with increasing emissions. The proposed ATCM also establishes maximum hourly emission limits for nickel. The maximum hourly nickel limit is 0.1 lb for point sources (sources with a stack), and 0.01 lb for volume sources (sources without a stack). The control efficiency requirements are designed to ensure that the maximum potential cancer risk is less than ten in a million. The maximum hourly nickel limits are designed to ensure that the acute hazard quotient from nickel emissions does not exceed one. These facilities must also use an enclosure and ventilation system that complies with designated operating standards. In addition, recordkeeping and regular monitoring are required to ensure the proper operation of the ventilation system and control device. All existing facilities that use materials containing chromium or nickel must submit an initial emission inventory and obtain a permit from their local air district.

A remotely located existing facility that uses products that contain chromium, chromium compounds, nickel or nickel compounds, may be able to comply with the proposed ATCM without installing additional controls if it meets all of the following criteria:

- facility emits less than 0.5 lb/yr of hexavalent chromium;
- facility is located at least 1,640 feet (500 meters) from a sensitive receptor;
- facility is equipped with an air pollution control device that achieves at least 90 percent control efficiency;
- facility submits an emissions inventory to the air district each year; and
- facility undergoes a site-specific analysis by the air district that demonstrates adequate protection of public health.

These criteria are designed to ensure that the potential cancer risk to the nearest sensitive receptor is less than ten in a million. A facility that meets the above listed criteria would undergo an annual review by the air district to ensure that the criteria continue to be met.

b. What are the requirements for modified facilities?

Modified facilities are thermal spraying operations that undergo a modification on or after January 1, 2005. Modifications can include production increases that result in increased emissions or equipment changes that require a permit modification. Modified facilities will be required to use an air pollution control device that achieves 99.97 percent control efficiency down to 0.3 microns (e.g., a HEPA filter). Modified facilities must comply with this requirement upon initial startup. If a facility already has a HEPA filter that achieves this control level, no additional upgrades are required after a modification.

c. What are the requirements for new facilities?

New facilities are thermal spraying operations that have an initial startup on or after January 1, 2005. This does not include the addition of a new permit unit at a facility that existed before January 1, 2005. New facilities must use an air pollution control device that achieves 99.97 percent control efficiency down to 0.3 microns (e.g., a HEPA filter). New facilities must also comply with a maximum hourly nickel limit of 0.1 lb. In addition, a new facility cannot operate unless it is located outside of a residential or mixed use zone and is located at least 500 feet from the border of a residential or mixed use zone.

All new facilities would also be subject to a site-specific analysis by the local air district to ensure adequate protection of public health. This type of analysis is already being done in many air districts as part of their permitting process for sources of TACs. These requirements are designed to address overall health impact and environmental justice concerns. New facilities must comply with the proposed ATCM upon initial startup.

d. What exemptions are allowed?

If an existing facility has very low emission levels (e.g., less than 0.001 lb/yr of hexavalent chromium and less than 0.3 lb/yr nickel), it may qualify for an exemption from installing additional controls. These facilities would be required to obtain a permit and report emissions annually to the air district.

3. What is the basis for the proposed ATCM?

The proposed ATCM is based on our evaluation of BACT for reducing hexavalent chromium and nickel emissions from thermal spraying operations, in consideration of health risk and cost. In evaluating BACT, we analyzed information from ARB's 2003 thermal spraying material manufacturer survey and ARB's 2004 thermal spraying facility survey. Based on this information and discussions with air districts, industry and control equipment manufacturers, we determined that suitable control devices are readily available and widely used. Further, the application of BACT, as proposed by staff, will result in potential cancer risk levels being reduced to less than three in a million for the nearest sensitive receptor. The non-cancer health impacts will be reduced to acceptable levels because both the acute hazard quotient for nickel and the chronic hazard index for hexavalent chromium and nickel will not exceed one.

4. Are the proposed standards technologically feasible?

Yes. The proposed ATCM standards are technologically feasible based on information from the ARB's 2004 thermal spraying facility survey, discussions with thermal spraying equipment providers, and manufacturers of air pollution control devices.

Most thermal spraying facilities already use control devices to minimize particulate emissions. In addition, many facilities have already installed HEPA filters, which are the most effective control devices available.

5. What alternatives to the proposed ATCM did staff consider?

California Government Code section 11346.2 requires the ARB to consider and evaluate reasonable alternatives to the proposed ATCM. We considered two alternatives to the proposed ATCM. The alternatives were evaluated in terms of applicability, effectiveness, enforceability, and cost/resource requirements. No action was the first alternative considered. The no action alternative was not acceptable because it would not address the public health risk posed by hexavalent chromium and nickel emissions from thermal spraying facilities.

The second alternative was to require that all thermal spraying facilities install HEPA filters if they use materials containing chromium or nickel. We determined that this alternative would be excessively burdensome and costly for facilities that have a minimal benefit for public health due to their low emissions. However, this alternative would be slightly more effective than the proposed ATCM in reducing emissions of and exposure to hexavalent chromium and nickel. Health and Safety Code (HSC) section 39666 requires consideration of cost and risk. Because of the very low risk reduction and high cost, this alternative was not selected.

6. What does the law require ARB to do to protect public health?

HSC section 39666 requires the ARB to adopt ATCMs to reduce emissions of TACs. When adopting ATCMs for TACs without a Board-specified threshold exposure level, HSC section 39666 requires the ATCM to reduce emissions to the lowest level achievable through the application of BACT or a more effective control method. The proposed ATCM is consistent with this requirement. To determine BACT, we evaluated the proposed control measure and alternatives to the proposed control measure. The proposed ATCM requires control technology that is technologically feasible and will provide the greatest reduction in exposure and risk at the lowest cost of any of the alternatives identified.

V. POTENTIAL IMPACTS OF THE PROPOSED AIRBORNE TOXIC CONTROL MEASURE: HEALTH, ECONOMIC AND ENVIRONMENTAL

1. What businesses and public agencies will be affected by the proposed ATCM?

The proposed ATCM is expected to impact 37 thermal spraying facilities, including 34 businesses, two federal government facilities, and one local government facility. Twenty-six of the 34 businesses have fewer than 100 employees and could be considered small businesses. Only three of the 37 impacted facilities are dedicated thermal spraying operations whose primary business is providing thermal spraying services. Twenty of the 37 facilities are job shops that provide machining and coating services to various industries. Ten are manufacturers whose products include aerospace components, gas turbines, printing equipment, electronics, and automotive parts. Four facilities conduct onsite maintenance and repair for their own military equipment, aircraft, and water treatment systems.

Twenty-four of the 37 affected facilities already have HEPA filters or other control devices that are expected to qualify as BACT under the proposed ATCM. For these 24 facilities, the requirements of the proposed ATCM will include: developing an emissions inventory; obtaining or modifying permits; improving ventilation system monitoring; and maintaining additional records.

Six of the remaining 13 facilities would be required to install control devices under the proposed ATCM. However, four of these facilities may choose to eliminate or reduce their thermal spraying operations rather than install additional controls. These 13 facilities would also be required to comply with requirements for emissions inventories, permitting, monitoring, and recordkeeping. Although we expect one public agency to be affected, it will only experience minor impacts from recordkeeping and monitoring since it is already permitted and equipped with a HEPA filter.

2. How would the proposed ATCM reduce risk to public health?

The proposed ATCM requires the use of air pollution control devices at thermal spraying facilities that will reduce hexavalent chromium emissions by nearly 80 percent overall (7 to 50 lbs/year), and reduce nickel emissions by 51 percent overall (54 to 377 lbs/year). Emissions from currently uncontrolled facilities would be reduced by over 99 percent. The facility with the greatest emissions would be required to install a HEPA system achieving over 99.9 percent control efficiency. As a result, the potential cancer risk to the nearest sensitive receptor from these facilities would be reduced from current levels to less than three potential cancer cases per million. In addition, neither the acute hazard quotient from exposure to nickel nor the chronic hazard index from exposure to hexavalent chromium and nickel would exceed one.

Another benefit of the proposed ATCM would be reduced worker exposure. The proposed ATCM would require the use of enclosures and ventilation systems that will pull contaminated air away from the worker and transport it to a control device. As a result, worker exposure to hexavalent chromium and nickel emissions from thermal spraying would be greatly reduced.

3. What is the total cost of the proposed ATCM?

ARB staff estimates the total cost of the proposed ATCM to affected businesses to range from $672,000 to $1,195,000 in initial capital and permitting costs, and $55,000 to $94,000 in annual recurring costs. The total annualized cost of the proposed ATCM ranges from $150,000 to $257,000. The annual cost for facilities that would not be required to install additional controls ranges from $600 to $850 per facility. The annual cost for facilities that would be required to install additional controls ranges from about $5,000 to $55,000 per facility. The annualized costs are based on the conservative assumption that air pollution control devices will have a 10 year useful life and blowers will have a five year useful life. If the equipment has a longer useful life, the annual costs will decrease.

These cost estimates are based on discussions with thermal spraying facilities, local air districts, filter manufacturers, and hazardous waste disposal companies.

4. What are the expected economic impacts of the proposed ATCM on businesses?

Most of the affected businesses will be able to absorb the costs of the proposed ATCM with no significant adverse impacts on their profitability. This finding is based on the staff's analysis of the estimated change in "return on owner's equity" (ROE). Generally, a decline of more than ten percent in ROE suggests a significant adverse impact on profitability. For 31 of the 37 affected businesses, the decline in ROE is 0.1 to 4.6 percent. For the six businesses that may need additional controls, the expected decline in ROE is 16 to 68 percent. One facility could have a higher decline in ROE, depending on the number of control systems they choose to install. However, the higher decline in ROE would result from a business decision to add more control systems than necessary to comply with the ATCM (see Chapter VII for additional discussion). Four of these six businesses may choose to eliminate or reduce their thermal spraying operations rather than installing control devices. However, such a decision would have only a small impact on these entities because thermal spraying provides less than five percent of their gross annual revenue and their employees spend less than one hour per day conducting thermal spraying.

We expect the two remaining businesses to install new control devices. One of these businesses which does small amounts of thermal spraying, indicated it would pass the cost of controls on to its customers to minimize the cost impacts.

However, the overall cost impact to its customers is not expected to be significant. The other business is a large dedicated thermal spraying facility. This facility has a gross annual revenue of nearly $10 million and the annual cost of compliance would amount to approximately 0.6 to 1.7 percent of their gross annual revenue, depending on the number of booths they choose to upgrade. Overall, we do not expect a significant increase in cost for products that require thermal spraying because most businesses will be able to absorb the cost of the proposed ATCM.

We do not expect the proposed ATCM to have a significant impact on employment; business creation, elimination or expansion; and business competitiveness in California. ARB staff also expects no significant adverse fiscal impacts on any local or State agencies. For the one public agency impacted by the proposed ATCM, we estimate the costs to be approximately $600 per year.

We do not expect manufacturers of thermal spraying materials to incur any costs, because the proposed ATCM does not regulate material formulations. However, it is possible that some thermal spraying facilities will choose to discontinue their use of materials that contain chromium and nickel, rather than install control devices. It is not expected that this potential decline in material usage will have a significant economic impact, because our research indicates that only facilities with very low usage levels are considering the elimination of chromium and nickel-based materials.

5. What are the expected environmental benefits of the proposed ATCM?

The proposed ATCM would reduce hexavalent chromium emissions by nearly 80 percent overall (7 to 50 lbs/yr), and would reduce nickel emissions by 51 percent overall (54 to 377 lbs/yr) from thermal spraying operations in California. These reductions will occur in six air districts, with the greatest benefits occurring in the SCAQMD and BAAQMD.

Some thermal spraying facilities generate hazardous waste in the form of metal sludge from water curtain booths. The proposed ATCM is expected to result in a small decrease in the quantity of metal sludge disposed as hazardous waste, as some water curtain booths are upgraded to more efficient dry filter systems.

The proposed ATCM's requirements for locating and controlling new thermal spraying facilities would also help to address environmental justice concerns about exposing the public to sources of hexavalent chromium emissions.

6. Are there any potential negative environmental impacts?

No significant adverse environmental impacts are expected to occur as a result of adopting the proposed ATCM. Some thermal spraying facilities generate hazardous waste in the form of contaminated filter media. Although, the proposed ATCM is expected to cause an increase in the disposal of filters as hazardous waste, the increase is not expected to be significant.

7. How are the AB 2588 "Hot Spots" requirements and the ATCM interrelated?

ARB staff is currently developing amendments to the Air Toxics "Hot Spots" Emission Inventory and Criteria Guidelines Regulation to address thermal spraying operations. These amendments would align with the proposed ATCM requirements to avoid duplicative requirements and ensure that potential risks are evaluated and mitigated where necessary. The amendments to the Air Toxics "Hot Spots" Emission Inventory and Criteria Guidelines Regulation are expected to be considered by the Board in 2005.

VI. NEXT STEPS

If the proposed ATCM is adopted, the local air districts must implement and enforce the ATCM. However, if an air district wishes to adopt an alternative regulation, it has 120 days to propose and six months to adopt a regulation that is at least as stringent as the proposed ATCM. Thermal spraying facilities would need to be in compliance by January 1, 2006.

VII. RECOMMENDATION

We recommend that the Board adopt the proposed ATCM contained in Appendix A. The proposed ATCM would require the use of BACT for thermal spraying facilities that use materials containing chromium or nickel. The proposed ATCM would also require facility owners or operators to conduct regular monitoring and inspections to ensure that control devices are operating properly. Benefits from the proposed ATCM include a reduction in public exposure and health risk, due to reduced emissions of hexavalent chromium and nickel from thermal spraying operations. In addition, the proposed ATCM would result in reduced workplace exposure.

I. INTRODUCTION

I.A. OVERVIEW

Thermal spraying (or metal spraying) is a process in which materials are heated to a molten or nearly molten condition and are sprayed onto a surface to form a coating. Materials can be heated by combustion of fuel gases (similar to welding) or by using electricity. Thermal spraying includes processes such as flame spraying, plasma spraying, high velocity oxyfuel (HVOF) spraying, and twin wire electric arc spraying. Thermal spraying can be used in a wide variety of industries for numerous applications. In addition, thermal spraying can be a replacement for some hard chromium electroplating processes. There are potential serious health risks associated with thermal spraying, as there are with hard chromium electroplating. As a result, the Air Resources Board (ARB or Board) directed staff to investigate the health risks associated with thermal spraying activities.

The ARB staff identified thermal spraying as a source of emissions of hexavalent chromium and nickel. Both of these compounds are classified as toxic air contaminants (TACs). Hexavalent chromium is a very potent carcinogen, relative to other carcinogens. For example, the cancer potency factor for hexavalent chromium is second only to dioxins in terms of carcinogenic potency and is 24,000 times more potent than perchloroethylene. Although nickel is a much less potent carcinogen than hexavalent chromium, short-term exposure to relatively low concentrations of nickel can result in acute health impacts. To reduce the potential health risks associated with these TACs, ARB staff has developed a proposed airborne toxic control measure (ATCM). This Initial Statement of Reasons (ISOR) describes the ATCM development process and provides information on the following items:

- Regulatory authority;
- Identification of TACs;
- Control of TACs;
- Physical characteristics of TACs;
- Description of thermal spraying operations;
- Manufacturer and facility survey data;
- Air emissions from thermal spraying operations;
- Ambient concentration, exposure and health risk assessment; and
- Proposed ATCM and its health, economic, and environmental impacts.

I.B. REGULATORY AUTHORITY

The ARB's statewide air toxics program was established in the early 1980's. Assembly Bill (AB) 1807 (Tanner, Chapter 1047, statutes of 1983), *The Toxic Air Contaminant Identification and Control Act,* created California's Toxic Air Contaminant Identification and Control Program (Air Toxics Program) to reduce the public's exposure to air toxics. This law is codified in Health and Safety Code (HSC) sections 39650 through 39675. AB 2588 (Connelly, Chapter 1252, statutes of 1987), *Air Toxics "Hot Spots" Information* *and Assessment Act,* supplements the Air Toxics Program by requiring a statewide air toxics inventory, notification of people exposed to a significant health risk, and facility plans to reduce these risks.

I.C. TOXIC AIR CONTAMINANT IDENTIFICATION

The identification phase of the Air Toxics Program requires that the ARB, with the participation of other State agencies, evaluate the health impacts of, and exposure to, substances and to identify as TACs those substances which pose the greatest health threat. The ARB's evaluation is made available to the public and is formally reviewed by the Scientific Review Panel (SRP) established under HSC section 39670. Following ARB's evaluation and SRP review, the Board identified hexavalent chromium as a TAC at its January 1986 Board hearing. The Board, at its August 1991 Board hearing, identified nickel as a TAC. Both compounds were determined to be human carcinogens without an identifiable threshold exposure level below which no significant adverse health effects are anticipated. Nickel was also deemed to have acute health impacts.

I.D. CONTROL OF TOXIC AIR CONTAMINANTS

1. Airborne Toxic Control Measures

Once a compound has been identified as a TAC, the Board is required to prepare a report on the need and appropriate degree of regulation for the compound, and adopt regulations to reduce emissions of the compound, per HSC section 39665. These regulations are called Airborne Toxic Control Measures (or ATCMs.) In this document, we use the terms ATCM, regulation, and control measure interchangeably. Since hexavalent chromium and nickel don't have Board-specified threshold exposure levels, California law requires this ATCM to be based on best available control technology (BACT) or a more effective control method where cost and risk are taken into consideration.

The Board has adopted three ATCMs to reduce emissions of hexavalent chromium:

- 1988 - *Hexavalent Chromium Airborne Toxic Control Measure for Chrome Plating and Chromic Acid Anodizing Operations* (ARB, 1998a);
- 1989 - *Airborne Toxic Control Measure for Hexavalent Chromium For Cooling Towers* (ARB, 1989); and
- 2001 - *Airborne Toxic Control Measure for Emissions of Hexavalent Chromium and Cadmium From Motor Vehicle and Mobile Equipment Coatings.*

* The Chrome Plating and Chromic Acid Anodizing ATCM is currently being updated and is *scheduled for Board consideration in 2005.*

None of the existing hexavalent chromium ATCMs address emissions from thermal spraying operations. Therefore, ARB has developed the proposed

Airborne Toxic Control Measure for Emissions of Hexavalent Chromium and Nickel Compounds from Thermal Spraying. The determination to control these emissions is based on the potential risk to human health from the use of thermal spraying materials containing chromium and/or nickel. Thus, this ATCM focuses on a relatively small segment of the materials that are used in the thermal spraying industry. The proposed ATCM was developed in cooperation with the local air districts, the affected industry, and other interested stakeholders.

2. Hexavalent Chromium Control Plan

In February 1988, the Board approved a hexavalent chromium control plan (control plan) (ARB, 1988). The purpose of this control plan was to set forth the overall course of action for controlling sources of hexavalent chromium. While the control plan listed chromium-electroplating facilities as sources to control, it did not specifically consider the control of hexavalent chromium from thermal spraying. However, facilities have begun to use thermal spraying as an alternative for hard chromium electroplating processes.

3. AB 2588 "Hot Spots" Program

The AB 2588 Air Toxics "Hot Spots" Information and Assessment Act was enacted in September 1987. Under the AB 2588 program, stationary sources are required to report the types and quantities of certain substances that their facilities routinely release into the air. The goals of this program are to collect emission data, identify facilities having localized impacts, ascertain health risks, notify nearby residents of significant risks, and reduce risks to public health. Some local air districts have found that thermal spraying facilities pose a community health risk due to hexavalent chromium emissions. These facilities are being addressed through the AB 2588 "Hot Spots" Program. The ARB staff plans to amend the "Hot Spots" regulation to include thermal spraying as a listed category. This would require all thermal spraying facilities to prepare and submit emissions inventories to their local air districts.

4. California Air District Rules

There are currently no local air district rules that specifically regulate thermal spraying operations. Some districts have permitted these operations and these permits have required control devices. Other districts have not required permits for thermal spraying operations, because the quantities of pollutants emitted fall below their general permitting thresholds.

Some districts have special permitting rules for facilities that emit toxic pollutants. These rules establish the health risk levels that trigger the need for installation of Best Available Control Technology for Toxics (T-BACT). The South Coast Air Quality Management District has Rule 1401 (New Source Review of Toxic Air Contaminants) and Rule 1402 (Control of Toxic Air Contaminants from Existing

Sources) to control toxic emissions. Rule 1401 applies to air permits for new, relocated, or modified sources that emit TACs. If the increase in cancer risk from a modification does not exceed one in a million, T-BACT controls are not required to obtain an air permit. If the increase in cancer risk is between 1 and 10 in a million, T-BACT controls are required to obtain an air permit. In addition, the cancer burden must not exceed 0.5 cases. Under Rule 1402, the action risk level is 25 in a million for cancer risk, a cancer burden of 0.5, or a total acute or chronic hazard index of 3.0 for any target organ system at any receptor location. Acute or chronic hazard index is the ratio of the estimated level of exposure over a specified period of time to its acute or chronic reference exposure level. Existing facilities that exceed the action risk level must develop risk reduction plans and implement measures to reduce risks to below the action level.

The San Diego County Air Pollution Control District (SDAPCD) has Rule 1200 (Toxic Air Contaminants – New Source Review) and Rule 1210 (Toxic Air Contaminant Public Health Risks – Public Notification and Risk Reduction) to control toxic emissions. If the increase in cancer risk does not exceed one in a million, T-BACT controls are not required to obtain an air permit. If the increase in cancer risk is between 1 and 10 in a million, T-BACT controls are generally required to obtain an air permit. If the increased cancer risk is greater than 10 and up to 100 in a million, it may still be possible to get an air permit if a facility can meet specific conditions.

The Bay Area Air Quality Management District (BAAQMD) does not have a specific rule for toxics permitting. However, BAAQMD's permitting policy is generally consistent with the SCAQMD and SDAPCD toxics new source review rules. All permit applications for new or modified sources are screened for emissions of TACs and sources that may present significant health risks are required to install T-BACT to minimize TAC emissions.

5. National Emission Standards for Hazardous Air Pollutants

In the federal Clean Air Act Amendments of 1990, the United States Environmental Protection Agency (U.S. EPA) identified chromium compounds and nickel compounds as Hazardous Air Pollutants (HAPs). Both compounds were known to have, or may cause adverse effects on human health and/or the environment. In 1992, AB 2728 (Tanner, Chapter 1161, statutes of 1992) specified that ARB must, by regulation, identify as TACs, the 189 substances identified by the federal government as HAPs.

For certain designated source categories, U.S. EPA has developed specific regulations called National Emission Standards for Hazardous Air Pollutants (NESHAPs). Thermal spraying is not one of the designated categories; therefore, no NESHAP regulation exists for this source category. However, the U.S. EPA has identified metal spraying as a process that could potentially be regulated in the future under their Urban Air Toxics program (EPA, 2002.)

I.E. PUBLIC OUTREACH

1. Outreach Efforts

The ARB staff has made extensive efforts to ensure public participation throughout the two-year ATCM development process. ARB's public outreach program involved interaction with:

- thermal spraying materials manufacturers and their associations;
- thermal spraying facility operators and their associations;
- California's air pollution control and air quality management districts;
- air pollution control agencies in other states;
- environmental/pollution prevention and public health advocates; and
- other interested parties.

These entities participated in the development and review of two surveys conducted by ARB staff: the 2003 Thermal Spraying Materials Survey (materials survey) and the 2004 Thermal Spraying Facilities Survey (facility survey). The ARB staff also coordinated conference calls, working group meetings, and three public workshops. Through these efforts, ARB staff obtained information on the use and emissions of hexavalent chromium, nickel, and other chemicals of concern in thermal spraying materials. All parties were given opportunities to express their concerns, both in public and in private meetings. As part of ARB's outreach program, staff made extensive personal contacts with industry and facility representatives, as well as other affected parties through meetings, telephone calls, and mail-outs.

<u>**Outreach Activities Included:**</u>

- Forming an ARB/District Working Group and conducting three conference calls with group members;
- Forming an ARB/Industry Working Group and conducting four conference calls with group members;
- Creating an ARB Thermal Spraying website and maintaining a List-Server to automatically update interested parties about ATCM developments;
- Providing copies of draft surveys to working group members to obtain their input and recommendations;
- Conducting a survey by mail and e-mail for 42 thermal spraying material manufacturers in the United States and Canada;
- Conducting a survey by phone, FAX, and e-mail for facilities in California identified as potentially conducting thermal spraying operations;
- Making a presentation at the International Thermal Spray Association's regional meeting on April 2, 2004, in San Diego.
- Mailing workshop notices and posting workshop materials on ARB's website;

- Conducting three public workshops which allowed for participation by phone;
- Conducting site visits to three thermal spraying operations to better understand the thermal spraying processes and facility layouts; and
- Preparing fact sheets regarding the development of the ATCM and making them available to industry associations, potentially affected facilities, and the public.

2. Public Involvement

As described below, affected industries, other government agencies, and organizations have been actively involved in the ATCM development process. In addition to conducting three public workshops, ARB has implemented other measures to increase the general public's awareness of and participation in this process.

The ARB staff have made ATCM information available via the ARB website at: (http://www.arb.ca.gov/coatings/thermal/thermal.htm) and have established a thermal spraying list server to automatically inform subscribers of modifications to any of the thermal spraying web pages.

Thermal spraying materials manufacturers and industry representatives have actively participated in the development of this ATCM. The industry has provided technical information, has commented on the materials survey, the facility survey, and the proposed regulatory language. Industry involvement included:

- numerous telephone conversations with staff;
- completion of the materials survey;
- completion of the facility survey; and
- participation in conference calls and workshops.

Local air districts have been actively involved in the ATCM development process. In addition to the ARB/District Working Group, the ARB staff has coordinated with the California Air Pollution Control Officers Association (CAPCOA) Toxics Subcommittee. Districts provided data on the thermal spraying facilities in their areas and information on their permitting requirements for the thermal spraying industry.

Also, staff obtained information on regulatory requirements in other states, contacting air pollution control agencies to obtain information on permitting and emission calculations for thermal spraying operations.

3. Data Collection Tools Used To Assist in Report Preparation

Efforts to obtain data for this ATCM included conducting surveys of air districts, thermal spraying material manufacturers, and thermal spraying facilities.

District Survey

On November 20, 2002, ARB staff solicited the input and participation of each air district via a written request to all Air Pollution Control Officers. To assist in ATCM development, ARB staff requested information regarding thermal spraying facilities, material usage, emissions data, and risk assessment information.

Manufacturer Survey

In May 2003, ARB staff mailed the materials survey to thermal spraying manufacturers throughout the United States and Canada. The materials survey included thermal spraying materials containing hexavalent chromium, nickel, and other chemicals of concern. The materials survey requested data on sales, chemical composition, type of thermal spraying process, customer industry identification, and customer location. The materials survey was distributed to 42 companies and the response rate was 90 percent (%).

Facility Survey

In January 2004, the ARB staff telephoned, mailed and FAXed a survey to facilities throughout California identified as using a thermal spraying process. The facilities were identified through information provided by the local air districts, industry organizations, internet searches, and telephone directories. The data collected included information on thermal spraying processes, pollution control devices, material usage, and operating parameters.

REFERENCES

ARB, 1988. Air Resources Board. "Proposed Hexavalent Chromium Control Plan". 1988.

ARB, 1988a. Air Resources Board. "Proposed Airborne Toxic Control Measure for Emissions of Hexavalent Chromium from Chrome Plating and Acid Anodizing Operations". Technical Support Document. 1988.

ARB, 1989. Air Resources Board. "Proposed Hexavalent Chromium Control Measure For Cooling Towers". 1989.

ARB, 2001. Air Resources Board. "Airborne Toxic Control Measure For Emissions Of Hexavalent Chromium And Cadmium From Motor Vehicle And Mobile Equipment Coatings: Staff Report: Initial Statement Of Reasons For Proposed Rulemaking. Executive Summary/Staff Report". 2001.

EPA, 2002. Environmental Protection Agency. "Description of New Source Categories that are Listed for Future Regulatory Development", EPA memorandum from Barbara Driscoll to Urban Strategy Docket, November 18, 2002.

II. PHYSICAL CHARACTERISTICS, SOURCES AND AMBIENT CONCENTRATIONS OF HEXAVALENT CHROMIUM AND NICKEL COMPOUNDS

This chapter summarizes general information on the physical properties, sources, emissions, ambient and indoor concentrations and atmospheric persistence of hexavalent chromium and nickel. The information is derived from the Toxic Air Contaminant Identification List Summaries, unless otherwise noted (ARB, 1997). This chapter also includes information from the following documents:

- Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Identification of Hexavalent Chromium as a Toxic Air Contaminant (ARB,1985);
- Proposed Hexavalent Chromium Control Measure for Cooling Towers (ARB, 1989);
- Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Identification of Nickel as a Toxic Air Contaminant (ARB, 1991);
- Proposed Airborne Toxic Control Measure for Emission of Toxic Metals From Non-Ferrous Metal Melting (ARB, 1992); and
- Airborne Toxic Control Measure for Emissions of Hexavalent Chromium and Cadmium from Motor Vehicle and Mobile Equipment Coatings: Initial Statement of Reasons for Proposed Rulemaking Executive Summary/Staff Report (ARB, 2001).

II.A. HEXAVALENT CHROMIUM AND HEXAVALENT CHROMIUM COMPOUNDS

1. Physical Properties

Chromium is an odorless, steel-gray, hard metal that is lustrous and takes a high polish. It is extremely resistant to corrosive agents. Chromium can exist in water in several different states, but under strongly oxidizing conditions may be converted to the hexavalent state and occur as chromate anions. Chromium is soluble in dilute hydrochloric acid and sulfuric acid, but is not soluble in nitric acid or strong alkalis or alkali carbonates. Table II-1 contains information on the physical properties of chromium.

Chromium metal is not found in nature, but is produced principally from the mineral chromite (chrome ore). Chromite contains chromium in the +3 oxidation state, or chromium (III). Chromium combines with various other elements to produce compounds, the most common of which contain either trivalent chromium (Cr^{+3}, the +3 oxidation state), or hexavalent chromium (Cr^{+6}, the +6 oxidation state). Trivalent chromium compounds are sparingly soluble in water, while most hexavalent chromium compounds are readily soluble in water. Chromium forms a number of compounds in other oxidation states; however, those of +2 (chromous), +3 (chromic) and +6 (chromates) are the most important.

Table II-1: Physical Properties of Hexavalent Chromium	
Synonyms:	Chrome VI, Cr^{+6}
Atomic Weight:	51.966
Atomic Number:	24
Valences:	1 – 6
Boiling Point:	2642 °C
Melting Point:	1900 °C
Vapor Pressure:	1 mm Hg at 1616 °C
Specific Gravity:	7.14

(ARB, 1997)

2. Sources

Thermal spraying is a source of hexavalent chromium emissions. Thermal spraying involves spraying molten or nearly molten materials to form a coating. Thermal spraying materials rarely contain hexavalent chromium as an ingredient. However, hexavalent chromium can be present as a contaminant or it can be created during the thermal spraying process. Based on ARB's 2003 Thermal Spraying Materials Survey (ARB, 2004), the most common use of chromium in thermal spraying is as part of a metal alloy (Cr, CAS# 7440-47-3). Other forms of chromium used in thermal spraying materials are chromium carbide (Cr_3C_2, CAS# 12012-35-0), chromium oxide (Cr_2O_3, CAS# 1308-38-9); and trivalent chromium (Cr^{+3}, CAS# 16065-83-1).

Chromium electroplating is another source of hexavalent chromium emissions. In the chromium electroplating process, an electrical charge is applied to a plating bath containing an electrolytic salt (chromium anhydride) solution. The electrical charge causes the chromium metal in the bath to fall out of solution and deposit onto various objects placed into the plating bath. The desired thickness of the metal layering determines the type of chromium electroplating process. Decorative chromium plating is the application of thin layers of chromium to a surface (e.g., faucets and automotive wheels). Hard chromium plating applies a substantially thicker layer on surfaces that require greater protection against corrosion and wear (e.g., engine parts and industrial machinery). Hexavalent chromium emissions appear as a mist from the plating bath during the electroplating process.

Hexavalent chromium is a permanent and stable inorganic pigment used in paints, rubber, and plastic products. The most commonly used form of hexavalent chromium pigment is lead chromate. The spraying of chromated paints is a source of hexavalent chromium emissions. Hexavalent chromium emissions can also occur from firebrick lining of glass furnaces. Other stationary sources of hexavalent chromium emissions are electrical services, aircraft and parts manufacturing, and steam and air conditioning supply services.

3. Emissions

Statewide hexavalent chromium emissions from stationary sources in 2002 are estimated to be about 1,085 pounds, based on data supplied under the Air Toxics "Hot Spots" Program. Statewide hexavalent chromium emissions from thermal spraying operations in 2002 are estimated to range from nine to 66 pounds. The nine pounds per year estimate represents actual emissions based on facility reports of material usage. The 66 pounds per year estimate is a maximum potential emissions quantity based on materials sales reported to ARB by thermal spraying material manufacturers.

4. Natural Occurrence

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases (ARB, 1997). Trivalent chromium is a component of most soils. In areas of serpentine and peridotite rocks, chromite is the predominant chromium mineral. Deposits of five to ten percent chromite have been found in beach sands and streams in several California counties. Also, chromium has been found in non-serpentine areas of California at concentrations as high as 500 parts per million (ARB, 1997).

Chromium in soil is generally in an insoluble, biologically unavailable form, mainly as the weathered form of the parent chromite or as the chromium (III) oxide hydrate. Weathering and wind action can transport chromium from the soil to the atmosphere. Generally, such mechanical weathering processes generate particles greater than ten micrometers in diameter, which have significant settling velocities. The extent to which natural sources of chromium contribute to measured ambient chromium levels in California is not known. Ambient chromium derived from soil is expected to exist as trivalent chromium (ARB, 1997).

5. Ambient Concentrations

Chromium compounds and hexavalent chromium are routinely monitored by the statewide ARB air toxics network. The monitoring results indicate that hexavalent chromium concentrations have declined in recent years. The statewide mean concentration of hexavalent chromium has decreased from 0.27 nanograms per cubic meter (ng/m^3) in 1992 to 0.101 ng/m^3 in 2002. For hexavalent chromium ambient monitoring, the limit of detection has also decreased from 0.2 ng/m^3 in 1992 to 0.06 ng/m^3 in 2003. Therefore, the mean concentrations for 2003 are based on more precise measurements of ambient concentrations. Monitoring results below the limit of detection are assumed to be one-half the limit of detection or 0.1 ng/m^3 prior to 2003 and 0.03 ng/m^3 since 2003.

Table II-2 shows the hexavalent chromium mean concentration at various monitoring sites in local districts with thermal spraying facilities (ARB, 2004a).

Table II-2: Hexavalent Chromium Mean Concentration in Local Air Districts with Thermal Spraying Facilities

District	ARB's Air Toxics Network Monitoring Site	Year	Mean Concentration (ng/m^3)
Bay Area Air Quality Management District	Fremont-40733 Chapel Way	2003	0.045
	San Francisco-10 Arkansas St.	2003	0.145
	San Jose-156B Jackson St.	2003	0.098
	San Jose-120B North 4th St.	2000	0.13
	Concord-2975 Treat Blvd.	1999	0.10
	San Pablo-759 El Portal	1999	0.10
	Richmond-1144 13th St.	1996	0.13
San Diego County Air Pollution Control District	Calexico-1029 Ethel St.	2003	0.088
	Chula Vista-80 E. J St.	2003	0.063
	El Cajon-Redwood Ave.	2003	0.038
San Joaquin Valley Air Pollution Control District	Bakersfield-5558 California Ave.	2003	0.053
	Stockton-1601 E. Hazelton St.	2003	0.13
	Fresno-3425 N. 1st St.	2003	0.05
	Modesto-814 14th St.	1999	0.10
	Modesto-1100 I St.	1997	0.11
	Bakersfield-225 Chester Ave.	1993	0.21
South Coast Air Quality Management District	Azusa-803 Loren Ave.	2003	0.09
	Los Angeles-1630 N. Main St.	2003	0.07
	Riverside-5888 Mission Blvd.	2003	0.348
	Burbank-228 W. Palm Ave.	2002	0.123
	N. Long Beach-3648 North Long Beach Blvd.	2002	0.078
Ventura County Air Pollution Control District	Simi Valley-5400 Cochran St.	2003	0.06

Data on ambient concentrations of hexavalent chromium indicate that hexavalent chromium comprises 3 to 8 percent of total ambient chromium concentrations. Chromium in ambient air has been reported to contain principally respirable particulates, with a mass median diameter of about 1.5 to 1.9 micrometers (ARB, 1997).

6. Indoor Sources and Concentrations

The extent of exposure to airborne chromium in the indoor environment, other than in the workplace, is not known. There are no direct consumer uses of chromium that could lead to indoor emissions of chromium compounds. Although cigarettes are known to contain chromium, the intake of chromium from smoking is not known (ARB, 1997).

In a field study conducted in Southern California, investigators collected particles (PM_{10}) inside 178 homes and analyzed the samples for selected elements, including chromium. Two consecutive 12-hour samples were collected inside and immediately outside of each home. Chromium was present in measurable amounts in less than 25 percent of the indoor or outdoor samples (ARB, 1997).

A study in Southern California measured chromium inside vehicles during the summer of 1987 and winter of 1988. An average chromium concentration of 12 ng/m^3 and a maximum concentration of 41 ng/m^3 were measured (ARB, 1997).

7. Atmospheric Persistence

Atmospheric reactions of chromium compounds were characterized in field reaction studies and laboratory chamber tests. These results demonstrated an average experimental half-life of 13 hours (ARB, 1997). Physical removal of chromium from the atmosphere occurs both by atmospheric fallout (dry deposition) and by washout and rainout (wet deposition). Measurements have shown that most chromium deposition occurs through wet deposition. Chromium particles of less than five micrometers (aerodynamic equivalent) diameter may remain airborne for extended periods of time, allowing long distance transport by wind currents. Consequently, meteorological conditions can play a significant role in the dispersion of chromium emitted from some sources (ARB, 1997).

II.B. NICKEL AND NICKEL COMPOUNDS

1. Physical Properties

Nickel is a silvery white metal that retains a high polish. Nickel is malleable, ductile, ferromagnetic, corrosion resistant and a good conductor of electricity and heat. Nickel compounds range from quite soluble in water to practically insoluble in water. The most common oxidation state of nickel is the divalent form (Ni^{2+}). Nickel acetate, bromide, chloride, iodide, nitrate and sulfate are soluble in water. Nickel oxides, hydroxides, sulfides, arsenide, chromate, carbonate, phosphate and selenide are insoluble in water. Properties for nickel compounds vary depending on the particular compound. See Table II-3 for information on the physical properties of nickel.

Table II-3: Physical Properties Of Nickel	
Synonyms:	Raney Alloy, Raney Nickel
Atomic Weight:	58.69
Atomic Number:	28
Valences:	2 and 3
Boiling Point:	2730 °C
Melting Point:	1453 °C
Vapor Pressure:	1mm at 1,810 °C
Specific Gravity:	8.9

(ARB, 1997)

2. Sources

Thermal spraying is a source of nickel emissions. Thermal spraying involves spraying molten or nearly molten materials to form a coating. Many thermal spraying materials are nickel-based and may contain a combination of nickel with chromium, cobalt, and other toxic air contaminants. Some materials contain more than 90% nickel and a small percentage of another metal (e.g., aluminum.) Based on the ARB's 2003 Thermal Spraying Materials Survey (ARB, 2003), the most common use of nickel in thermal spraying is as part of a metal alloy (Ni, CAS# 7440-02-0).

Nickel is normally used in the manufacture of various metal alloys. Generally, nickel is alloyed with iron, copper, chromium, aluminum and zinc. Nickel and nickel compounds are used in electroplating, ceramics, welding, jewelry and coins. Nickel is also used for manufacturing corrosion-resistant alloys and the production of catalysts and batteries (ARB,1991.)

Nickel acetate is used as a hydrogenation catalyst. It is an intermediate in the formation of other nickel compounds, and is used as a sealant in aluminum manufacturing and in electroplating. Nickel carbonate is used as a purification intermediate in refining nickel; and as a catalyst in the petroleum, plastic and rubber industries (ARB, 1991.)

Fuel combustion (residential oil, distillate oil, coke and coal) accounts for the majority of statewide emissions of nickel. Particles that result from combustion are characteristically less than one micrometer (μm) in diameter, while large particles (greater than 10 μm) are likely to arise from dust and fugitive emissions. Nickel has also been discovered or identified in vehicle exhaust (ARB, 1997.)

3. Emissions

Statewide emissions of nickel and nickel compounds from stationary sources in 2002 are estimated to be at least 54 tons per year, based on data supplied under the Air Toxics "Hot Spots" Program.

The statewide emissions of nickel and nickel compounds from thermal spraying are estimated to range from 105 to 740 pounds in 2002. The 105 pounds per year estimate represents actual emissions based on facility reports of material usage. The 740 pounds per year estimate is a maximum potential emissions quantity based on raw materials sales reported to ARB by thermal spraying raw material manufacturers.

4. Natural Occurrence

Nickel is present in the earth's crust at 0.018 percent and is found in ores (sulfides, arsenides, antimonides and oxide or silicates). The most prevalent forms are nickel sulfate and oxides. Primary sources are chalcopyrite, pyrrhotite, pentlandite, ganierite, nicolite, and millerite. Nickel and nickel compounds comprise 0.03 percent of the particulate matter in the atmosphere. Nickel powders are deposited as meteoritic dust from the stratosphere. Sources of natural emissions of airborne particles containing nickel are included in soil, sea spray, volcanoes, forest fires and vegetation. Wind erosion and volcanic activity contribute 40 to 50 percent of the atmospheric nickel from natural sources (ARB, 1991.)

5. Ambient Concentrations

ARB's statewide air toxics network regularly monitors nickel and nickel compounds. Identified as a TAC in June 1991, ARB estimated that emissions of nickel and nickel compounds result in a population-weighted annual concentration of 7.30 ng/m^3 (ARB, 1991). The statewide mean concentration of nickel compounds has remained relatively stable at 4.1 ng/m^3 in 1992 to 4.5 ng/m^3 in 2002. For nickel monitoring, the limit of detection has decreased from 2 ng/m^3 in 1992 to 1 ng/m^3 in 2003. Therefore, the mean concentrations for 2003 are based on more precise measurements of ambient concentrations.

Table II-4 shows the mean concentration of nickel and nickel compounds at various monitoring sites in local districts with thermal spraying facilities (ARB, 2004b).

Table II-4: Nickel Mean Concentration in Local Air Districts with Thermal Spraying Facilities

District	ARB's Air Toxics Network Monitoring Site	Year	Mean Concentration (ng/m^3)
Bay Area Air Quality Management District	San Francisco-10 Arkansas St.	2002	4.2
	San Jose-120B North 4th St.	2001	4.6
	Fremont-40733 Chapel Way	2000	2.3
	Concord-2975 Treat Blvd.	1999	3.3
	San Pablo-759 El Portal	1999	2.2
	Richmond-1144 13th St.	1996	3.1
San Diego County Air Pollution Control District	Calexico-1029 Ethel St.	2003	3.5
	Chula Vista-80 E. J St.	2003	3.8
	El Cajon-Redwood Ave.	2002	3.2
San Joaquin Valley Air Pollution Control District	Bakersfield-5558 California Ave.	2003	3.3
	Stockton-1601 E. Hazelton St.	2002	6.1
	Fresno-3425 N. 1St St.	2002	2.2
	Modesto-814 14th St.	1999	2.3
	Modesto-1100 I St.	1997	2.4
	Bakersfield-225 Chester Ave.	1993	4.8
South Coast Air Quality Management District	Azusa-803 Loren Ave.	2002	12.5
	Burbank-228 W. Palm Ave.	2002	5.6
	Los Angeles-1630 N. Main St.	2002	6.4
	N. Long Beach-3648 North Long Beach Blvd.	2001	7.4
	Riverside-5888 Mission Blvd.	2002	5.4
Ventura County Air Pollution Control District	Simi Valley-5400 Cochran St.	2002	2.6

6. Indoor Sources and Concentrations

Tobacco smoke is an indoor source of nickel. A single cigarette contains one to three micrograms (*μg*) of nickel and a portion of that nickel becomes airborne during smoking (ARB, 1991.) Other sources of indoor airborne nickel emissions include house dust and the use of consumer products containing nickel (ARB, 1997.)

In a field study in Southern California, investigators collected particles (PM_{10}) inside 178 homes and analyzed them for selected elements, including nickel. Two consecutive 12-hour samples were collected inside and immediately outside of each home. Nickel was present in measurable amounts in less than 10 percent of the indoor or outdoor samples (ARB, 1997).

7. Atmospheric Persistence

For nickel and nickel compounds, the atmospheric half-life and lifetime are estimated to be 3.5 to 10 days and 5 to 15 days, respectively. Nickel particulate is removed from the atmosphere by wet or dry deposition. The nickel associated with atmospheric pollutants is almost always detected in particulate matter. Nickel is continuously transferred between air, water and soil by natural, chemical and physical processes such as weathering, erosion, runoff, precipitation, and stream and river flow (ARB, 1991).

REFERENCES

ARB, 1985. Air Resources Board. "Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Identification of Hexavalent Chromium as a Toxic Air Contaminant". 1985.

ARB, 1989. Air Resources Board. "Proposed Hexavalent Chromium Control Measure For Cooling Towers". 1989.

ARB, 1991. Air Resources Board. "Proposed Identification of Nickel As A Toxic Air Contaminant". Technical Support Document. Final Report.

ARB, 1992. Air Resources Board. "Proposed Airborne Toxic Control Measure for Emissions of Toxic Metals from Non-Ferrous Metal Melting". Technical Support Document. 1992.

ARB, 1997. Air Resources Board. "Toxic Air Contaminant Identification List – Summaries". September 1997.

ARB, 2001. Air Resources Board. "Airborne Toxic Control Measure For Emissions Of Hexavalent Chromium And Cadmium From Motor Vehicle And Mobile Equipment Coatings: Staff Report: Initial Statement Of Reasons For Proposed Rulemaking. Executive Summary/Staff Report". 2001.

ARB, 2004. Air Resources Board. "2003 Thermal Spraying Materials Survey". 2004.

ARB, 2004a. Air Resources Board. Online, Internet at http://www.arb.ca.gov/adam/toxics/sitelists/cr6sites.html (20 September 2004).

ARB, 2004b. Air Resources Board. Online, Internet at http://www.arb.ca.gov/adam/toxics/sitelists/nisites.html (20 September 2004).

III. SUMMARY OF THERMAL SPRAYING OPERATIONS

This chapter provides a general overview of thermal spraying operations and a brief description of the materials used in these operations.

III.A. OVERVIEW

Thermal spraying (or metallizing) is a process in which metals are deposited in a molten or nearly molten condition to form a coating. Typical coating thickness ranges from 25 to 11,000 micrometers and bond strengths can range from 5,000 – 45,000 pounds per square inch (psi) (Gansert, 2003). Coating materials can include pure metals, metal alloys, carbides, oxides, ceramics, and ceramic metals (cermets). The material is usually in the form of a powder or wire, but there are some applications where a ceramic rod is used. Powders are manufactured in a variety of mesh particle sizes, usually finer than 120 mesh
(125 microns) (AWS, 1985).

Energy sources include use of an oxyacetylene flame and an electric arc. Once the material becomes molten, it is delivered to the surface with air or gas pressure. The coating is formed by building up layers of molten droplets that flatten and solidify, thereby forming a mechanical bond to the surface. During the deposition process, the part surface remains much cooler than the molten material, rarely exceeding 250°F -300°F. Therefore, thermal spraying can be a suitable coating technique for substrates that cannot tolerate high temperatures.

For more severe service, a thermally sprayed coating may be sealed with a thin conventional organic coating (paint) or silicone. In many cases, thermally sprayed surfaces are machined to provide the desired finish.

Thermal spraying began in Europe in the early 20th century and was introduced in the United States in the 1920s. During World War II, the use of thermal spraying increased significantly as a method for repairing parts in industrial equipment. The use of thermal spraying has steadily increased over the years and the thermal spraying market was estimated to be greater than two billion dollars in 2000 (ITSA, 2003).

Thermal spraying is conducted at a variety of facilities. Some businesses conduct thermal spraying as a service to other businesses, while others use thermal spraying at their own manufacturing and repair facilities (e.g., aerospace rework). Most of the businesses in California are machine shops or job shops that provide thermal spraying services to other businesses. Smaller businesses will generally use the relatively low-cost thermal spraying technologies (e.g., twin-wire electric arc spraying and flame spraying), while larger businesses may invest in more expensive technologies (e.g., High Velocity Oxygen Fuel (HVOF)) and robotically-controlled application methods.

III.B. THERMAL SPRAYING PROCESSES

Table III-1 summarizes the primary types of thermal spraying processes that are in use. Each of these processes is described in greater detail in the following sections.

Table III-1: Thermal Spraying Processes

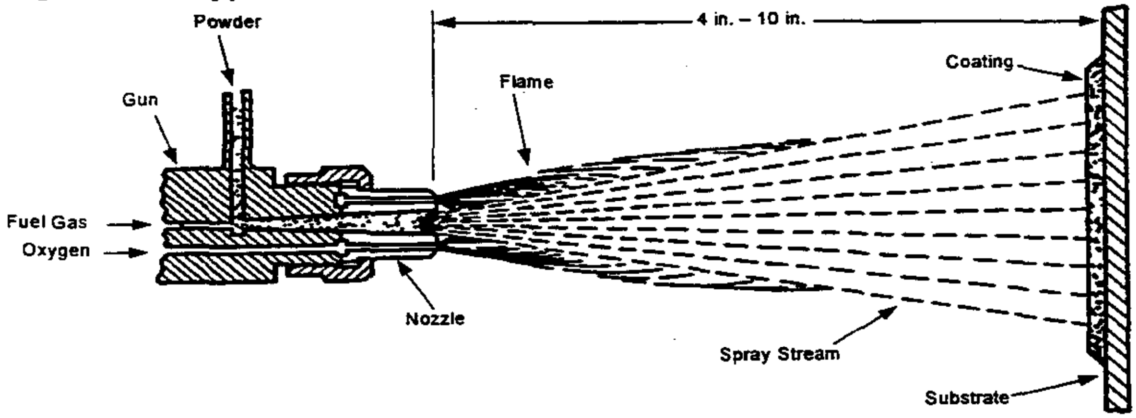
Process	***Material Form***	***Energy Source***
Flame Spraying	Powder, Wire, Rod	Oxyacetylene Flame
Twin-Wire Electric Arc Spraying	Wire	Electric Arc
Plasma Arc Spraying	Powder	Plasma Gun
HVOF	Powder	Oxygen, Hydrogen, & Fuel (e.g. methane)
Detonation Gun	Powder	Spark Ignition of Explosive Gas Gun

1. Flame Spraying

Flame spraying can be accomplished using materials in either a powder form or a wire/rod form. The flame can be produced using acetylene, propane, or another flammable gas. Flame-sprayed coatings may not be suitable for high-quality applications that require a very low level of oxides and porosity.

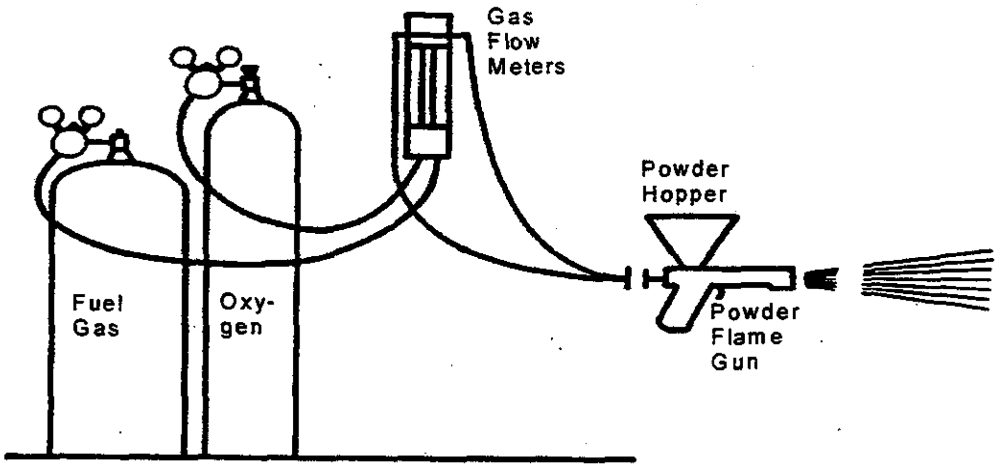
For powder flame spraying, the powder is stored in a hopper and is propelled through the gun by compressed gas (see Figures III-1 and III-2). The molten drops are propelled to the part surface by a high-velocity stream of air that surrounds the flame or via a diverted stream of the fuel gases. Powder flame spraying can achieve particle velocities of 130 ft/s (40 m/s) (Halldearn, 2001) and temperatures of 5,400°F (3,000°C) (Sulzer Metco, 2003). The deposition rate for powder flame spraying can reach up to 22 lbs/hr (10 kg/hr) of applied material (Halldearn, 2001). This is a relatively inexpensive process that is suitable for portable applications.

Figure III-1: Typical Powder Flame Spraying Gun



(AWS, 1985)

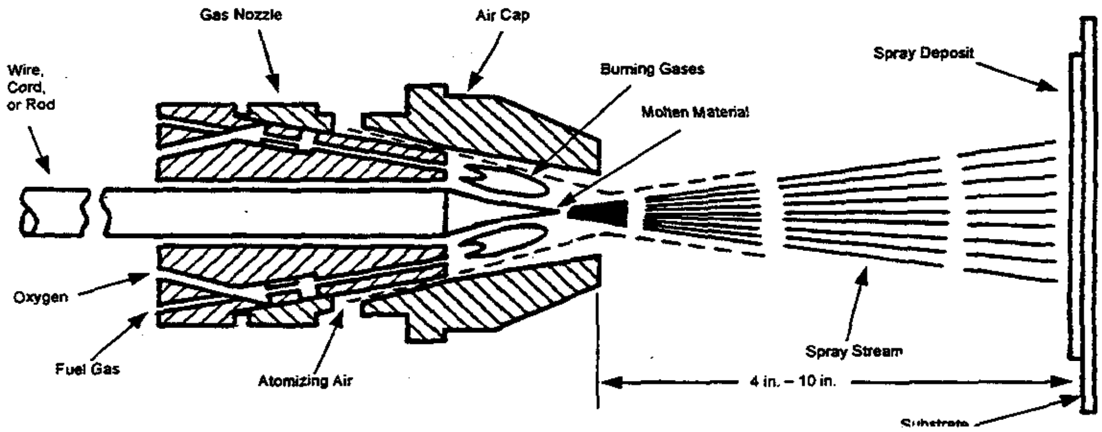
Figure III-2: Typical Powder Flame Spraying Equipment



(AWS, 1985)

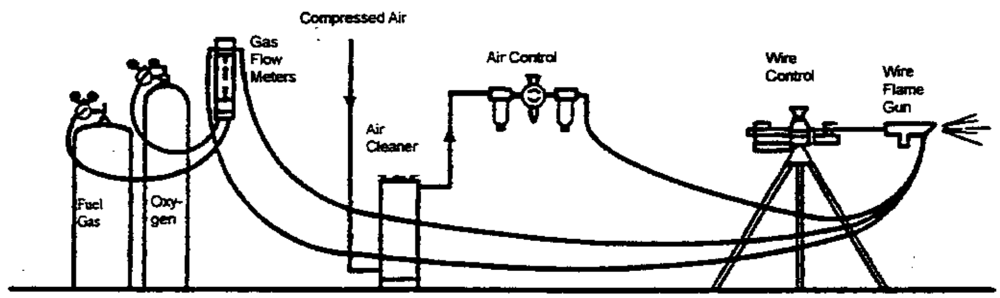
For wire flame spraying, a mechanized system feeds the wire through the gun into the oxygen-fuel flame where it is melted (see Figures III-3 and III-4). The molten drops are propelled to the part surface by a high-velocity stream of air that surrounds the flame. Particle spray velocities can be as high as 1,150 ft/sec (350 m/sec) (ATEM, 2001) and flame temperatures can reach 5,400°F (3000°C) (Sulzer Metco, 2003). The deposition rate for wire flame spraying can be as high as 130 lbs/hr (60 kg/hr) (Halldearn, 2001). This is a relatively inexpensive process that is suitable for portable applications.

Figure III-3: Typical Wire Flame Spraying Gun



(AWS, 1985)

Figure III-4: Typical Wire Flame Spraying Equipment

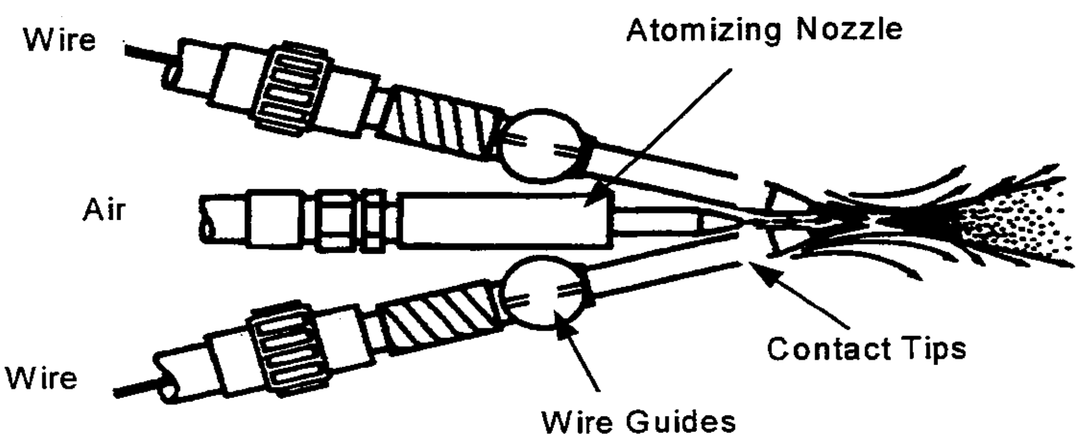


(AWS, 1985)

2. Twin-Wire Electric Arc Spraying

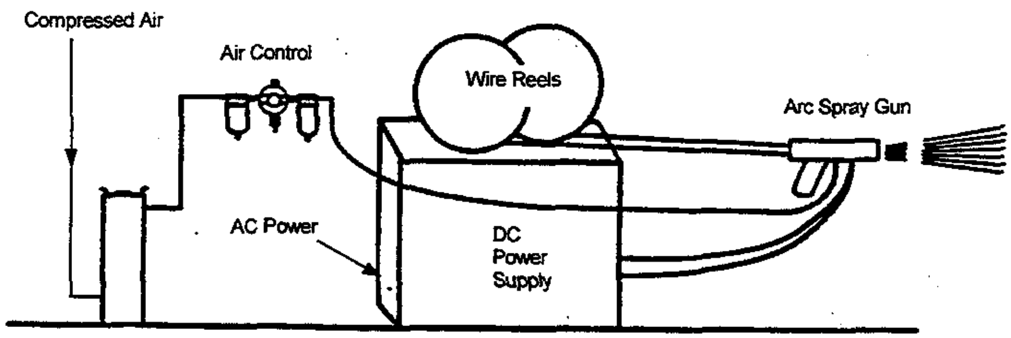
Two oppositely-charged wires are fed through a gun and brought together where they form an electric arc that melts the wires (see Figures III-5 and III-6). A high-velocity air stream (up to 100 m/s) propels the molten drops to the part surface where they form a dense coating that can be superior to flame-sprayed coatings (Halldearn, 2001). This process can generate temperatures up to 10,000°F (5,538°C) (Flame Spray, 2003). Electric arc equipment is considered to have the highest productivity rate among thermal spraying processes and it can deposit up to 132 lbs/hr (60 kg/hr) (Halldearn, 2001) with particle velocities as high as 250 m/sec (820 ft/sec) (Zowarka, 1998). This is a relatively inexpensive process and it doesn't require the use of a fuel gas. It is also suitable for portable applications.

Figure III-5: Typical Twin-Wire Electric Arc Spray Gun



(AWS, 1985)

Figure III-6: Typical Twin-Wire Electric Arc Spray Equipment

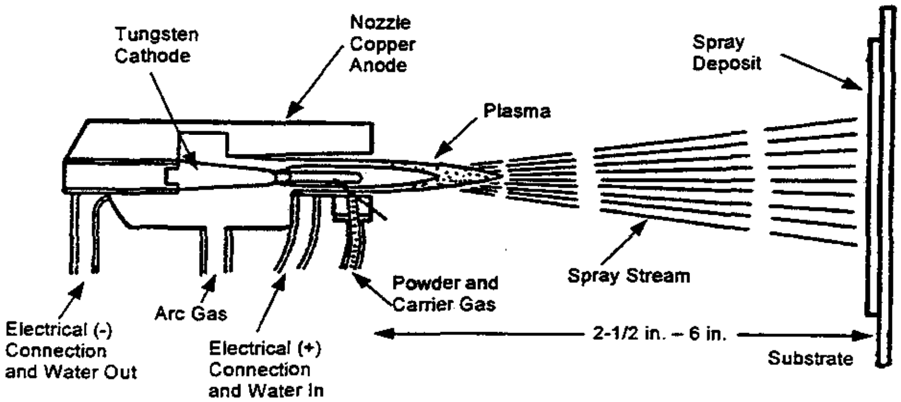


(AWS, 1985)

3. Plasma Arc Spraying

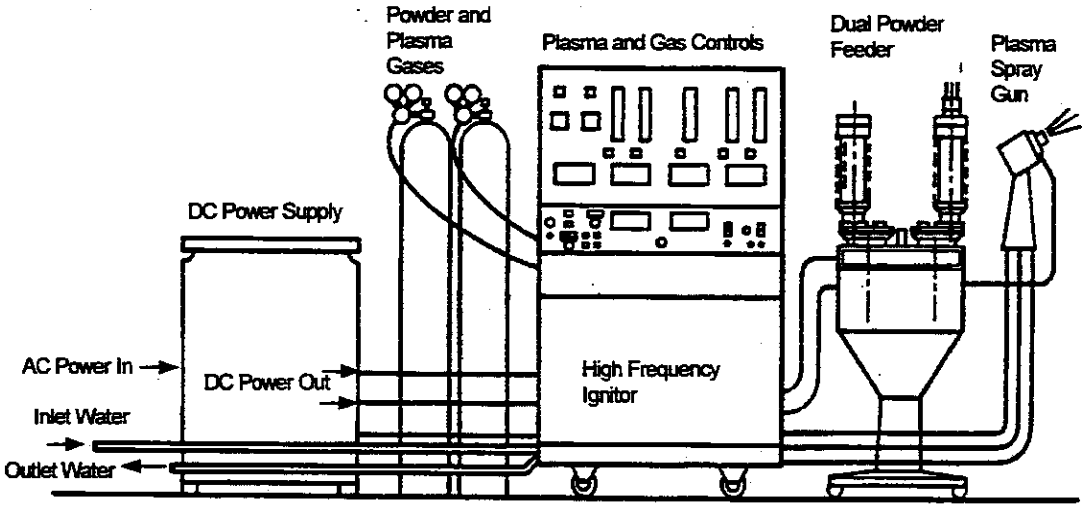
A plasma jet is generated by feeding a gas (e.g., hydrogen, nitrogen, argon, helium) through an electric arc which ionizes the gas (see Figures III-7 and III-8). The plasma process can generate particle velocities greater than 500 m/s, which forms a dense coating (AWS, 1985). Higher impact velocities result in higher bond strengths. Plasma spraying can generate the highest temperatures of all thermal spraying processes, reaching as high as 28,800°F (16,000°C) (Sulzer Metco, 2003). Therefore, plasma spraying can be used for ceramics and other materials that cannot be melted in other thermal spraying processes. The deposition rate for plasma spraying can reach 10 lbs/hr (5 kg/hr) (Halldearn, 2001). This is a relatively expensive process, as compared to flame spraying and twin-wire electric arc spraying.

Figure III-7: Typical Plasma Spray Gun



(AWS, 1985)

Figure III-8: Typical Plasma Flame Spraying Equipment



(AWS, 1985)

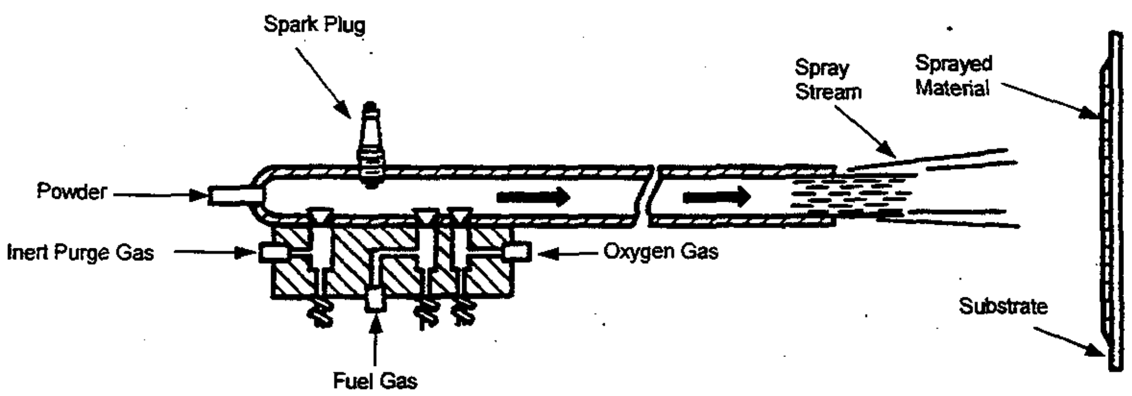
4. High Velocity Oxygen Fuel (HVOF)

HVOF uses a unique nozzle design and extremely high velocity gas to propel molten drops to a part surface. Gas temperatures are as high as 5,400°F (3,000°C) (Sulzer Metco, 2003). Particle velocities can reach 1000 m/s (Halldearn, 2001). The HVOF process can create extremely dense coatings that have high bond strengths and low stresses. The deposition rate for HVOF can be as high as 10 lbs/hr (5 kg/hr) (Halldearn, 2001). This is a relatively expensive process, as compared to flame spraying and twin-wire electric arc spraying.

5. Detonation Gun

The detonation gun has a long barrel, into which powder and fuel gas are injected. The fuel gas is ignited by a spark plug within the barrel and the resulting explosion melts the powder and propels the molten drops to the part surface (see Figure III-9). After each detonation, the barrel is purged with nitrogen gas. Repeated detonations build up a hard, dense coating surface. Detonation guns can achieve particle velocities of 2,500 ft/s (760 m/s) and temperatures of 6,000°F (3,315°C) (AWS, 1985).

Figure III-9: Typical Detonation Gun



(AWS, 1985)

6. Other Related Processes

Plasma Transferred Arc (PTA) surfacing is a welding process in which the powder is introduced into a combined arc/plasma stream to form a molten pool on the work-piece. The arc between work-piece and gun also results from surface melting of the base material, and a dilution of 5–15% in the deposit is typical. Coating thickness ranges from 1–6 mm, and deposit rate is up to 12 kg/h. Some thermal spraying materials can be used for both PTA and flame spraying processes.

III.C. THERMAL SPRAYING APPLICATIONS

Thermal spraying has a wide variety of applications in numerous industries, including the following:

- Repair or build-up of worn or damaged surfaces
- Wear Resistance
- Corrosion Resistance
- Undercoat for paint
- Temperature Resistance/Insulation
- Electrical Conductance

1. Benefits

The benefits of thermal spraying have led to a continual expansion of applications and technologies. For corrosion prevention, the cost of thermal spraying may initially be higher than traditional painting, but thermally sprayed coatings can last much longer. Therefore, the life cycle cost for thermal spraying may actually be lower than the cost of painting. In addition, thermal spraying does not require time for curing and it can eliminate or reduce emissions of volatile organic compounds. For damaged or worn surfaces, the cost of using a thermally sprayed coating to repair the surface can be much less than the cost of replacing the part. In some cases, inexpensive metals can be used to form a part that can be coated by thermal spraying to produce a high-quality surface. If thermal spraying is used as a replacement for hard chromium electroplating, it can reduce the emissions of hexavalent chromium.

2. Industrial Applications

Table III-2: lists some of the industrial applications for thermal spraying and the types of materials that are used to form a coating.

Table III-2: Thermal Spraying Industrial Applications

Industry	Apply Coatings To:	Coating Materials	Benefit
Aerospace	Jet engine components	Chromium carbide cermet, tungsten carbide/cobalt	Heat control, wear resistance, and build up of damaged surfaces
	Jet engine fan blades	Tungsten Carbide, Copper/Nickel/Indium Alloy, Chromium Carbide	Improve durability and prevent surface fatigue wear
	Jet engine gas path seals	Abradable materials (Al, Co, Cu, Ni), alumina, alumina-titania, nickel-aluminum cermet, nickel-chromium-chromium carbide	Wear resistance for rotating blade tips
	Aircraft landing gear	Tungsten carbide, chromium carbide	Sliding wear resistance, replacement for hard chrome electroplating
	Jet engine turbine components	Tungsten carbide-cobalt	Fretting wear resistance
	Airfoils, combustors, blades, vanes	Cobalt-chromium-nickel	Build up damaged surfaces and prevent oxidation
Aerospace	Composite aircraft panels	Aluminum	Protect against lightning strikes and dissipate electricity
	Jet engine combustors and nozzle guide vanes	Zirconia-yttria	Thermal barrier coating
	Helicopter pulleys	High carbon steel	Rebuild surface

Table III-2: Thermal Spraying Industrial Applications			
Industry	**Apply Coatings To:**	**Coating Materials**	**Benefit**
Agriculture	Crop harvesting machinery (knives, blades, flails, bars)	Tungsten carbide-cobalt	Wear resistance
Automotive	Plastic components in automobile ignitions	Aluminum, stainless steel, zinc	Electromagnetic Interference (EMI) shielding
	Engine valve lifters (made of aluminum rather than steel)	Iron-carbon- silicon-manganese	Reduce engine weight
	Aluminum brake discs	Ceramic	Reduce brakes weight
	Integrated circuit brackets in automotive computers	Aluminum oxide/ Magnesium oxide	Prevent electrical shorting
Chemical Manufacturing	Storage vessel	Stainless steel	Corrosion resistance
Computers/ Electronics	Apply metal coatings to non-conductive substrates	Aluminum, copper, silver, zinc	Create electrical circuits
	Paper or polymeric capacitors	Tin/Zinc	Enable electrical connection
	Electronic component housings	Aluminum, copper, zinc	EMI shielding
	Electronic components	Aluminum oxide, magnesium oxide	Wear resistance and insulation
Medical	Replacement hips	Titanium, synthetic bone	Promote fixation in body
Marine	Marine structures	Copper-nickel, aluminum bronze	Corrosion resistance
	Ship hulls, decks, rudders, lifeboats, etc.	Zinc	Corrosion resistance
	Piers, pilings, ferry berths	Zinc	Corrosion resistance
Military	Landing gear on military aircraft	Cobalt, tungsten carbide; aluminum	Resurfacing, replacement for hard chromium electroplating
	High temperature steam valves on Navy ships	Zirconia- titanium oxide-yttria	Resurfacing
	Helicopter flight decks on Navy ships	Aluminum	Non-skid coating

Table III-2: Thermal Spraying Industrial Applications			
Industry	**Apply Coatings To:**	**Coating Materials**	**Benefit**
Oil/Gas exploration and refining	Drill bit cones and other drilling components	Tungsten carbide-cobalt, chromium oxide	Prevent corrosion and provide wear resistance
	Offshore platforms	Aluminum, zinc	Corrosion resistance
	Pipelines	Zinc	Corrosion resistance
Power plants	Transmission towers, water tanks, etc.	Aluminum, zinc	Corrosion resistance
	Combustion components (e.g., boiler tubes, hydroelectric turbine parts)	Yttria-Zirconia, stainless steel	Prevent oxidation damage and provide corrosion protection
	Turbine combustion chambers	Zirconia coating	Thermal barrier coating
Pulp and paper	Drive rollers	Tungsten carbide	Provide a long-lasting surface that is rough enough to move paper without tearing paper
	Yankee dryers that dry tissue paper at paper mills	Stainless steel, molybdenum-nickel-chromium-boron-silicon (MoNiCrBSi)	Resurfacing and wear resistance
	Central impression cylinders at printing presses	Nickel superalloy	Resurfacing
	Anilox rolls that transport ink in flexographic printing machines	Chromium oxide ceramic	Resurfacing and wear resistance
	Gloss calendar rolls	Tungsten carbide-nickel-chromium, tungsten carbide-cobalt	Wear resistance
Pump/Motors	Pump sleeves, shafts, etc.	Stainless steel	Corrosion resistance and wear resistance

Table III-2: Thermal Spraying Industrial Applications			
Industry	**Apply Coatings To:**	**Coating Materials**	**Benefit**
Steel Mills	Hearth rolls that transport steel sheets through annealing furnaces	Ceramic	Repair surface, provide wear resistance, and prevent thermal shock
	Repair sink rolls that transport steel sheet through the galvanizing pot.	Tungsten, carbon, cobalt, chromium, nickel, aluminum, yttrium, oxide	Repair surface
	Process rolls in a steel mill		Resurfacing and corrosion resistance
Textile	Thread guides, rollers, etc.	Ceramic, chromium oxide, alumina-titania	Protect against abrasive fibers
Transportation	Bridges and concrete columns	Aluminum, zinc	Corrosion resistance
	Railroad cars	Zinc	Corrosion resistance, prevent contamination of transported fluid
	Bicycle rims	Aluminum oxide ceramics, carbide-based ceramic metals	Wear resistance

III.D. THERMAL SPRAYING ANCILLARY EQUIPMENT

1. Spray Booths

For many sources, thermal spraying is conducted in spray booths, equipped with filters or water curtains which capture most of the solid overspray that is not deposited on the part. Traditionally, the spray booths for thermal spraying were equipped with water curtains, but the use of high-efficiency dry filters has increased with increasing concerns about toxic emissions. Smaller facilities may use local exhaust to draw fumes away from the operator, but these units may not be equipped with filters that control particulate emissions. Other facilities may not use any type of control equipment or local exhaust.

2. Control Devices

Thermal spraying generates airborne metal dusts that can result in toxic air emissions, as well as explosion hazards. Aluminum dust is considered to be particularly hazardous, because it can generate explosive hydrogen gas in the presence of water. Ventilation and dust collection systems must be designed with explosion vents and other safety devices to ensure safe operation. In some cases, it is necessary to install a cyclone or other device to knock out the larger hot metal particles before they contact the dry filter media.

Older facilities have traditionally used water curtain booths to control emissions from thermal spraying processes. Water curtain booths can have a relatively low control efficiency (70% - 90%). Some of the larger air districts have required facilities to install HEPA filters for newly installed or modified thermal spraying operations. HEPA filters can achieve greater than 99.9% control efficiency (SDAPCD, 1998), but they can cost significantly more than a water curtain booth.

III.E. THERMAL SPRAYING MATERIALS

Thermal spraying materials can be divided into two main categories: powders and wires. Some manufacturers sell hundreds of different products with a wide variety of chemical compositions and physical properties, specifically formulated for different spraying processes and application methods. Many manufacturers in the aerospace and defense industries have specifications which govern the types of thermal spraying materials that can be applied to the surfaces of their products. Suppliers of thermal spraying materials often refer to these specifications when marketing their products. Specifications for thermal spraying materials are also maintained by trade organizations and the military, as provided below:

- American Welding Society AWS C2.25 "Specification for Solid and Composite Wires and Ceramic Rods for Thermal Spraying" (June 2002)
- Military Specification MIL-R-171731C "Rods and Powders, Welding, Surfacing" (16 January 1981)
- Military Specification MIL-STD-1687A "Thermal Spray Processes for Naval Ship Machinery Applications" (11 February 1987)

Based on information reported in ARB's 2003 survey of material suppliers, more than 50 different powders and more than 10 different wires containing chromium or nickel were sold in California in 2002.

III.F. THERMAL SPRAYING AS AN ALTERNATIVE TO HARD CHROMIUM ELECTROPLATING

Thermal spraying can be an alternative to hard chromium electroplating. Hard chromium electroplating is a process in which a layer of chromium metal is deposited directly on metal substrates such as engine parts, industrial machinery, and tools to provide protection against corrosion and wear. The electrical charge during the chromium plating process causes the hexavalent chromium to be emitted from the bath as a mist or aerosol.

In California, airborne emissions from chromium electroplating processes are regulated by a statewide ATCM, which requires the use of control technologies, depending on the type of facility. Other regulations that apply to hard chromium electroplating are South Coast Air Quality Management District (SCAQMD) Rule 1469 ("Hexavalent Chromium Emissions from Chrome Plating and Chromic Acid Anodizing Operations") and the federal National Emission Standards for Chromium Emissions from Hard and Decorative Chromium Electroplating and Chromium Anodizing Tanks (40 CFR Subpart N).

Worker exposures for hexavalent chromium are subject to the permissible exposure level (PEL) of 100 micrograms/cubic meter, as established by the Occupational Safety and Health Administration (OSHA) (CCR, 2002). In response to court action, OSHA is working on a revision of the current PEL, with a court-ordered deadline of October 4, 2004, for the proposed rule and a deadline of January 18, 2006, for the final rule (OSHR, 2003). Preliminary information indicates that the revised PEL could be in the range of 0.5 to 5.0 micrograms/cubic meter, a significant reduction from the current level. If the PEL is reduced significantly, it will become more challenging to provide the necessary worker protection while conducting hard chromium electroplating.

In an effort to reduce toxic emissions and reduce regulatory burdens, many electroplating facilities are investigating alternatives to the hard chromium electroplating process. For example, the Hard Chrome Alternatives Team (HCAT) includes representatives from the military and the aerospace industry in the United States and Canada. HCAT is investigating the use of HVOF thermal spraying as a replacement for hard chromium electroplating for a variety of applications. The HCAT research program has determined that HVOF coatings can provide superior performance and can be applied more quickly than electroplated coatings for certain applications (HCAT, 2003). In conjunction with the HCAT program, Hill Air Force Base has begun to use the HVOF process to apply tungsten carbide-cobalt coatings. According to officials at Hill Air Force Base, the hard chromium electroplating process required five days, while the HVOF process only required one day and less rework, due to the precision of the robotic HVOF system (Berk, 2002). A Northwestern University study estimated that HVOF coatings have the capability of replacing up to 80% of all hard chromium coatings at Department of Defense (DOD) maintenance activities (Sartwell, 1998).

Some advantages of thermal spraying as an alternative to hard chromium electroplating are provided below:

Cost – Thermal spraying often costs less than electroplating. The capital cost of establishing a thermal spraying facility is usually much less than the cost for a hard chromium electroplating facility with similar production throughput. In addition, the labor costs for thermal spraying can be much lower than the cost for electroplating, because the thermal spraying deposition process takes less time. Material costs for thermal spraying may be higher than for electroplating, but the savings in labor and operating costs can offset the increased material costs, resulting in a net savings for thermal spraying.

Facility Size – The floor space for a thermal spraying facility can be significantly less than the space required for a plating facility.

Coating Properties – Some HVOF coatings have higher hardness ratings and superior wear resistance, when compared to coatings applied by hard chromium electroplating. Improved wear resistance means an increase in the usable life of a coating, which can result in fewer overhauls and lower costs.

Fatigue – Hard chromium electroplating can reduce the fatigue strength of a part, but some studies have indicated that HVOF causes little or no reduction in fatigue strength (Sartwell, 1998).

Flexibility – A thermal spraying facility can be used to apply a wide variety of coatings to various substrates, while hard chromium electroplating only applies chromium. Thermal spraying coating materials can be formulated to provide very specific properties, depending on the chemical composition and physical form of the material being sprayed.

Waste Disposal – Thermal spraying generates a much smaller quantity of hazardous waste than hard chromium electroplating. Wastes from thermal spraying may include dry powder overspray, wastewater from water curtains, and contaminated filters from dust collectors. Electroplating can generate large quantities of wastewater that require treatment and/or disposal, as well as contaminated filters from filtration devices.

While thermal spraying has several advantages, it does not perform as well as hard chromium electroplating in certain applications. For each proposed application, it is often necessary to conduct an extensive evaluation to compare thermal spraying to electroplating. Therefore, thermal spraying is not considered to be a complete drop-in replacement for all hard chromium electroplating applications. Listed below are some of the disadvantages of thermal spraying that may limit its suitability as a replacement technology:

Geometry – Thermal spraying is most suitable for relatively simple geometries and is usually limited to line-of-sight applications. Some inner diameters can be adequately coated by adding extensions to thermal spraying guns, but electroplating may be more appropriate for parts that have complex geometries because the plating solution can flow into and around the part.

Coating Properties – Thermal spraying coatings may provide less corrosion protection than hard chromium on aluminum alloys (Sartwell, 1998).

Noise – Thermal spraying is much louder than electroplating with noise levels from 90 decibels to more than 130 decibels (similar to the noise level of a jet engine) (USACE, 1999). Hearing protection can be an issue for thermal spraying operators, as well as other workers within a facility. In some cases, it may be necessary to conduct spraying in a separate room or booth, to reduce the noise levels. Some facilities use robotically-controlled equipment that allows the operator to be outside of the booth while spraying is being conducted.

Surface Finishing – After plating or thermal spraying, it may be necessary to grind the coating to obtain the desired surface finish. For a chromium surface, a standard carbide wheel can be used for the grinding, but some thermally sprayed coatings (e.g., tungsten carbide-cobalt) may require the use of a diamond wheel, which is much more expensive (Legg, 2000).

Conversion Cost – Chromium electroplating may present environmental issues, but it is a well-known process that has a long history of use. For thermal spraying, it may be necessary to devote significant resources to research and testing to verify that thermal spraying will be a suitable replacement for electroplating.

REFERENCES

A-Flame, 2003. A-Flame Corporation. Online Internet at http://www.homestead.com/aflame/files/AirFiltrationSystemforSprayBooth.htm (30 July 2003).

ATEM, 2001. "Developments in Thermal Spray Coatings." Aircraft Technology Engineering and Maintenance, Engine Yearbook 2001, 92-99. Online, Internet at http://www.ai-group.co.uk/atem (30 July 2003).

AWS, 1985. American Welding Society, "Thermal Spraying, Practice, Theory, and Application". 1985.

Berk, 2002. Berk, Sue. "New Process Improves Aircraft Parts Protection," 29 May 2002. Air Force News. Online. Internet at http://www.af.mil/news/May2002/n20020529_0862.shtml (12 August 2003).

CCR, 2002. California Code of Regulations, Title 8, Division 1, Chapter 4, Subchapter 7, Group 16, Article 107, Section 5155, Airborne Contaminants, Table AC-1. 2002.

Flame Spray, 2003. Flame Spray Inc., "General Description of Thermal Spraying". Online, Internet at http://www.flamesprayinc.com/process.htm (30 July 2003).

Gansert, 2002. Air Resources Board staff discussions with Robert Gansert, Hardface Alloys Inc., November 2002.

Gansert, 2003. Gansert , R.V. "Thermal Spray Coatings". Online. Internet at http://www.hardfacealloys.com/THERMALSPRAYCOATINGS.html (22 July 2003).

Halldearn, 2001. Halldearn, Richard. "Arc Spraying (April 2001)." TWI World Centre For Materials Joining Technology, Online, Internet at http://www.twi.co.uk/j32k/protected/band_3/ksrdh002.html (30 July 2003).

HCAT, 2003. Hard Chrome Alternatives Team. Online. Internet at http://www.hcat.org/replace_hc.html. (30 July 2003)

ITSA, 2003. International Thermal Spray Association. Online, Internet at http://www.thermalspray.org/history.asp (30 July 2003).

Legg, 2000. Legg, K., B. Sartwell. "Hard Chromium Alternatives Team Update – Improving Performance While Reducing Cost". January 2000. Online. Internet at http://www.hcat.org/documents/AESF-EPA%20Jan%202000.pdf (30 July 2003).

Mills, 2002. Air Resources Board staff discussions with David Mills, Sulzer Metco, November 2002.

OSHR, 2003. "Third Circuit Orders OSHA to Issue Proposed, Final Rules by January 2006." Occupational Safety & Health Reporter, Volume: 33 Number: 15, 10 April 2003.

Sartwell, 1998. Sartwell, B.D., P.M. Natishan, I.L. Singer, K.O. Legg, J.D. Schell, J.P. Sauer. "Replacement of Chromium Electroplating Using HVOF Thermal Spray Coatings." AESF Plating Forum, March 1998.

SDAPCD, 1998. San Diego County Air Pollution Control District. "Metal Deposition – Plasma and Flame Spray Operations." Updated October 1998. Online internet at http://www.sdapcd.co.san-diego.ca.us/toxics/emissions/metdep/metdep.html (July 12, 2004.)

Sulzer Metco, 2003. Sulzer Metco, "Comparison of Thermal Spraying Coating Processes". Online, Internet at http://www.sulzermetco.com/eprise/Sulzermetco/Sites/Products/AboutThermalSpray/pr_comp.html (30 July 2003).

USACE, 1999. U.S. Army Corps of Engineers, "Engineer Manual 1110-2-3401, Thermal Spraying: New Construction and Maintenance." 1999.

Zowarka, 1998. Zowarka, R.C., J.R. Uglum, J.L. Bacon, M.D. Driga, R.L. Sledge, and D.G. Davis. "Electromagnetic Powder Deposition Experiments." Center for Electromechanics, the University of Texas at Austin. 1998.

IV. EMISSIONS FROM THERMAL SPRAYING OPERATIONS

IV.A. OVERVIEW

This chapter presents estimates of hexavalent chromium and nickel emissions from thermal spraying activities in California. Emission estimates are based on ARB survey results, data provided by local air districts, and emission factors that were developed from stack tests, scientific studies, and industry information.

IV.B. MATERIAL SALES DATA - ARB SURVEY

Data on material sales were obtained by ARB from companies that manufacture thermal spraying materials (ARB, 2004). In May 2003, ARB staff conducted a survey of companies that supply thermal spraying materials to California facilities. The survey collected data on sales quantities, chemical constituents, industrial applications, and applicable thermal spraying processes for materials sold in California during calendar year 2002. The survey only gathered data for thermal spraying materials that contain hexavalent chromium, nickel, and other specified chemicals of concern. A copy of the survey package is contained in Appendix B. The survey was distributed to 42 companies identified by the ARB as potential manufacturers of thermal spraying materials. The survey had a high response rate of 90%, with 15 companies reporting sales and 23 companies stating that they did not have any California sales of the targeted materials. Four companies did not respond to the survey, but it is expected that these companies represent a very small percentage of the market, based on discussions with an industry working group. Table IV-1 contains a summary of key survey results. A report of the manufacturer survey results can be obtained on ARB's website (http://www.arb.ca.gov/coatings/thermal/thermal.htm).

Table IV-1: Thermal Spraying Materials Survey – Key Results	
Number of manufacturers that were surveyed	42
Number of manufacturers that responded	38
Number of manufacturers that reported 2002 sales in California	15
Reported sales of materials that contained chemicals of concern*	103 tons
Reported quantity of chemicals of concern in thermal spraying materials	64 tons
# of companies that reported products with chromium or chromium compounds	14
Reported sales of materials that contained chromium or chromium compounds	72 tons
Reported quantity of chromium in thermal spraying materials	18 tons
# of companies that reported products with nickel or nickel compounds	14
Reported sales of materials that contained nickel or nickel compounds	63 tons
Reported quantity of nickel in thermal spraying materials	34 tons

* Chemicals of concern include Toxic Air Contaminants and Copper, which may present an acute health risk.

ARB treats a company's reported sales data as confidential information. To maintain confidentiality, but still allow the publishing of survey results, the ARB implemented the historical practice of concealing all sales data values that did not represent at least three companies, otherwise known as the "Three Company Rule." The term "Protected Data" (or PD) is used to reflect that compliance with the "Three Company Rule" could not be satisfied and the data were concealed. Table IV-2 provides sales totals based on the material form (powder or wire) and the type of process.

Table IV-2: Thermal Spraying Materials Survey – Sales Summary

Material/Process Description*		CA Sales in 2002 (Lbs)	CA Sales in 2002 (Tons)
Powder:	Flame Spray	9,967	5.0
	Flame Spray/Other	PD	PD
	Flame Spray/Plasma Spray	PD	PD
	HVOF	10,827	5.4
	HVOF/Flame Spray/Plasma Spray	PD	PD
	HVOF/Plasma Spray	20,654	10.3
	Plasma Spray	17,382	8.7
	Plasma Spray/Other	PD	PD
	Powder Subtotal =	**103,980**	**52.0**
Wire:	Single-Wire Flame Spray	PD	PD
	Twin-Wire Electric Arc	PD	PD
	Wire Subtotal =	**102,249**	**51.1**
	GRAND TOTAL =	**206,230**	**103.1**

* If a product was designated for more than one process, all process descriptions are listed.
"PD": Protected data (fewer than three companies reported sales).

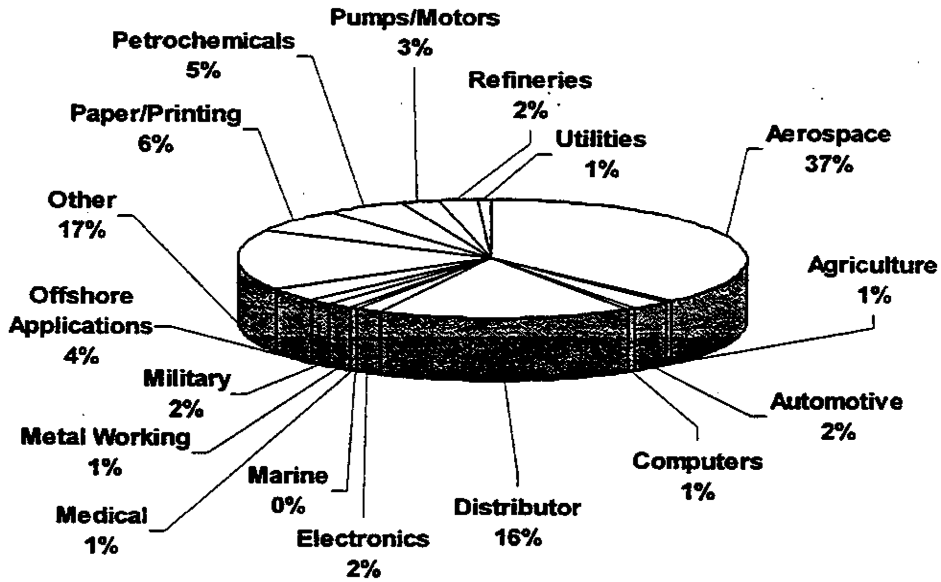
Table IV-3 lists the chemicals of concern and the associated sales quantities for each chemical. The table also contains the reported weight percentages of these chemicals in thermal spraying materials, including the sales-weighted averages (SWAs.)

Table IV-3: Thermal Spraying Materials Survey –Chemicals of Concern

Chemical Name	CAS	Form	Weight Percent			Quantity of Chemical Sold (lbs)
			Min.	Max.	SWA	
Antimony	7440-36-0	Wire	7.5	7.5	7.5	66
Chromium	7440-47-3	Powder	0.1	70.3	30.7	17,163
Chromium	7440-47-3	Wire	8.0	27.0	20.1	11,376
Chromium^{3+} (trivalent)	16065-83-1	Wire	13.0	13.0	13.0	2,991
Chromium Oxide (Cr_2O_3)	1308-38-9	Powder	91.0	99.3	99.1	7,551
Cobalt	7440-48-4	Powder	0.3	66.4	30.2	13,080
Cobalt	7440-48-4	Wire	1.0	1.0	1.0	4
Copper	7440-50-8	Powder	0.1	99.0	35.1	1,777
Copper	7440-50-8	Wire	3.5	99.0	81.3	5,099
Lead	7439-92-1	Wire	0.1	0.3	0.2	2
Manganese	7439-96-5	Powder	0.3	2.0	0.9	56
Manganese	7439-96-5	Wire	0.5	8.5	1.8	673
Nickel	7440-02-0	Powder	0.3	99.8	54.1	36,736
Nickel	7440-02-0	Wire	0.3	99.0	53.1	30,580
					TOTAL (lbs) =	**127,153**
					TOTAL (tons) =	**63.6**

Figure IV-1 illustrates the thermal spraying material sales breakdown by industry, based on total sales in California during 2002.

Figure IV-1: Thermal Spraying Materials Survey – Industrial Breakdown



IV.C. THERMAL SPRAYING FACILITY DATA – ARB SURVEY

Data on material usage and operating conditions for thermal spraying facilities were obtained from businesses that perform thermal spraying. In January 2004, the ARB staff conducted a survey of thermal spraying facilities in California. The data collected included information on thermal spraying processes, pollution control devices, material usage, and operating parameters. Data from this survey and information from districts were combined to compile a list of active thermal spraying facilities in California. Table IV-4 contains a listing of thermal spraying facilities and the associated air districts.

Table IV-4: Number of Thermal Spraying Facilities in California			
Air District	Total Facilities	%	Permitted Facilities
Bay Area AQMD	9	18%	3
Feather River AQMD	1	2%	0
North Coast Unified AQMD	1	2%	0
South Coast AQMD	26	51%	16
San Diego County APCD	8	16%	8
San Joaquin Valley APCD	4	8%	0
Ventura County APCD	2	4%	1
Totals =	**51**		**28**

Table IV-5 contains permit and control device information for facilities that reported the use of chromium or nickel. Many districts have not required permits for thermal spraying facilities, due to the relatively low emission quantities and the lack of specific regulations for these types of facilities.

Table IV-5: Thermal Spraying Facility Data		
	Facilities that Use Chromium	**Facilities that Use Nickel**
Total Number	30	35
Have Air Permits	15	17
Unpermitted	15	18
Best Control Device*		
HEPA Filter	15	17
Dry Filter	9	10
Water Curtain	2	3
Uncontrolled	4	5

* Many facilities have multiple booths and different booths may have different control devices. This table reflects the best control device (i.e., the highest control efficiency) at each facility.

IV.D. CHROMIUM FUMES FROM THERMAL SPRAYING

Hexavalent chromium and hexavalent chromium compounds are classified as toxic air contaminants, but hexavalent chromium compounds are not generally present in thermal spraying materials as a raw ingredient. The types of chromium that are listed as ingredients include:

- Chromium CAS # 7440-47-3
- Chromium +3 (trivalent) CAS # 16065-83-1
- Chromium Oxide CAS # 1308-38-9

Even though hexavalent chromium compounds are not originally present in thermal spraying materials, numerous stack tests have measured emissions of hexavalent chromium from thermal spraying facilities. This indicates that a conversion occurs during the thermal spraying process to change chromium from an elemental or trivalent state to a hexavalent state. A supplier of thermal spraying materials has found that hexavalent chromium may be produced when materials are exposed to the high temperatures that are involved in many thermal spraying processes (Praxair, 2002). In addition, a thermal spraying industry report states that vaporized metallic chromium can cause a small fraction of the chromium to oxidize and form chromates that contain a hexavalent form of chromium (Smith, 1994). This conversion to hexavalent chromium was measured during Sawatari's study of a plasma metal spraying process with chromium metal (Sawatari, 1986). Results indicated that the fumes contained 30% hexavalent chromium compounds and 70% trivalent chromium compounds. A 1990 study by Serita found that plasma spraying with chromium powder produced fumes that contained 26.4% hexavalent chromium (Serita, 1990). The California Occupational Safety and Health Administration (Cal/OSHA) measured 33% hexavalent chromium in plasma spraying fumes and the National Institute for Occupational Safety and Health (NIOSH) measured 11% hexavalent chromium in twin-wire electric arc spraying fumes (Gold, 2000; NIOSH, 1989).

As these studies demonstrate, the formation of hexavalent chromium during thermal spraying has been documented for a variety of sources, but the quantities that are emitted can vary widely, depending on the type of process and the type of control device. Some stack tests have found that more than 90% of the total chromium being measured consists of hexavalent chromium, while other tests have found less than 5%. The most conservative approach for estimating statewide emissions would be to assume maximum conversion to hexavalent chromium and complete consumption of all materials sold in California during 2002. However, ARB staff has developed emission factors for thermal spraying, based on data that were compiled from a variety of sources for a range of control devices (see Table IV-6.) Appendix C contains a detailed explanation of the methods that were used to develop emission factors and estimate hexavalent chromium emissions on an annual and average hourly basis.

IV.E. HEXAVALENT CHROMIUM EMISSION ESTIMATES FROM THERMAL SPRAYING

The general approach for estimating hexavalent chromium emissions involves multiplying emission factors by material usage rates. Emission factors were obtained from a variety of sources, based on the type of process, the form of material being used (i.e., powder or wire), and the type of control device. In some cases, emission factors were taken directly from stack test results, while other factors were derived from a combination of stack test results, research data, and control efficiency information. Table IV-6 summarizes the emission factors that were used and Appendix C describes how these factors were derived.

Table IV-6: Emission Factor Summary – Hexavalent Chromium				
Process	Emission Factors (lbs Cr^{+6}/lb Cr sprayed)			
	0% Ctl. Eff. (Uncontrolled)	90% Ctl. Eff. [1] (e.g. Water Curtain)	99% Ctl. Eff. (e.g. Dry Filter)	99.97% Ctl. Eff. (e.g., HEPA Filter)
Single-Wire Flame Spray[2]	4.68E-03	4.68E-04	4.68E-05	1.40E-06
Twin-Wire Electric Arc Spray[2]	6.96E-03	6.96E-04	6.96E-05	2.09E-06
Flame Spray[3]	6.20E-03	1.17E-03	6.20E-05	1.86E-06
HVOF[3]	6.20E-03	1.17E-03	6.20E-05	1.86E-06
Plasma Spray[4]	1.18E-02	6.73E-03	2.61E-03	2.86E-06
Other Thermal Spraying[5]	7.17E-03	2.05E-03	5.70E-04	2.01E-06

1. Listed below the control efficiencies are examples of control devices that may meet the control efficiency.
2. Emission factors based on American Welding Society study (AWS, 1979.)
3. Emission factors based on SDAPCD stack test data for flame spraying.
4. Emission factors based on stack test results compiled by CATEF, SCAQMD, and SDAPCD.
5. For "Other Thermal Spraying" processes, we used an average of the emission factors for the listed thermal spraying processes.

ARB staff estimated annual emissions using two approaches: (1) potential to emit, based on manufacturer sales data, and (2) actual emissions, based on usage data as reported by individual facilities. When calculating the potential to emit, we used material sales data from ARB's 2003 Thermal Spraying Material Survey. When calculating actual emissions, we used material throughput data from thermal spraying businesses, that were obtained from ARB's 2004 Thermal Spraying Facility Survey.

Table IV-7 summarizes the California sales in 2002 for thermal spraying products that contain chromium and the associated quantity of chromium contained in those products. Table IV-7 also contains the associated processes and annual potential to emit values. To calculate potential emissions, we multiplied the applicable emission factor times the quantity of chromium sold. As shown in Table IV-7, 18 tons of chromium were potentially used at thermal spraying facilities and the potential to emit is 66 pounds for hexavalent chromium statewide in 2002.

To calculate actual emissions, we multiplied the applicable emission factor times the quantity of chromium usage reported by individual facilities. Actual emissions were estimated to be 9.4 pounds, based on usage data, process descriptions, and control device information as provided by facilities. It is expected that our estimates of actual emissions and the potential to emit represent lower and upper boundaries for statewide emissions. Therefore, we estimate that annual hexavalent chromium emissions from thermal spraying are in the range of 9.4 to 66 pounds. The difference between estimates of maximum potential emissions and actual emissions may be due to the following factors: 1) materials sold in one year may be used over multiple years; 2) some materials sold to California distributors may be redistributed out of State; and 3) some businesses that conduct thermal spraying may not have been captured by the ARB facility survey.

For this thermal spraying ATCM, we estimated the potential range of emission reductions based on data from the ARB 2004 Thermal Spraying Facility Survey, the 2003 ARB Thermal Spraying Materials Survey, and the proposed ATCM control efficiency requirements. Implementation of this thermal spraying ATCM is expected to reduce hexavalent chromium emissions significantly. For a facility with no existing control devices, the proposed ATCM would require at least a 99% reduction in emissions. For the largest facility in the State, the proposed ATCM would require that the control device efficiency be increased from a minimum of 81% to at least 99.97%. Overall, the proposed ATCM is expected to reduce hexavalent chromium emissions by nearly 80 percent (7 to 50 lbs/yr.)

Table IV-7: Thermal Spraying Sales & Potential to Emit Summary - Hexavalent Chromium

Process	Material	Sales of Products Containing Chromium (lbs) [1]	Qty. of Chromium in Products (lbs Cr)	Potential to Emit (lbs Cr^{+6}/yr)[2]
Flame Spray	Powder	6,788	713.4	0.6
Flame Spray/Other	Powder	PD	2,415.0	2.8
Flame Spray/Plasma Spray	Powder	PD	736.5	1.7
HVOF	Powder	7,731	3,279.0	2.8
HVOF/Flame Spray/Plasma Spray	Powder	PD	2,860.7	5.3
HVOF/Plasma Spray	Powder	10,918	5,307.9	12.4
Plasma Spray	Powder	14,780	6,962.3	26.5
Plasma Spray/Other	Powder	PD	22.8	0.1
	Powder Subtotal =	**63,612**	**22,298**	**52.1**
Single-Wire Flame Spray	Wire	PD	1,330.1	0.9
Twin-Wire Electric Arc	Wire	PD	13,036.6	12.6
	Wire Subtotal =	**79,708**	**14,367**	**13.4**
	GRAND TOTAL =	**143,320**	**36,664**	**65.6**

1. "PD": Protected data (fewer than three companies reported sales).
2. Based on survey data, it was assumed that 13% of products are used at uncontrolled facilities and 87% of products are used at controlled facilities (i.e., those equipped with a dry filter control device.)

In addition to estimating annual emissions, we also determined the average hourly emissions, which were estimated to be **9.8E-05** grams Cr^{+6}/second. Average hourly emissions (in units of grams/second) are used for estimating cancer risks.

Maximum hourly emissions are used to calculate impacts from short-term acute exposures. Reference Exposure Levels (RELs) for short-term acute exposures have not yet been established for hexavalent chromium. Therefore, we did not calculate maximum hourly emissions for hexavalent chromium.

IV.F. NICKEL EMISSIONS ESTIMATES FROM THERMAL SPRAYING

The general approach for estimating nickel emissions involves multiplying emission factors by material usage rates. Emission factors were obtained from a variety of sources, based on the type of process and control device. In some cases, emission factors were taken directly from stack test results, while other factors were derived from a combination of stack test results and data on control efficiencies. Table IV-8 summarizes the emission factors that were used and Appendix D describes how these factors were derived.

Table IV-8: Emission Factor Summary – Nickel

Process	Emission Factors (lbs Ni/lb Ni sprayed)			
	0% Ctl. Eff. (Uncontrolled)	90% Ctl. Eff. [1] (e.g. Water Curtain)	99% Ctl. Eff. (e.g. Dry Filter)	99.97% Ctl. Eff. (e.g., HEPA Filter)
Twin-Wire Electric Arc Spray[2]	6.0E-03	6.0E-04	6.0E-05	1.8E-06
Flame Spray[3]	1.10E-01	4.64E-02	1.10E-03	3.30E-05
HVOF[3]	1.10E-01	4.64E-02	1.10E-03	3.30E-05
Plasma Spray[4]	1.5E-01	3.67E-02	1.5E-03	1.72E-05
Other Thermal Spraying[5]	9.4E-02	3.25E-02	9.4E-04	2.13E-05

1. Listed below the control efficiencies are examples of control devices that may meet the control efficiency.
2. Uncontrolled emission factor based on Wisconsin stack test data.
3. Emission factors based on SDAPCD stack test data for flame spraying.
4. Emission factors based on SCAQMD and SDAPCD stack test data.
5. For "Other Thermal Spraying" processes, we used an average of the emission factors for the listed thermal spraying processes.

Table IV-9 summarizes the California sales in 2002 for thermal spraying products that contain nickel and the associated quantity of nickel contained in those products. Table IV-9 also contains the associated processes and annual potential to emit values. As shown in Table IV-9, 34 tons of nickel were potentially used at thermal spraying facilities and the potential to emit is 740 pounds for nickel statewide in 2002.

Actual emissions were estimated to be 105 pounds, based on usage data, process descriptions, and control device information as provided by individual facilities. It is expected that our estimates of actual emissions and the potential to emit represent lower and upper boundaries for statewide emissions. Therefore, we estimate that annual nickel emissions from thermal spraying are in the range of 105 – 740 pounds. The difference between estimates of maximum potential emissions and actual emissions may be due to the following factors: 1) materials sold in one year may be used over multiple years; 2) some materials sold to California distributors may be redistributed out of State; and 3) some businesses that conduct thermal spraying may not have been captured by the ARB facility survey.

For this thermal spraying ATCM, we estimated the potential range of emission reductions based on data from the ARB 2004 Thermal Spraying Facility Survey, the ARB 2003 Thermal Spraying Materials Survey, and the proposed ATCM control efficiency requirements. Implementation of this thermal spraying ATCM is expected to reduce nickel emissions by 51 percent (54 to 377 lbs/yr).

In addition to estimating annual emissions, we also determined the average hourly emissions (which were estimated to be **9.6E-04** grams Ni/sec) and the maximum hourly emissions (as shown in Table IV-10). Average hourly emissions (in units of grams/second) are used for estimating cancer risks. Maximum hourly emissions are used to calculate impacts from short-term acute exposures.

Table IV-9: Thermal Spraying Sales & Potential to Emit Summary - Nickel

Process	Material	Sales of Products Containing Nickel (lbs)[1]	Qty. of Nickel in Products (lbs Ni)	Potential to Emit (lbs Ni/yr)[2]
Flame Spray	Powder	9,917	7,021.1	114.8
Flame Spray/Other	Powder	PD	8,429.3	162.8
Flame Spray/Plasma Spray	Powder	PD	9,567.7	184.8
HVOF	Powder	5,776	1,361.3	22.3
HVOF/Flame Spray/Plasma Spray	Powder	PD	828.0	15.2
HVOF/Plasma Spray	Powder	11,473	6,408.4	123.8
Plasma Spray	Powder	9,435	3,056.7	68.1
Plasma Spray/Other	Powder	PD	63.6	1.4
Powder Subtotal =		**67,911**	**36,736**	**693.1**
Single-Wire Flame Spray	Wire	PD	1,259.4	20.6
Twin-Wire Electric Arc	Wire	PD	29,320.2	26.1
Wire Subtotal =		**57,640**	**30,580**	**46.7**
GRAND TOTAL =		**125,550**	**67,316**	**739.9**

1. "PD": Protected data (fewer than three companies reported sales).
2. Based on survey data, it was assumed that 14% of products are used at uncontrolled facilities and 86% of products are used at controlled facilities (i.e., those equipped with a dry filter control device.)

The maximum hourly emissions depend on the hourly spray rate for a given facility. To estimate maximum hourly emissions, we used a range of spray rates (low, medium, and high) to cover a variety of scenarios. For most thermal spraying processes, the hourly spray rates for nickel were 0.5, 5, and 15 lbs/hr (or 0.063, 0.63, and 1.89 g/s). Twin-Wire Electric Arc spraying can achieve a substantially higher spray rate than flame spraying, according to information from manufacturers and technical literature. Therefore, the "high" estimated spray rate for electric arc spraying was 25 lbs/hr (or 3.15 g/s) instead of 15 lbs/hr (1.89 g/s).

Maximum hourly emission rates were estimated for uncontrolled facilities and for facilities equipped with a control device that achieves 99% control efficiency. The maximum hourly values were calculated for low, medium, and high nickel spray rates. Table IV-10 contains the high-end values that were calculated for low, medium, and high spray rates. For the purposes of risk assessment, these data are presented in units of "grams/second", rather than units of "lbs/hr".

Table IV-10: Maximum Hourly Emissions – Nickel			
	Estimated Emissions (grams Ni/sec)		
	Low Spray Rate	**Medium Spray Rate**	**High Spray Rate**
Uncontrolled	9.45E-03	9.45E-02	2.83E-01
Controlled (dry filter)	9.45E-05	9.45E-04	2.83E-03

REFERENCES

ARB, 2004. Air Resources Board. "2003 Thermal Spraying Materials Survey". 2004.

AWS, 1979. American Welding Society. "Fumes and Gases in the Welding Environment". 1979.

ERM, 1995. "Chemtronics Inc., Plasma-Arc Metal Spray Device, Emissions Testing of Associated Control Equipment". Test Date Oct. 25, 1994. Prepared by Environmental and Risk Management, Inc. for Chemtronics Inc. and submitted to the SDAPCD. 1995.

Gold, 2000. Gold, Deborah. "Chromium and Other Hazards in a Plasma Spray Operation", presented at the American Industrial Hygiene Conference and Exposition, May 2000.

NIOSH, 1989. National Institute for Occupational Safety and Health. "Health Hazard Evaluation Report, HETA 88-136-1945, Miller Thermal Technologies." January 1989.

PES, 2000. "Final Report, Development of Emission Inventory for Metal Welding, Cutting, and Spraying Operations". Prepared by Pacific Environmental Services for the SCAQMD. 2000.

Praxair, 2002. Praxair/TAFA. 2002. Material Safety Data Sheet #T122 (TAFA Bondarc Wire-75B) and #T124 (TAFA 88T UltraMachinable Stainless Wire).

Sawatari, 1986. Sawatari, K. and F. Serita. 1986. "Determination of Chromium Speciation in Fumes Prepared by a Plasma Metal Sprayer as a Model of Actual Welding Fumes," Industrial Health 24:51-61.

SCEC. 1998. "Emission Testing of a HEPA Filter System". Test Date Nov. 17, 19, 20, 1997. Prepared by SCEC for Flame Spray Inc. and submitted to the SDAPCD. 1998.

SCEC. 1998a. "Emission Testing of a Water Wash Booth". Test Date Dec. 9, 1997. Prepared by SCEC for Flame Spray Inc. and submitted to the SDAPCD. 1998.

SCEC. 2001. "Toxic Air Contaminant Public Health Risk Assessment Testing of a Plasma Flame Spray Facility". Test Date Feb. 26-27, 2001. Prepared by SCEC for Chromalloy San Diego and submitted to the SDAPCD. 2001.

Serita, 1990. F. Serita, K. Homma, K. Fukuda, K. Sawatari, Y. Suzuki, and T. Toya. 1990. "Development of an Inhalation System of High Melting Point Metal Fumes and Its Use for Exposure of Rats to Chromium and Nickel Fumes," Industrial Health 28:185-197.

Smith, 1994. Smith, R.W., P. Mathur, D. Sprigs. "Thermal Spray Industry Environmental Guideline". ASM International. 1994.

V. HEALTH ASSESSMENT FOR THE PROPOSED AIRBORNE TOXIC CONTROL MEASURE

This chapter presents an overview of the health risk assessment process that forms the health basis for this ATCM, the potential health impacts from exposure to hexavalent chromium and nickel from thermal spraying, as well as information on control devices that can reduce risk levels. This chapter also addresses the benefits of the proposed ATCM in terms of statewide emissions and potential health impacts. Appendix F contains a more detailed explanation of the health risk assessment methods.

V.A. OVERVIEW

A health risk assessment (HRA) is an evaluation or report that a risk assessor develops to describe the potential a person or population may have of developing adverse health effects from exposure to a facility's emissions. Some health effects that are evaluated include cancer, developmental effects, and respiratory illness. We evaluated the cancer and non-cancer health impacts and found that the potential cancer health impacts were more significant than non-cancer impacts. Therefore, the following sections focus on the cancer risk assessment. Section V.E. contains a discussion of non-cancer health impacts.

Exposure to toxic air contaminants (TAC) can occur through pathways that include inhalation, skin exposure, and the ingestion of soil, water, crops, fish, meat, milk, and eggs. According to the Office of Environmental Health Hazard Assessment (OEHHA), hexavalent chromium and nickel are only treated as carcinogenic by the inhalation route (OEHHA, 2003.) Therefore, we only evaluated the cancer risk impacts of hexavalent chromium and nickel via the breathing or inhalation pathway. Appendix F contains a detailed explanation of the health risk assessment calculations.

Generally, to develop a HRA, the risk assessor would consider information developed under the following four steps:

Step 1 - Hazard Identification	The risk assessor determines if a hazard exists, and if so, identifies the pollutant(s) and the type of effect, such as cancer or respiratory effects.
Step 2 - Dose-Response Assessment	The risk assessor characterizes the relationship between a person's exposure to a pollutant and the occurrence of an adverse health effect.
Step 3 - Exposure Assessment	The risk assessor estimates the extent of public exposure by looking at who is likely to be exposed, how exposure will occur, and the magnitude of exposure (e.g., the airborne concentration of a pollutant.)
Step 4 - Risk Characterization	The risk assessor combines airborne pollutant concentrations with cancer potency factors (for cancer risk) and reference exposure levels (for non-cancer effects) to quantify the potential cancer risk and non-cancer health impacts.

The methods used in this risk assessment are consistent with the Tier 1 analysis presented in the OEHHA Air Toxics "Hot Spots" Program Risk Assessment Guidelines, the Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (OEHHA, 2003).

Table V-1 summarizes the key parameters that were used when conducting the air dispersion modeling and the health risk assessment.

Table V-1: Key Parameters for Air Dispersion Modeling and Health Risk Assessment	
Air Dispersion Model:	U.S. EPA, Industrial Source Complex Short Term (ISCST3), Version 02035
Source Type:	Volume and Point
Dispersion Setting:	Urban
Receptor Height:	1.2 meters
Stack Information (Point Sources):	
Stack Diameters	0.55, 0.81, and 0.88 meters
Stack Heights	5.5, 10.7, and 13.7 meters
Stack Temperatures	300, 294, and 293 degrees Kelvin
Stack Exhaust Velocities	24, 19, and 13 meters/second
Volume Source Information:	
Release Height	1.8 meters
Lateral Dimension	9.9 meters
Vertical Dimension	2.3 meters
Meteorological Data:	Los Angeles area – Vernon, West LA San Francisco Bay area – San Francisco Airport San Diego area – Barrio Logan, Miramar Naval Air Station, Lindbergh Airport
Receptor's Hypothetical Exposure Time:	70 yrs, 350 days/year
Adult Daily Breathing Rates:	393 liters/kg body weight-day (high-end) 302 liters/kg body weight-day (80th percentile) 271 liters/kg body weight-day (mean)
Adult Body Weight:	70 kg
Cancer Inhalation Potency Factors:	Hexavalent Chromium – 510 $(mg/kg\text{-}day)^{-1}$ Nickel – 0.91 $(mg/kg\text{-}day)^{-1}$
Non-Cancer Acute Reference Exposure Levels (RELs) – Inhalation:	Hexavalent Chromium – not established Nickel – 6.0 ug/m^3
Non-Cancer Chronic RELs - Inhalation:	Hexavalent Chromium – 0.20 ug/m^3 Nickel – 0.05 ug/m^3
Non-Cancer Chronic RELs - Oral:	Hexavalent Chromium – 0.02 mg/kg-day Nickel – 0.05 mg/kg-day

V.B. FACTORS THAT AFFECT THE OUTCOME OF A HEALTH RISK ASSESSMENT

The results of a health risk assessment include an evaluation of potential adverse health impacts from exposure to TACs. Factors that affect the potential health impacts include:

- product usage rates and quantities;
- the concentration of TAC (e.g., chromium or nickel) in the products being used at a facility;
- the toxicity of a pollutant;
- the facility operating schedule;
- the physical dimensions of the facility; and
- local meteorology.

The combination of these factors will ultimately determine the potential health impact. Due to the variability of these factors, the potential health impacts can also vary. For example, if only the chromium content was to increase, and all other factors were held constant, the resulting potential health impacts would also increase. In addition, hexavalent chromium is a very toxic chemical, so the potential health impacts can be quite significant even if the level of exposure is relatively low.

V.C. MULTI-PATHWAY HEALTH RISK ASSESSMENT

In evaluating the potential health effects of a pollutant, it is important to identify the different routes by which an individual could be exposed to the pollutant. The appropriate pathways to include in a HRA are dependent on the specific toxic air pollutant that a person (receptor) is exposed to, and can include inhalation, dermal exposure, and the ingestion of soil, water, crops, fish, meat, milk, and eggs. However, hexavalent chromium and nickel are only considered to be carcinogenic via inhalation exposure (OEHHA, 2003.) In addition, our analysis indicates that the inhalation pathway and the potential impacts on the respiratory endpoint would present the most significant non-cancer chronic health impacts. Therefore, this health risk assessment focused upon the impacts of exposure to hexavalent chromium and nickel via the inhalation pathway.

V.D. HEALTH RISK ASSESSMENT PROCESS

The following sections describe details of the health risk assessment process and the resulting health risk estimates.

Step 1 - Hazard Identification

Thermal spraying can generate emissions of TACs, such as hexavalent chromium, nickel, and cobalt. Hexavalent chromium and nickel have been formally identified by the Board as TACs without threshold exposure levels below which adverse health effects are not anticipated.

Both hexavalent chromium and nickel are classified as carcinogens. Exposure to hexavalent chromium may cause lung and nasal cancers, respiratory irritation, severe nasal and skin ulcerations and lesions, perforation in the nasal septum, liver and kidney failure and birth defects. Exposure to nickel may cause lung and nasal cancers, allergic sensitization, asthma, and other respiratory ailments.

Step 2 - Dose-Response Assessment

OEHHA develops dose-response factors to characterize the relationship between a person's exposure to a pollutant and the occurrence of an adverse health effect. A cancer potency factor is used when estimating potential cancer risks and reference exposure levels (RELs) are used to assess potential non-cancer health impacts (OEHHA, 1999; OEHHA, 2002; OEHHA, 2003). Cancer potency factors are the upper bound probability of developing cancer, assuming continuous lifetime exposure to a substance at a dose of one milligram per kilogram of body weight. Hexavalent chromium is a very potent carcinogen in comparison to other common carcinogens, as shown in Table V-2.

Table V-2: Inhalation Cancer Potency Factors for Common Carcinogens (in descending order)

Compound	Cancer Potency Factor $(mg/kg\text{-}day)^{-1}$
Dioxin (2,3,7,8-Tetrachlorodibenzo-p-Dioxin)	1.3 E+5
Hexavalent Chromium	**5.1 E+2**
Cadmium	1.5 E+1
Arsenic (inorganic)	1.2 E+1
Diesel Exhaust	1.1 E+0
Nickel	**9.1 E-1**
1,3-Butadiene	6.0 E-1
Ethylene Oxide	3.1 E-1
Vinyl Chloride	2.7 E-1
Ethylene Dibromide	2.5 E-1
Carbon Tetrachloride	1.5 E-1
Benzene	1.0 E-1
Ethylene Dichloride	7.2 E-2
Lead	4.2 E-2
Formaldehyde	2.1 E-2
Perchloroethylene	2.1 E-2
Chloroform	1.9 E-2
Acetaldehyde	1.0 E-2
Trichloroethylene	7.0 E-3
Methylene Chloride	3.5 E-3

(OEHHA, 2003)

A REL is used as an indicator of potential non-cancer adverse health effects, and a REL is defined as a concentration level at or below which no adverse health effects are anticipated. RELs are designed to protect the most sensitive persons in the population by including safety factors in their development, and can be created for both acute and chronic exposures. An acute exposure is defined as one or a series of short-term exposures generally lasting less than 24 hours. Chronic exposure is defined as long-term exposure usually lasting from one year to a lifetime.

Non-cancer acute RELs have been established for nickel, but not for hexavalent chromium. Table V-3 contains non-cancer RELs and toxicological endpoints for hexavalent chromium and nickel.

Table V-3: Health Effects Values Used in Health Risk Assessment

	Hexavalent Chromium	Nickel
Non-Cancer Reference Exposure Levels		
Acute – Inhalation (ug/m^3)	N/A	6.0
Chronic – Inhalation (ug/m^3)	0.20	0.05
Chronic – Oral (mg/kg-day)	0.02	0.05
Toxicological Endpoints		
Acute – Inhalation	N/A	Immune System and Respiratory System
Chronic – Inhalation	Respiratory system	Hematopoietic System and Respiratory System
Chronic - Oral	Hematologic	Alimentary

(OEHHA, 2003)

Step 3 - Exposure Assessment

Hexavalent chromium and nickel are only considered to be carcinogenic when exposure occurs by the inhalation route (OEHHA, 2003.) Therefore, we evaluated the cancer risk impacts of hexavalent chromium and nickel via the breathing or inhalation pathway only.

For thermal spraying activities, the persons that are most likely to be exposed include off-site workers located near the facility or nearby residents. On-site workers could be impacted by the emissions; however, they are not included in this HRA because Cal/OSHA has jurisdiction over on-site workers.

The magnitude of exposure was assessed through the following process. ARB staff conducted air dispersion modeling to provide downwind airborne concentrations of hexavalent chromium and nickel in the air. The downwind concentration is a function of the quantity of emissions, release parameters at the source, and appropriate meteorological conditions. Results of the modeling are detailed in Appendix E.

Air dispersion modeling was conducted using the U.S. EPA, Industrial Source Complex Short Term (Version 02035) air dispersion model (ISCST3 model). The ISCST3 model estimates concentrations at specific locations around each facility, directly caused by each facility's emissions. When conducting the modeling, ARB staff used operating data from four actual thermal spraying facilities whose annual emissions of hexavalent chromium ranged from 0.0001 to 0.02 pounds per year. We also used meteorological data from three areas (Bay Area, Los Angeles, and San Diego) when conducting modeling for each of these facilities The modeling analyzed airborne concentrations for potential receptor distances that ranged from 30 – 5,000 meters (or 100 –16,400 feet) away from the thermal spraying facilities.

Step 4 - Risk Characterization

This section presents the results of the health risk assessment for thermal spraying facilities that use materials containing chromium and/or nickel. The analyses included the cancer and non-cancer health impacts for potential receptors located at distances from 30 – 5,000 meters (or 100 – 16,400 feet) away from the thermal spraying facilities. When evaluating potential health risks for individual facilities, we used actual emissions data, based on each facility's reported material usage. Emissions were quantified using the methods discussed in Chapter IV and Appendices C and D.

Figures V-1 and V-2 illustrate the cancer risk levels for set emission levels of hexavalent chromium at different receptor distances. The shaded areas indicate cancer risks that are less than or equal to 10 in a million, based on the 95th percentile daily breathing rate.

Figure V-1: Hexavalent Chromium - Estimated Risk Range vs. Receptor Distance for Thermal Spraying Point Sources

Emissions (lbs Cr^{+6}/yr)								
0.004	A	A	A	A	A	A	A	A
0.01	A	A	A	A	A	A	A	A
0.05	B	B	B	A	A	A	A	A
0.1	B	B	B	A	A	A	A	A
0.5	C	C	C	B	A	A	A	A
	40	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**
	Receptor Distance (meters)							

KEY: A: ≤ 10 in a million
B: >10 and ≤ 100 in a million
C: >100 in a million

Figure V-2: Hexavalent Chromium – Estimated Risk Range vs. Receptor Distance for Thermal Spraying Volume Sources

Emissions (lbs Cr^{+6}/yr)									
0.004	A	A	A	A	A	A	A	A	A
0.01	B	B	B	A	A	A	A	A	A
0.05	B	B	B	B	A	A	A	A	A
0.1	C	C	C	B	A	A	A	A	A
0.5	C	C	C	C	B	A	A	A	A
	30	**40**	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**
	Receptor Distance (meters)								

KEY A: ≤ 10 in a million
B: >10 and ≤ 100 in a million
C: >100 in a million

The results illustrated in Figures V-1 and V-2 show that a very low level of hexavalent chromium emissions can lead to cancer risks that exceed 10 in a million at nearby receptors.

Figures V-3 and V-4 illustrate the cancer risk levels for set emission levels of nickel at different receptor distances. Figures V-3 and V-4 are based on nickel emission levels that are much higher than the hexavalent chromium emission levels shown in Figures V-1 and V-2. Even though the nickel emissions are higher than the emissions of hexavalent chromium, the health risks from nickel are much lower than the risks caused by hexavalent chromium because nickel is less toxic. For example, 0.01 pounds of hexavalent chromium could trigger a potential cancer risk of 10 in a million, while it would take 5 pounds of nickel to trigger a 10 in a million cancer risk.

Figure V-3: Nickel – Estimated Risk Range vs. Receptor Distance for Thermal Spraying Point Sources

Emissions (lbs Ni/yr)								
2	A	A	A	A	A	A	A	A
5	A	A	A	A	A	A	A	A
10	A	A	A	A	A	A	A	A
50	B	B	B	A	A	A	A	A
100	B	B	B	B	A	A	A	A
	40	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**
	Receptor Distance (meters)							

KEY A: ≤ 10 in a million
B: >10 and ≤ 100 in a million

Figure V-4: Nickel - Estimated Risk Range vs. Receptor Distance for Thermal Spraying Volume Sources

Emissions (lbs Ni/yr)									
2	A	A	A	A	A	A	A	A	A
5	B	B	B	A	A	A	A	A	A
10	B	B	B	A	A	A	A	A	A
50	C	C	C	B	A	A	A	A	A
100	C	C	C	B	B	A	A	A	A
	30	**40**	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**
	Receptor Distance (meters)								

KEY A: ≤ 10 in a million
B: >10 and ≤ 100 in a million
C: >100 in a million

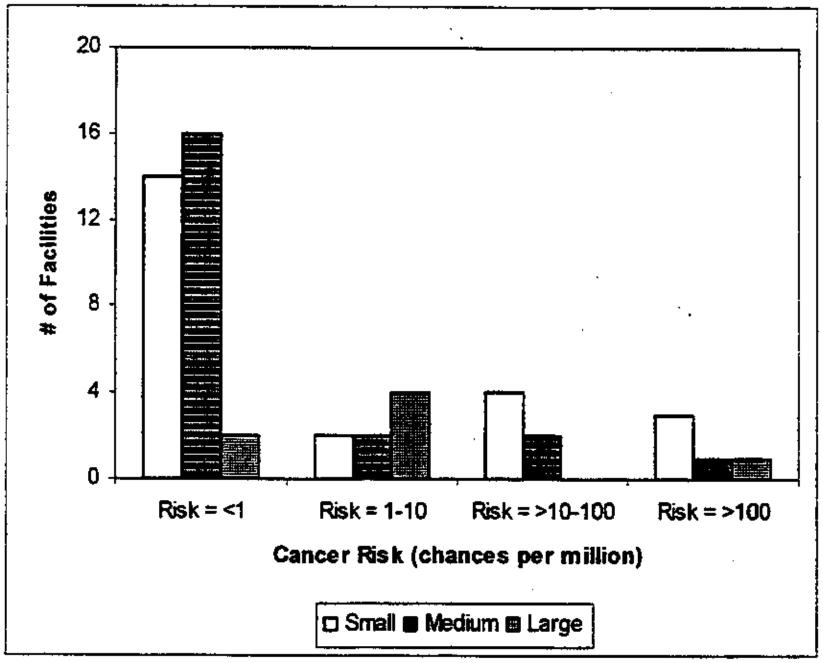
Table V-4 summarizes the maximum estimated cancer risks from hexavalent chromium emitted by small, medium, and large thermal spraying facilities. This table shows all thermal spraying facilities, including those that do not use materials containing chromium. Small facilities are those that reported an annual usage of 500 pounds or less of thermal spraying materials. Medium facilities reported an annual material usage of 500 to 5,000 pounds. Large facilities reported usage of more than 5,000 lbs/yr of thermal spraying materials.

Table V-4: Distribution of Maximum Cancer Risks from Thermal Spraying Hexavalent Chromium Emissions

Maximum Cancer Risk	**Number of Facilities**		
	Small (500 lbs/yr or less)	**Medium** (500 – 5,000 lbs/yr)	**Large** (>5,000 lbs/yr)
Risk = <1	14	16	2
Risk = 1-10	2	2	4
Risk = >10-100	4	2	0
Risk = >100	3	1	1
Totals:	**23**	**21**	**7**

Figure V-5 illustrates the distribution of maximum estimated cancer risks from thermal spraying hexavalent chromium emissions, based on facility size (i.e. the quantity of thermal spraying materials used annually.) This figure includes facilities that do not use materials containing chromium. The potential cancer risk ranges from less than one per million up to approximately 300 per million for most facilities, with one facility having a potential cancer risk of 2,800 per million. ARB is working with the SCAQMD to address the impacts from the facility with a potential cancer risk of 2,800 per million as soon as possible and prior to the adoption and implementation of the proposed ATCM. The SCAQMD has notified this facility that it is subject to the AB 2588 program requirements and must perform a health risk assessment. The facility will be conducting a source test to quantify their emissions for use in the health risk assessment.

Figure V-5: Maximum Estimated Cancer Risk from Hexavalent Chromium Based on Facility Size



Small - 500 lbs/yr or less; Medium - > 500 - 5000 lbs/yr; Large - > 5000 lbs/yr

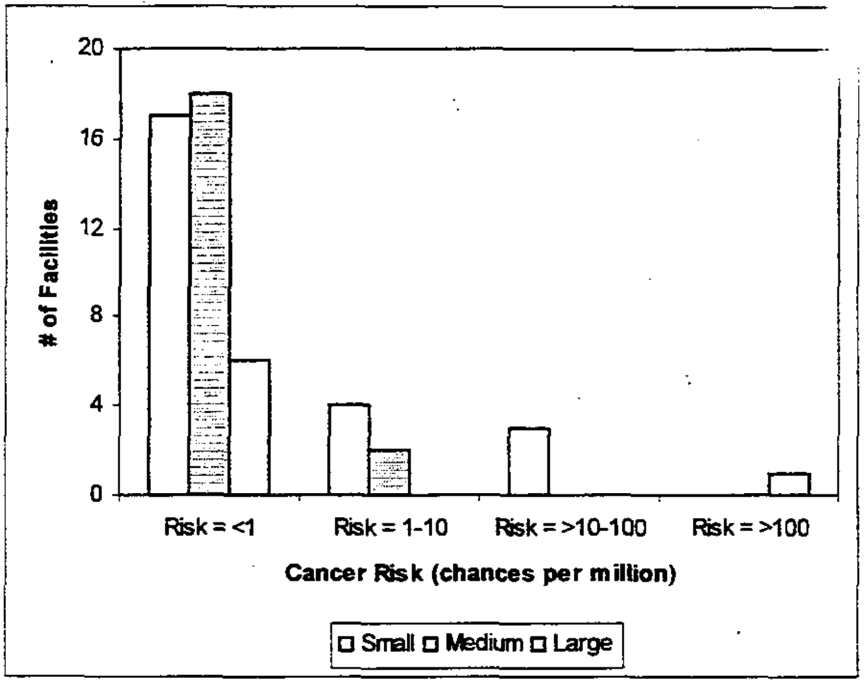
Table V-5 summarizes the maximum estimated cancer risks from nickel emitted by thermal spraying facilities. This table shows all thermal spraying facilities, including those that do not use materials containing nickel.

Table V-5: Distribution of Maximum Cancer Risks from Thermal Spraying Nickel Emissions

Maximum Cancer Risk	Number of Facilities		
	Small (500 lbs/yr or less)	**Medium** (500 – 5,000 lbs/yr)	**Large** (>5,000 lbs/yr)
Risk = <1	17	18	6
Risk = 1-10	4	2	0
Risk = >10-100	3	0	0
Risk = >100	0	0	1
Totals:	**24**	**20**	**7**

Figure V-6 illustrates the distribution of maximum estimated cancer risks from thermal spraying nickel emissions, based on facility size (i.e. the quantity of thermal spraying materials used annually). This figure shows all thermal spraying facilities, including those that do not use materials containing nickel.

Figure V-6: Maximum Estimated Cancer Risk from Nickel Based on Facility Size



Small - 500 lbs/yr or less; Medium - > 500 - 5000 lbs/yr; Large - > 5000 lbs/yr

V.E. NON-CANCER RISK ASSESSMENT

For the purposes of this risk assessment, we performed a multi-pathway risk assessment for non-cancer health impacts. The assessment included potential impacts from long-term (chronic) exposures and short-term (acute) exposures. Potential chronic and acute health impacts are expressed in terms of a hazard quotient (for a single substance) or a hazard index (for multiple substance.) Typically, a hazard quotient or hazard index that is greater than 1.0 is considered to be unacceptable.

Our chronic risk analysis was based on the assumption that both hexavalent chromium and nickel could be emitted simultaneously. The analysis indicated that long-term exposure to hexavalent chromium and nickel emissions from a small number of high-use thermal spraying facilities could result in a chronic hazard index greater than one. For long-term chronic health impacts, all but a few of the thermal spraying facilities in the State are expected to have hazard indices less than 1.0. The highest estimated hazard index for a specific thermal spraying facility was approximately two.

We also determined the minimum emission rates that would likely result in a potential chronic hazard index that does not exceed 1.0 for hexavalent chromium and nickel combined. For hexavalent chromium, the emission rates that would likely result in a chronic hazard quotient of up to 1.0 are much higher than the emission rates that would trigger the need for additional controls to protect against cancer risk. Therefore, the controls that would be required to protect against cancer impacts would keep emission rates well below the level that could result in chronic health impacts from either hexavalent chromium or nickel.

If nickel was the only pollutant being emitted, the emission rates that would likely result in a chronic hazard quotient of up to 1.0 are higher than the emission rates that would trigger the need for additional controls to protect against cancer risk. Therefore, the controls that would be required to protect against cancer impacts would keep emission rates below the level that could result in chronic health impacts.

The primary non-cancer health impacts from thermal spraying are potential acute impacts from short-term exposure to nickel. Our analysis indicated that hourly nickel emissions from thermal spraying facilities could result in a hazard quotient that is greater than 1.0. The peak hourly nickel emission rates that would likely result in a potential acute hazard quotient of up to 1.0 are lower than the annual average hourly emission levels that would likely result in a potential cancer risk of up to 10 in a million or chronic hazard quotient of 1.0. Therefore, it is possible to have a potential acute hazard quotient that is greater than 1.0, even though the potential cancer risk from nickel is less than 10 in a million. For that reason, the proposed ATCM would include an hourly emission limit for nickel to protect against acute health risks. This hourly limit is designed to ensure that the acute hazard quotient does not exceed 1.0. Hexavalent chromium does not have an established acute reference exposure level. Therefore, our evaluation for acute impacts only included nickel.

V.F. RISK REDUCTION TECHNIQUES

The health risks associated with thermal spraying are directly related to the emissions of hexavalent chromium and nickel. Therefore, limiting emissions of these pollutants will result in reduced health risks. A very high degree of emission reductions can be achieved by using add-on air pollution control equipment. Section III.D. describes some of the common control devices that are in use at thermal spraying facilities. Each facility would need to evaluate their particular operation to determine which type of control equipment would be most suitable. Our risk assessment indicates that all facilities that exceed defined thresholds must use some type of control device to protect public health. For a small facility that uses very small quantities of chromium-containing materials, a water curtain or high-efficiency dry filter may limit emissions to levels that result in very low risk. For a larger facility that uses chromium-containing materials on a regular basis, it may be necessary to install a HEPA filter system.

The risk assessment (as illustrated in Figures V-1 and V-2) shows that there are two situations which result in cancer risks of 10 in a million or less:

1. Limiting hexavalent chromium emissions to 0.01 lbs Cr^{+6}/yr (for point sources) and 0.004 lbs Cr^{+6}/yr (for volume sources); or
2. Locating thermal spraying facilities at least 1,640 feet (or 500 meters) from sensitive receptors and limiting hexavalent chromium emissions to 0.5 lb/yr.

Limiting emissions could be difficult for facilities that are not equipped with air pollution controls. For example, emissions of 0.01 lbs Cr^{+6}/yr could be generated at an uncontrolled facility by using approximately 5 lbs/yr of flame spraying powder (containing 30.7% by weight chromium).

Another alternative for emission reduction is a limitation on the quantity of chromium-containing materials used at a facility. If a facility keeps their usage low enough to remain below the threshold levels that would trigger a health risk, it may be possible to protect public health without having to install new controls or upgrade to HEPA filters. In some cases, it may be possible to use non-chromium thermal spraying materials as a replacement for chromium-containing products. However, existing aviation and military specifications may limit the amount of product replacement that can be achieved in the near term.

Cold spraying is another potential alternative for reducing the emissions of hexavalent chromium. In cold spraying, powder particles at or near room temperature are sprayed onto surfaces at velocities of 500 to 1500 meters/second, using a supersonic gas jet (Sandia, 2000). The high velocity causes the particles to flatten and bond with the substrate surface. Since the process occurs at room temperature, oxidation is minimized, which may prevent the formation of chromium oxides that contain the hexavalent form of chromium. Additional research is needed to quantify hexavalent chromium emissions from cold spraying. This technology is currently in the early stages of development, but it may be a suitable alternative for some industrial applications in the future.

V.G. STATEWIDE EMISSION AND RISK REDUCTION BENEFITS OF THE AIRBORNE TOXIC CONTROL MEASURE

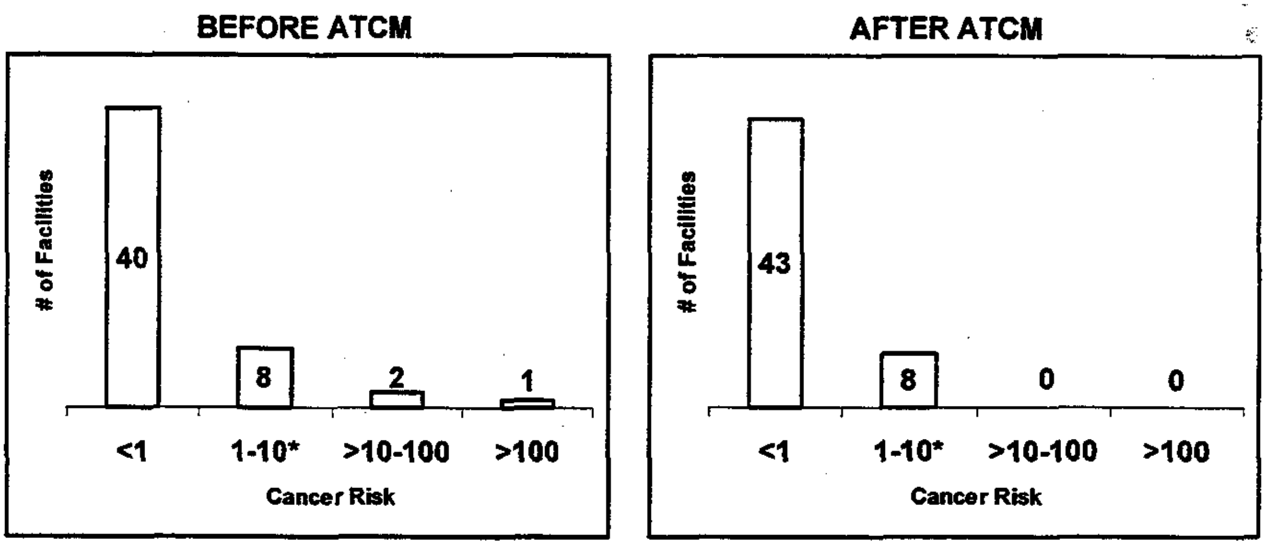
Estimated statewide emissions from thermal spraying range from 9.4 to 66 lbs/yr for hexavalent chromium and 105 to 740 lbs/yr for nickel. For a facility with no existing control devices, the proposed ATCM would require at least a 99% reduction in emissions. For the largest facility in the State, the proposed ATCM would require that the control device efficiency be increased from a minimum of 81% to at least 99.97%. Overall, the proposed ATCM is expected to reduce hexavalent chromium emissions by nearly 80 percent (7 to 50 lbs/yr) and nickel emissions by 51 percent (54 to 377 lbs/yr) from thermal spraying facilities.

The health risk assessment indicates that using small quantities of thermal spraying materials can cause near-source potential cancer risks that exceed 10 in a million. Hence, the proposed ATCM would eliminate a significant near-source cancer risk from facilities that currently use chromium- or nickel-containing thermal spraying materials and are not equipped with the best available control technology.

Figure V-7 illustrates the distribution of estimated cancer risks, before and after implementation of the ATCM. This chart represents the potential cancer risks at the nearest sensitive receptor. However, the proposed ATCM is designed to ensure that potential cancer risks remain below 10 in a million, regardless of where a receptor may be located.

Figure V-7 includes all 51 thermal spraying facilities in California, including the fourteen facilities that don't use chromium or nickel. For 40 of the 51 facilities, our analysis indicated that hexavalent chromium and nickel emissions would likely result in potential cancer risks of less than 1 per million, prior to implementation of the ATCM. The proposed ATCM will require the three facilities that exceed 10 in a million to install control devices or eliminate their thermal spraying operations that use chromium. After implementation of the ATCM, 43 of the 51 facilities are expected to have potential cancer risks of less than 1 per million and the remaining facilities are expected to have potential cancer risks that do not exceed 3 per million.

Figure V-7: Estimated Cancer Risk from Hexavalent Chromium and Nickel, Before and After ATCM Implementation



* The maximum cancer risk in the "1-10" range is 3 in a million.

In addition to the risk reduction benefits for potential receptors, we expect a reduction in overall ambient levels of hexavalent chromium and nickel. By reducing ambient levels of hexavalent chromium and nickel, overall statewide risk reduction benefits will be achieved.

V.H. WORKPLACE EXPOSURE

Hexavalent chromium and nickel are human carcinogens. As such, the California Department of Industrial Relations, Division of Occupational Safety and Health Administration (Cal/OSHA) regulates these compounds in the workplace environment. To protect worker safety, Cal/OSHA has established permissible exposure limits (PEL) for these compounds. The PEL is the maximum, eight-hour, time-weighted average concentration for occupational exposure and is 0.01 mg/m^3 for hexavalent chromium and 0.1 mg/m^3 for nickel (CCR, 2002.) Since the proposed ATCM will require ventilation systems for certain uncontrolled facilities, worker exposure to hexavalent chromium and nickel from the use of these products will be reduced.

REFERENCES

CAPCOA, 1993. California Air Pollution Control Officer's Association (CAPCOA). "Air Toxics Hot Spots Program Revised 1992 Risk Assessment Guidelines". October 1993.

CCR, 2002. California Code of Regulations, Title 8, Division 1, Chapter 4, Subchapter 7, Group 16, Article 107, Section 5155, Airborne Contaminants, Table AC-1. 2002.

OEHHA, 1999. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots. Program Risk Assessment Guidelines, Part I, The Determination of Acute Reference Exposure Levels for Airborne Toxicants". March 1999.

OEHHA, 2000. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Assessment and Stochastic Analysis". September 2000.

OEHHA, 2002. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II, Technical Support Document for Describing Available Cancer Potency Factors". December 2002.

OEHHA, 2003. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots Program Risk Assessment Guidelines, the Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments". August 2003.

Sandia, 2000. "Materials Researchers Bring Russian Cold Spray Technology to Sandia". Sandia Technology, Volume 2, No. 4. Winter 2000-2001.

VI. PROPOSED AIRBORNE TOXIC CONTROL MEASURE AND ALTERNATIVES

In this chapter, staff provides a "plain English" discussion of key requirements of the proposed ATCM to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying. This chapter begins with a general summary of the proposed ATCM, and then discusses and explains each major requirement.

VI.A. SUMMARY OF THE PROPOSED AIRBORNE TOXIC CONTROL MEASURE

The text of the proposed ATCM can be found in Appendix A to this staff report. The proposed ATCM only applies to thermal spraying operations in California that use products containing chromium, chromium compounds, nickel, or nickel compounds. The regulation will reduce hexavalent chromium and nickel emissions from thermal spraying operations at stationary sources, but it does not prohibit the use of thermal spraying materials containing chromium, chromium compounds, nickel or nickel compounds. Reducing emissions of hexavalent chromium and nickel is accomplished by requiring air pollution control systems.

For existing thermal spraying operations, defined as those in existence before January 1, 2005, the level of control efficiency required by the proposed ATCM varies, depending on the type of thermal spraying operation (point or volume source) and the thermal spraying operation's total emissions of hexavalent chromium and nickel from thermal spraying activities. Control efficiency requirements increase in stringency as the emissions quantity increases.

Modified thermal spraying operations (those modified on or after January 1, 2005) must install a HEPA filter or equivalent control device. New thermal spraying operations (those not in existence until on or after January 1, 2005) must install a HEPA filter or equivalent control device. In addition, new thermal spraying operations cannot operate in, or within 500 feet of, the boundary of a residential or mixed use zone. New thermal spraying operations must also undergo a site-specific analysis to ensure adequate protection of public health.

The proposed ATCM establishes requirements for new and modified thermal spraying operations that are more stringent than the requirements for existing thermal spraying operations. January 1, 2005, is the cutoff date in the proposed ATCM for distinguishing between existing operations, and new and modified operations. For example, a thermal spraying operation is considered "new" if it begins initial operations on or after January 1, 2005. A thermal spraying operation is considered "modified" if it undergoes a physical modification on or after January 1, 2005, that requires an application for an authority to construct and/or a permit to operate. We are proposing this cutoff date for two reasons. First, we want to minimize the potential for existing thermal spraying operations to modify their operations prior to the ATCM's effective date in order to avoid the more stringent requirements for modified operations. Secondly, we want to minimize the potential that companies considering construction of a new thermal spraying operation will begin initial operations before the ATCM's effective date in order to avoid the more stringent requirements that apply to new operations. The January 1, 2005, cutoff date will also provide such companies adequate notice of the ATCM requirements before they undertake the expense of construction.

In addition, we would like to clarify that the proposed ATCM does not impose retroactive requirements on thermal spraying operations. California law is quite clear that the proposed ATCM cannot become legally effective until it is adopted by the ARB and is approved by the Office of Administrative Law (OAL). Since it is very unlikely that both the ARB and OAL will approve the ATCM before January 1, 2005, this date should be viewed as the demarcation line between existing thermal spraying operations, and new and modified thermal spraying operations, that will apply once the ATCM becomes legally effective (and is enforced by the local air districts as provided in Health and Safety Code section 39666(d)). Until then, thermal spraying operations are not required to comply with any requirement specified in the ATCM, unless a local district independently imposes the same or similar requirement pursuant to its own local rules or permitting authority.

For example, section (c)(3)(A)1. of the ATCM requires that upon initial startup a new thermal spraying operation must install a HEPA filter or equivalent control device. However, a new thermal spraying operation could begin operations in January 2005 without a HEPA filter if the ATCM had not yet been approved by OAL (assuming that the local district did not independently impose such a requirement). And the thermal spraying operation could continue operating without a HEPA filter (again assuming that the local district did not independently require it) until such time as the ATCM is approved by OAL and the local district begins enforcing this requirement under section 39666(d). When this happens, the thermal spraying operation must have a HEPA filter (or equivalent control device) in place and operating as specified in the ATCM.

Following is a more detailed discussion of the provisions of the proposed ATCM.

1. Applicability

The proposed ATCM applies to thermal spraying operations at stationary sources that use materials containing chromium, chromium compounds, nickel, or nickel compounds. The proposed ATCM does not apply to portable thermal spraying operations (i.e., temporary offsite field applications that do not remain in one place for more than 30 consecutive days.)

2. Exemption

There is one exemption allowed in the proposed ATCM. The exemption is for thermal spraying operations with low emissions. An existing thermal spraying operation that is a point source is not subject to the control efficiency requirements if it meets all of the following criteria: annual hexavalent chromium emissions are less than 0.004 pound; annual nickel emissions are less than 2.1 pounds; and maximum hourly nickel emissions do not exceed 0.1 pound. There are also no additional requirements for enclosure or ventilation. However, the owner or operator of the thermal spraying operation must still comply with the permitting, monitoring, and recordkeeping requirements of the proposed ATCM. The owner or operator of the thermal spraying operation must also provide the permitting agency an annual report quantifying their emissions of hexavalent chromium and nickel.

An existing thermal spraying operation that is a volume source is not subject to the control efficiency requirements, if it meets all of the following criteria: annual hexavalent chromium emissions are less than 0.001 pound; annual nickel emissions are less than 0.3 pound; and maximum hourly nickel emissions do not exceed 0.01 pound. There are also no additional requirements for enclosure or ventilation. However, the owner or operator of the thermal spraying operation must still comply with the permitting, monitoring, and recordkeeping requirements of the proposed ATCM. The owner or operator of the thermal spraying operation must also provide the permitting agency an annual report quantifying their emissions of hexavalent chromium and nickel.

The criteria for exempt thermal spraying operations is designed to ensure that the potential health risks are kept at low levels. The criteria are designed to ensure that potential cancer risks do not exceed 10 in a million, as well as ensuring that the chronic hazard index and acute hazard quotient do not exceed one.

3. Definitions

The definitions listed in subsection (b) of the proposed ATCM were taken from prior ARB rulemakings, local air districts' regulatory language, and thermal spraying industry documents. Please refer to subsection (b) of the proposed ATCM for a list of definitions.

4. Standards

Effective January 1, 2006, all existing thermal spraying operations must control emissions of hexavalent chromium and nickel as described in the proposed ATCM. For existing thermal spraying operations, the amount of hexavalent chromium and nickel emitted will determine what level of control is required under the proposed ATCM.

To determine if a thermal spraying operation's emissions of hexavalent chromium and nickel trigger control requirements under the proposed ATCM, it is necessary to first determine the type of source. A thermal spraying operation can be either a point source or a volume source. If the thermal spraying operation's emissions come through a stack, chimney, or vent, it is considered a point source and must comply with the control efficiency requirements for point sources. If the thermal spraying operation's emissions are released inside a building prior to being released to the outside, are released through a horizontal stack (e.g., the side of a building), or are released directly to the outside, it is considered a volume source and must comply with the control efficiency requirements for volume sources. Remotely located thermal spraying operations may qualify for a 90 percent control efficiency requirement.

5. Hourly Emissions Limits for Nickel

The proposed ATCM limits the maximum hourly emissions of nickel to 0.1 pound for point sources and 0.01 pound for volume sources. Emissions are determined using the methodology in Appendix 1 of the proposed ATCM, or may be based on the results of an emissions source test approved by the permitting agency. The hourly nickel emissions limit is designed to protect against acute health impacts and ensure that the potential acute hazard quotient does not exceed one.

6. Control Efficiency Requirements

a) Existing Thermal Spraying Operations: The proposed ATCM establishes control efficiency requirements for existing thermal spraying operations. Three tiers of requirements, increasing in stringency from Tier 1 to Tier 3, are established for point and volume sources, based on the annual emissions of hexavalent chromium and nickel from all thermal spraying operations. These control efficiency requirements are designed to ensure that the maximum potential cancer risk is less than 10 in a million. For thermal spraying operations with a permit, annual emissions are calculated based on their potential to emit as specified in the permit and the emission calculation methods in Appendix 1 of the proposed ATCM. Permitted thermal spraying operations may also base their emissions on the results of an emissions source test that is approved by the permitting agency. For thermal spraying operations without a permit, emissions can be determined by using the emission calculation methods described in Appendix 1 of the proposed ATCM or may be based on the results of an emissions source test approved by the permitting agency. This emissions information would then be used to establish permit limits for the thermal spraying operation.

After a thermal spraying operation calculates its emissions, the control efficiency requirement can be determined. The control efficiency requirements for point sources and volume sources are shown in Tables VI-1 and VI-2, respectively. These tables appear as Tables 1 and 2 in subsection (c)(1) of the proposed ATCM. It is possible that the emissions from the thermal spraying operation may be used to establish that no additional air pollution control system requirements are necessary (i.e., if the point or volume source has emissions that are less than the minimum emissions specified in the tables).

Table VI-1: Point Sources -
Control Efficiency Requirements for Existing Thermal Spraying Operations

Tier	Annual Hexavalent Chromium Emissions from Thermal Spraying	Annual Nickel Emissions from Thermal Spraying	Minimum Control Efficiency Requirements
1	≥ 0.004 lbs/yr and ≤ 0.04 lbs/yr	≥ 2.1 lbs/yr and ≤ 20.8 lbs/yr	90% by weight (e.g., a water curtain)
2	> 0.04 lbs/yr and ≤ 0.4 lbs/yr	> 20.8 lbs/yr and ≤ 208 lbs/yr	99.999% @ 0.5 microns (e.g., a high-efficiency dry filter)
3	> 0.4 lbs/yr	> 208 lbs/yr	99.97% @ 0.3 microns (e.g., a HEPA filter)

Table VI-2: Volume Sources -
Control Efficiency Requirements for Existing Thermal Spraying Operations

Tier	Annual Hexavalent Chromium Emissions from Thermal Spraying	Annual Nickel Emissions from Thermal Spraying	Minimum Control Efficiency Requirements
1	≥ 0.001 lbs/yr and ≤ 0.01 lbs/yr	≥ 0.3 lbs/yr and ≤ 3.1 lbs/yr	99% by weight (e.g., a dry filter)
2	> 0.01 lbs/yr and ≤ 0.1 lbs/yr	> 3.1 lbs/yr and ≤ 31 lbs/yr	99.999% @ 0.5 microns (e.g., a high-efficiency dry filter)
3	> 0.1 lbs/yr	> 31 lbs/yr	99.97% @ 0.3 microns (e.g., a HEPA filter)

Please note that the emissions from all thermal spraying activities at a thermal spraying operation must be considered when determining the total emissions for the thermal spraying operation, and the most stringent Tier applies. For example, if a thermal spraying operation emits 3 lbs/yr of nickel (Tier 1) and 0.5 lbs/yr of hexavalent chromium (Tier 3), the thermal spraying operation would have to comply with the more stringent Tier 3 requirements. The tiers are designed to ensure that potential cancer risks do not exceed 10 in a million at the point of maximum impact which provides public health protection for all potential receptors, regardless of location.

All existing thermal spraying operations subject to Tier 1, Tier 2, or Tier 3 control efficiency requirements are also subject to the enclosure and ventilation requirements of the proposed ATCM (see subsection (c)(1)(B) and (c)(1)(C) of the proposed ATCM). All existing thermal spraying operations must meet the requirements for control device, enclosure, and ventilation systems by January 1, 2006, and new or modified thermal spraying operations must meet these same requirements upon initial startup.

b) Remotely Located Existing Thermal Spraying Operations: Some existing thermal spraying operations may be able to comply with the proposed ATCM without installing additional controls, if they are remotely located and have low emissions. An existing thermal spraying operation may qualify for a less stringent 90 percent control efficiency requirement if it is located at least 1,640 feet (or 500 meters) from the nearest sensitive receptor and emits no more than 0.5 pound per year of hexavalent chromium. Qualifying for this standard is contingent upon the thermal spraying operation's submission of a permit application and annual reports of hexavalent chromium and nickel emissions. In addition, before the standard is approved, a site-specific analysis of public health impacts must be conducted by the permitting agency. The permitting agency will verify annually that the thermal spraying operation continues to meet the requirements for this standard.

c) Modified Thermal Spraying Operations: Thermal spraying operations that will emit hexavalent chromium or nickel and who modify operations on or after January 1, 2005, must install a HEPA filter (or equivalent control device).

d) New Thermal Spraying Operations: Thermal spraying operations that will emit hexavalent chromium or nickel and who begin operations on or after January 1, 2005, can not operate in, or within 500 feet of, the boundary of a residential or mixed use zone. In addition, new thermal spraying operations must install a HEPA filter (or equivalent control device) and are required to undergo a site-specific analysis to ensure adequate protection of public health.

7. Enclosures and Ventilation

Those thermal spraying operations required to comply with Tier 1, Tier 2, or Tier 3 requirements for control efficiency are also required to meet the proposed ATCM standards for enclosures and ventilation. The requirements for enclosures and ventilation are the same for new, modified, and existing thermal spraying operations. Existing thermal spraying operations must meet enclosure and ventilation requirements by January 1, 2006, and new or modified thermal spraying operations must meet enclosure and ventilation requirements upon initial startup.

All enclosures must have an exhaust and be ventilated with continuous air flowing at either a minimum velocity of 100 feet per minute or the minimum velocity as defined for metal spraying facilities in "Industrial Ventilation, A Manual of Recommended Practice." Any openings other than make-up air vents must be covered, and a minimum of three air exchanges must occur after thermal spraying ceases and before the enclosure is opened. Material collected by the control system must be discharged into a completely sealed closed container or enclosed system.

8. Test Requirements and Test Methods

a) Testing of Enclosure and Ventilation Systems: Thermal spraying operations must conduct testing to ensure compliance with enclosure and ventilation standards for all new and modified thermal spraying operations and all existing thermal spraying operations that are subject to Tier 1, Tier 2, or Tier 3 requirements in the proposed ATCM. The air velocity (or "inward face velocity") must be measured at least every 30 days with a velocity measuring device approved by the permitting agency. Appendix 2 of the proposed ATCM describes these velocity measuring devices and defines the areas where measurements are to be made. Thermal spraying operations must also conduct a visual leak inspection test, as described in Appendix 3 of the proposed ATCM, at least every 90 days.

For existing thermal spraying operations, testing of the enclosure or ventilation system must take place no later than 60 days after the date the permitting agency enforces the proposed ATCM. For new or modified thermal spraying operations, testing of the enclosure or ventilation system must be conducted no later than 60 days after initial startup. The owner or operator must inform the permitting agency at least 30 days prior to conducting testing on enclosure and ventilation systems.

b) Verifying Control Efficiency: All new and modified and all existing thermal spraying operations subject to Tier 2 or Tier 3 control efficiency requirements must use control devices with the control efficiency verified by the manufacturer. There are four test methods listed in subsection (d)(2)(A) through (d)(2)(D) of the proposed ATCM, which are acceptable for use by the manufacturer. Existing thermal spraying operations subject to Tier 1 control efficiency requirements do not need manufacturer verification of control efficiency.

c) Source Testing to Determine Emissions of Hexavalent Chromium and Nickel: Source testing is not required by the proposed ATCM, however, permitting agencies may require that a source test be performed. The owner/operator of the thermal spraying operation may choose to have a source test conducted if they do not wish to use the emissions calculation methods described in Appendix 1 of the proposed ATCM. All source tests must be conducted by an independent tester, and the test protocol must be approved by the permitting agency. A source test conducted prior to January 1, 2006, may be used with permission of the permitting agency. Test methods to determine emissions of hexavalent chromium and nickel are in subsection (d)(3)(B)1. and subsection (d)(3)(B)2. of the proposed ATCM, respectively. In addition to the test methods set forth in the proposed ATCM, the permitting agency may approve alternative test methods. The owner or operator must use an independent tester to conduct the source test and a pre-test protocol must be submitted to the permitting agency at least 60 days prior to the source test. The requirements for the pre-test protocol are in subsection (d)(3)(C) of the proposed ATCM.

9. Monitoring, Inspection, Maintenance and Recordkeeping Requirements

a) Dry Particulate Filter Systems (e.g. HEPA Filter and Dry Filter Cartridge): While conducting thermal spraying, a pressure differential gauge must continually monitor pressure drop across the control device, and this pressure drop must be recorded once per work shift.

If at any time the pressure drop on a dry particulate filter system is outside of the acceptable limits, the owner or operator must immediately shut down the thermal spraying operation and take corrective action to get the pressure drop within the specified limit(s). The requirements for pressure drop gauges and their operation are in subsection (e)(2) of the proposed ATCM.

The control device, filter media, and ductwork from the work area to the control device needs to be visually inspected to ensure there are no leaks, and the filter replaced per the manufacturer's recommendations or the permitting agency's requirements. Appendix 3 of the proposed ATCM provides a checklist for conducting and recording visual inspections. The inward face velocity at each opening must be measured and recorded, as defined in Appendix 2 of the proposed ATCM, at least once every 30 days.

b) Conventional Water Curtain: While conducting thermal spraying, a flow meter must continuously monitor the flow rate of the water. Water curtain booths must provide a continuous sheet of water down the rear wall of the booth, without any gaps or dry spots, and the water curtain must be visually inspected to ensure there are no gaps. The water flow rate and results of the visual inspection of the water curtain must be recorded once per week.

At least once every 90 days, a visual inspection of the ductwork, from the booth to the exhaust stack, must be conducted and the results recorded. A Leak Check Visual Inspection Checklist, found in Appendix 3 of the proposed ATCM, includes the minimum requirements for conducting a leak check. Additional requirements specified by the manufacturer, if any, must be added to this checklist. The inward face velocity at each opening must be measured and recorded, as defined in Appendix 2 of the proposed ATCM, at least once every 30 days.

c) Pumpless Water Curtain: While conducting thermal spraying, monitoring of booth performance according to manufacturer's recommendations must be conducted. Water curtain booths must provide a continuous sheet of water down the rear wall of the booth, without any gaps or dry spots, and the water curtain must be visually inspected to ensure there are no gaps. Results of the monitoring and visual inspection of the water curtain must be recorded once per week.

At least once every 90 days, a visual inspection of the ductwork, from the booth to the exhaust stack, must be conducted and the results recorded. A Leak Check Visual Inspection Checklist, found in Appendix 3 of the proposed ATCM, includes the minimum requirements for conducting a leak check. Additional requirements specified by the manufacturer, if any, must be added to this checklist. The inward face velocity at each opening must be measured and recorded, as defined in Appendix 2 of the proposed ATCM, at least once every 30 days.

d) Recordkeeping: In addition to keeping records specific to the type of air pollution control system used by the thermal spraying operation such as the visual inspections, filter changes, flow rate, and inward face velocity described above, the owner/operator must keep records on all maintenance performed and any repairs made. A monthly record, with annual usage to date, must also be kept for thermal spraying materials used that contain chromium, chromium compounds, nickel, or nickel compounds. Source test records and records detailing malfunctions or failure of equipment, and the action taken to correct the malfunction or failure must be maintained. All records must be kept at the thermal spraying operation and readily accessible for review for a period of at least five years. The requirement to retain records for five years is consistent with existing permitting agency practices.

10. Reporting Requirements

a) Initial Reporting for All Existing Thermal Spraying Operations: The owners or operators of all thermal spraying operations in existence before January 1, 2005, whether or not the thermal spraying operation has a permit and regardless of their location, must submit an emission inventory for hexavalent chromium and nickel to the permitting agency no later than October 1, 2005. The emission inventory is necessary to determine the applicable control efficiency requirement.

b) Modification of Thermal Spraying Operation: Existing thermal spraying operations that were not initially using hexavalent chromium,

chromium compounds, nickel, or nickel compounds but begin using these materials on or after January 1, 2005, shall notify the permitting agency at least 45 days prior to use of these materials.

c) Remotely Located and Low Emitting Existing Thermal Spraying Operations: Those thermal spraying operations that have been determined by the permitting agency to be subject to the standard for remotely located thermal spraying operations under subsection (c)(1)(E) or are exempt from the air pollution control system requirements of the ATCM under subsection (c)(1)(F) must provide the permitting agency with an annual report quantifying their emissions of hexavalent chromium and nickel. This report is necessary to verify that these thermal spraying operations still qualify for the less stringent standard or the exemption.

d) Reports of Malfunction: The operator or owner of a thermal spraying operation that experiences an equipment breakdown, malfunction or failure must report these incidences to the permitting agency as required. This requirement is consistent with existing permitting agency practices.

e) Source Tests: The owner or operator of the thermal spraying operation must notify the permitting agency at least 60 days before a source test to measure emissions of hexavalent chromium or nickel is performed, and must provide the permitting agency the results of the test no more than 60 days after the test is conducted. The permitting agency may allow changes to the due dates and content of reports at its discretion, as long as the same information is provided and the changes will not reduce the overall frequency of reporting.

11. Severability

This provision ensures that if any part of the proposed ATCM is found to be invalid, the remaining parts of the proposed ATCM will still be in effect.

VI.B. BASIS FOR THE PROPOSED AIRBORNE TOXIC CONTROL MEASURE

The proposed ATCM is based on our evaluation of BACT for reducing hexavalent chromium and nickel emissions from thermal spraying operations, in consideration of health risk and cost. In evaluating BACT, we analyzed information from ARB's 2003 thermal spraying material manufacturer survey and ARB's 2004 thermal spraying facility survey. Based on this information and discussions with air districts, industry and control equipment manufacturers, we determined that suitable control devices are readily available and widely used. Further, the application of BACT, as proposed by staff, will result in potential cancer risk levels being reduced to less than three in a million for the nearest sensitive receptor. In addition, the application of BACT will ensure that the chronic hazard index and acute hazard quotient do not exceed one.

VI.C. ALTERNATIVES TO THE PROPOSED AIRBORNE TOXIC CONTROL MEASURE

California Government Code section 11346.2 requires the ARB to consider and evaluate reasonable alternatives to the proposed ATCM and to provide reasons for rejecting these alternatives. This section discusses the alternatives evaluated and provides the reasons they were not chosen. Staff considered the following alternatives to the proposed ATCM: no action and require HEPA filters (the most effective control system) for all thermal spraying operations using chromium, chromium compounds, nickel or nickel compounds.

We evaluated each of the alternatives and determined that the alternatives did not meet the objective of HSC section 39666 to reduce emissions to the lowest level achievable through the application of BACT, or a more effective control method, in consideration of cost, health risk, and environmental impacts.

1. No Action

The "no action" alternative would not address the public health risk posed by hexavalent chromium and nickel emissions from thermal spraying operations. Since hexavalent chromium is a potent human carcinogen, and short-term exposure to nickel emissions can result in acute health effects, this alternative would not be protective of public health.

2. Require All Thermal Spraying Operations to Install HEPA Filters

Another alternative to the proposed ATCM would require that all chromium or nickel containing thermal spraying materials be applied inside an enclosed booth that is equipped with a HEPA filter (or equivalent control device).

It is not uncommon for large thermal spraying operations to have a booth and control device, but smaller thermal spraying operations (e.g., machine shops) do not generally have booths in which to conduct their thermal spraying operations. Requiring the installation of booths and control devices at thermal spraying operations with very low emissions and low risk would impose a significant cost burden on these operations.

In addition to capital costs, these businesses would incur ongoing labor, maintenance, utility and repair costs. Operators would also be required to check and record pressure drop across the filter, perform or schedule filter replacement and booth maintenance, and quantify the thermal spraying materials usage inside the spray booth.

State law requires control measures for TACs to be based on BACT, or a more effective control method, in consideration of cost and health risk. While this alternative would be slightly more effective in reducing health risk, the cost to industry would be nearly three times the cost of the proposed ATCM. The proposed ATCM will be health protective because it will reduce the potential cancer risk from thermal spraying to less than three potential cancer cases per million for the nearest sensitive receptor. It will also ensure that the chronic hazard index and acute hazard quotient do not exceed one. Therefore, we decided not to choose this alternative.

VII. ECONOMIC IMPACTS OF PROPOSED AIRBORNE TOXIC CONTROL MEASURE

In this chapter, ARB staff presents the estimated costs and economic impacts associated with implementation of the proposed airborne toxic control measure (ATCM) for thermal spraying operations. The expected initial capital costs and annual recurring costs for potential compliance options are discussed. The costs and associated economic impacts are given for private companies and governmental agencies.

VII.A. SUMMARY OF THE ECONOMIC IMPACTS

Overall, the proposed ATCM is not expected to have a significant adverse impact on the profitability of operators of thermal spraying facilities in California. Profitability impacts were estimated by calculating the decline in the return on owner's equity (ROE). A decline in ROE of 10 percent or more indicates a significant adverse impact. The proposed ATCM is expected to result in an ROE decline of less than five percent for most businesses impacted, which is not considered to be a significant impact on the profitability of affected businesses. One thermal spraying facility may experience a significant adverse economic impact, as discussed below in Section VII.B. The primary customers of thermal spraying facilities are other businesses in the aerospace, petrochemical, paper/printing and electronics industries. These businesses sell their products or services to consumers. Thermal spraying customers may absorb any increased costs in thermal spraying or pass some or all of the cost increase on to the consumers. We expect any increased cost to consumers to be negligible because of the small impact on the affected facilities as shown by the decline in ROE.

Overall, we expect the proposed ATCM to have no significant impact on employment; business creation, elimination or expansion; or business competitiveness in California. We also expect no significant adverse fiscal impacts on any local or State agencies.

Of the 37 facilities affected by the proposed ATCM, only six would be required to expend significant capital to meet the requirements of the proposed ATCM. Some of these operators may have difficulty securing the required capital to finance the control device upgrades required by the proposed ATCM. Four of these facilities may stop using chromium and nickel in their thermal spraying operations or cease their thermal spraying operations altogether, because it is a minor part of their overall gross revenue and less than an hour per day is spent on thermal spraying. If this occurs, four employees could be affected adversely, but these businesses are expected to retain these employees to perform other duties.

We expect the two remaining facilities to install new control devices. One of these facilities may incur a significant adverse cost impact. This facility is a large dedicated thermal spraying operation that poses the greatest public health risk. This facility has a gross annual revenue of about $10 million. The annual cost of compliance with the proposed ATCM would be about 0.6 to 1.7 percent of their gross annual revenue depending on the number of spray booths they choose to upgrade.

We estimate the total cost of the proposed ATCM to affected businesses to range from approximately $672,000 to $1,195,000 in initial capital and permitting costs and $55,000 to $94,000 in annual recurring costs. This corresponds to a total annualized cost of $150,000 to $257,000 over the useful life of the control equipment. This cost represents the capital cost of equipment, annualized over its useful life, plus the permitting and annual recurring costs in 2004 dollars. The annual cost for facilities that would not be required to install additional controls ranges from $600 to $850 per facility. The annual cost for facilities that would be required to install additional controls ranges from about $5,000 to $55,000 per facility.

One public agency, the Eastern Municipal Water District in Riverside County, would be minimally impacted. The public agency would need to conduct monitoring, recordkeeping, and reporting. The annual cost to the public agency is estimated to be $600.

VII.B. ECONOMIC IMPACT ANALYSIS AS REQUIRED BY THE ADMINISTRATIVE PROCEDURE ACT

1. Legal Requirements

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California's jobs, business expansion, elimination or creation, and the ability of California businesses to compete with businesses in other states.

In addition, State agencies are required to estimate the cost or savings to any State or local agency and school district in accordance with instructions adopted by the Department of Finance. The estimate shall include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the State.

Health and Safety Code section 57005 requires the ARB to perform an economic impact analysis of submitted alternatives to a proposed regulation before adopting any major regulation. The proposed ATCM is not considered to be a "major regulation", because the estimated cost to California business enterprises does not exceed 10 million dollars in any single year.

2. Affected Businesses

Any business operating a thermal spraying device that uses materials containing chromium, chromium compounds, nickel, or nickel compounds would be affected by the proposed ATCM. Also potentially affected are businesses that are customers of thermal spraying facilities, such as the aerospace and electronics industries. The focus of this analysis, however, will be on thermal spraying facilities because these businesses would be directly affected by the proposed ATCM.

The affected businesses fall under a number of Standard Industrial Classification (SIC) and North American Industry Classification System (NAICS) codes. A list of these codes is provided in Table VII-1.

Table VII-1: List of Industries with Affected Facilities

SIC Code	NAICS Code	Description
2851	32551	Paints and Allied Products
3471	332813	Plating and Polishing
3479	333812	Metal Coating and Allied Services *
3599	333999	Industrial Machinery And Equipment, NEC *
3679	334419	Electronic Components, NEC
3721	336411	Aircraft Manufacturing
4581	488119	Airports, Flying Fields, and Services
7349	56179	Building Maintenance Services, NEC
7694	335312	Armature Rewinding Shops Repair *
7699	81131	Repair Services, NEC *

* A total of six facilities in these categories are expected to need control device upgrades to comply with the proposed ATCM. The cost to install and operate controls may result in a significant economic impact for these facilities.

3. Potential Impacts on Profitability for Affected Businesses

The approach used in evaluating the potential economic impact of the proposed ATCM on California businesses is as follows:

- All affected facilities are identified from responses to the ARB's 2004 Thermal Spraying Facility Survey (ARB, 2004c.) Standard Industrial Classification (SIC) codes associated with these businesses are listed in Table VII-1 above.
- Dun and Bradstreet 2002-2003 financial data and net profit data are identified for typical businesses in each affected industry (Dun, 2003).
- The annual cost of compliance is estimated for the businesses that are affected by the proposed ATCM.
- The annual cost of compliance for each business is adjusted for both federal and state taxes.
- These adjusted business costs are subtracted from net profit data (Dun and Bradstreet) and the results are used to recalculate the ROE.
- The resulting ROE is then compared with the ROE before the subtraction of the adjusted fees to determine the impact on the profitability of the businesses. A reduction of more than 10 percent in profitability is considered

to indicate a potential for significant adverse economic impacts. This threshold is consistent with the thresholds used by the U.S. EPA and the ARB in previous regulations.

California businesses are affected by the proposed ATCM to the extent that the implementation of the regulation reduces their profitability. Using ROE to measure profitability, we estimate the decline in ROE for most affected businesses would be less than five percent based on 2002-3 financial data. This does not represent a noticeable decline in the profitability of most affected businesses. However, for the six businesses that would be required to install HEPA filters, dry filters, or water curtains the estimated decline in profitability ranges from 16 to 68 percent. Four of these businesses are expected to cease thermal spraying instead of installing control devices because it provides a small fraction of their revenue.

One of the two remaining businesses required to install control devices could incur a significant adverse cost impact. This business could experience a decline in profitability of 68 percent if they installed one HEPA system for three spray booths to comply with the ATCM. Based on information provided by the facility, we believe that one HEPA system for three spray booths would be sufficient to accommodate the quantities of chromium- and nickel-based materials being used at the facility. However, if the business chose to install three HEPA systems for nine spray booths, the estimated decline in profitability is 202 percent. This business poses the greatest health risk of all the thermal spraying facilities in California. The other remaining business which does small amounts of thermal spraying, indicated it would pass the cost of controls on to its customers to minimize the cost impacts. However, the overall cost impact on its customers is not expected to be significant.

The remaining 31 businesses are required to obtain or modify permits, conduct monitoring, and maintain records. The decline in profitability for these businesses ranged from 0.1 to 4.6 percent. This magnitude of change in profitability is not considered to be significant.

4. Assumptions for Business Profitability Analysis

The business profitability ROE calculations were based on the following assumptions.

- All affected businesses are subject to federal and State tax rates of 35 percent and 9.3 percent, respectively.
- Affected businesses absorb the costs of the proposed ATCM instead of increasing the prices of their products or lowering their costs of doing business through cost-cutting measures.

5. Potential Economic Impacts for Individual Thermal Spraying Facilities

We have identified 37 thermal spraying facilities in California that use materials containing chromium or nickel. Thirty-four are businesses, two are federal government facilities, and one is a local government facility. The two federal facilities are the U.S. Naval Aviation Depot and the 32nd Street Naval Station, both in the San Diego area. The local government facility is the Eastern Municipal Water District in Riverside County. Twenty-six of the 34 affected businesses are small businesses (<100 employees). Twenty-four facilities already meet the best available control technology (BACT) requirements, and would only need to obtain or modify their permit, report their emissions, and meet monitoring and recordkeeping requirements. We estimate the cost of obtaining an air permit to be $2,232, and the annual permit fees to be $246. This represents the upper range of costs that could be incurred by the permitting process, as most districts have permit application and annual fees that are less than the figures used in this analysis. We estimate the cost to keep records as specified in the proposed ATCM to be $600 per year. This includes the cost of labor to track emissions and to submit this information to the districts. Annualized costs for these facilities range from $600 per year for facilities which would only need to keep records, to $1,362 per year for facilities that would need to obtain a new permit, keep records and pay annual permit fees. The initial permit costs are annualized over five years.

We estimate that nine facilities may qualify for the standard for remotely located thermal spraying operations. Seven of these facilities are expected to meet the 90 percent control efficiency standard with their existing control devices. These facilities may need to obtain a new permit or modify their existing permit in addition to keeping records and reporting emissions annually. The cost for these facilities ranges from $600 annually for facilities that would only need to start keeping records and report emissions, to an annualized cost of $1,362, which would cover recordkeeping, reporting and permitting costs. Two facilities may need to install a control device such as a water curtain. The annual cost for these facilities is estimated to be $5,000 per facility.

For the six facilities needing to install new control devices, the cost is estimated to be $629,200 to $1,152,800 for initial capital costs (including installation) and $33,600 to $72,000 in annual recurring costs. This equates to an annualized cost of $118,000 to $226,900 in 2004 dollars over the life of the equipment. The estimated costs for individual facilities installing new control devices range from $28,600 for initial capital costs and $1,200 in annual recurring costs for a facility with low material usage installing a water curtain system, up to $787,700 for initial capital costs and $58,200 in annual recurring costs for a larger facility installing three HEPA systems to control emissions from nine spray booths.

6. Assumptions for Facility Cost Estimates

The facility cost estimates are based on the following assumptions. First, we assumed that facilities that need to meet the 99.999 percent control efficiency requirement will install a dry cartridge filter system. We also assumed that facilities that need to meet the 99.97 percent control efficiency requirement will install a dry cartridge filter system with a HEPA filter unit. We assumed that the two uncontrolled facilities that may qualify for the 90 percent standard for remotely located thermal spraying operations would install a water curtain.

We also assumed that installation would not require any special modification to the facility, which could significantly increase the installation costs. We assumed that three filters will fit in a 55-gallon drum for disposal purposes (Jettan, 2004; Donaldson 2004), and that the hopper discharge collection drum containing particles released from the filter system's self-cleaning cycle is disposed when the filters are changed. The cost of labor to operate the filter systems was assumed to be negligible. A sales tax of 8.25% was added to the cost of the filter systems (BOE, 2004).

We annualized non-recurring fixed costs using the Capital Recovery Method. Using this method, we multiplied the non-recurring fixed costs by the Capital Recovery Factor (CRF) to convert these costs into equal annual payments over a project horizon at a discount rate. The Capital Recovery Method for annualizing fixed costs is recommended by Cal/EPA (Cal/EPA, 1996), and is consistent with the methodology used in previous cost analyses for ARB regulations (ARB, 2000a; ARB, 2000b).

The CRF is calculated as follows:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

where,

CRF = *Capital Recovery Factor*
i = *discount interest rate (assumed to be 5%)*
n = *project horizon or useful life of equipment*

All costs of the control devices were annualized over 10 years, except the cost of the blower, which was annualized over five years. These values are based on a conservative estimate of the expected lifetime of the equipment. The permit application or renewal fees were annualized over five years. The total annualized cost was obtained by adding the annual recurring costs to the annualized fixed costs derived by the Capital Recovery Method.

The annual recurring cost estimates assuming all six facilities subject to control requirements elect to install new control devices, were based on discussions with control equipment manufacturers, hazardous waste disposal companies, and published prices for filters and electricity. Recurring costs include replacement filters, disposal of filters and hopper discharge collection drums, electrical usage, annual permit fees, monitoring, recordkeeping and reporting costs (Donaldson, 2004; Jettan, 2004; Gottes, 2004; BLS, 2004). More details of these costs can be found in Appendix G.

7. Potential Impact on Manufacturers of Thermal Spraying Materials and Suppliers

We do not expect manufacturers of thermal spraying materials to incur any costs, because the proposed ATCM does not regulate material formulations. However, it is possible that some thermal spraying facilities will choose to discontinue their use of materials that contain chromium and nickel, rather than install control devices. It is not expected that this potential decline in material usage will have a significant economic impact, because our research indicates that only facilities with very low usage levels are considering the elimination of chromium and nickel-based materials.

8. Potential Impact on Consumers

The potential impact of the proposed ATCM on consumers depends upon the extent to which affected businesses are able to pass on the increased cost to consumers in terms of higher prices for their goods and services. Given the small impact of the proposed ATCM on the profitability of most affected thermal spraying businesses, we do not expect a noticeable change in the prices of goods and services provided by these businesses. We anticipate the impact, if any, on consumers to be negligible.

9. Potential Impact on Employment

Of the 37 affected businesses, 35 provided employee data and they reported a total of 120 employees that perform thermal spraying. These 35 businesses also reported a total job base of 14,222 employees. We expect the proposed ATCM to have a minimal impact on most of the employees that do thermal spraying. Approximately one-third of the affected employees spend less than one hour per day performing thermal spraying and most affected employees spend less than four hours per day on thermal spraying tasks. Nonetheless, the ATCM may impose hardship on six businesses if they elect to continue thermal spraying operations. These six businesses have 13 employees who do thermal spraying. Of the six businesses, we expect four to cease using materials containing chromium or nickel or cease their thermal spraying operations completely. For these four businesses, thermal spraying provides a minor portion (<5 percent) of their overall gross revenue and less than one hour per day is spent on thermal spraying. If these four businesses decide to cease their thermal spraying operations, the workload for four employees is likely to be affected, but the employees are not expected to lose their jobs.

10. Potential Impact on Business Creation, Elimination or Expansion

The proposed ATCM would have no noticeable impact on the status of California businesses. The compliance costs of the proposed ATCM are expected to be minor for most thermal spraying operators as demonstrated above by small impacts on the profitability of most affected businesses. Only one business that is required to install HEPA filters is likely to be affected adversely. The other businesses subject to control requirements are expected to pass the cost on to their customers or cease the operations of their thermal spraying units and shift the resources to other parts of their business.

11. Potential Impact on Business Competitiveness

The proposed ATCM is not expected to have a significant impact on the ability of California businesses to compete with businesses from another state. Most thermal spraying businesses are independent operations (e.g., machine shops, job shops) who compete for local business within their region and rarely seek business from outside the State. In addition, many thermal spraying operations are conducted as internal support services for manufacturing or repair businesses and they don't compete with external thermal spraying businesses from outside the State. As indicated above, one business that is a large dedicated thermal spraying operation could be affected adversely by the proposed ATCM.

12. Costs to Public Agencies

Health and Safety Code (HSC) section 39666 requires that, after the adoption of the proposed ATCM by the Board, the air districts must implement and enforce the ATCM or adopt an equally effective or more stringent regulation. Because the air districts will have primary responsibility for implementing and enforcing the proposed ATCM, we evaluated the potential cost to the air districts. We also evaluated the potential cost to local and State agencies. This section provides the conclusions we reached and the basis for those conclusions.

We expect one local public agency that performs thermal spraying using materials that contain chromium or nickel to be minimally impacted. The annual cost to this agency, the Eastern Municipal Water District in Riverside County, is estimated to be $600. These costs are not State-mandated costs that are required to be reimbursed under State law, because the proposed ATCM applies generally to all thermal spraying facilities that use chromium or nickel in the State and does not impose unique requirements on local agencies.

The thermal spraying facilities affected by the proposed ATCM are located in six air districts, as shown in Table VII-2. Most of the facilities are located in the South Coast Air Quality Management District (AQMD), San Diego County Air Pollution Control District (APCD), and the Bay Area AQMD.

Table VII-2: Location of Thermal Spraying Facilities in California		
Location	**Affected Facility**	**Percent**
Bay Area AQMD	6	16
Feather River AQMD	1	3
South Coast AQMD	18	49
San Diego APCD	7	20
San Joaquin Valley APCD	3	8
Ventura County APCD	2	5
Total	**37**	**100**

The costs to districts from the proposed ATCM would be incurred through permitting, inspections, annual inventory reviews, and coordinating stack testing, if necessary. Districts that do not currently permit thermal spraying facilities would incur costs, which the districts can recover through fees charged to the facilities. The total increased cost for six districts is expected to be approximately $60,200. This is based on an estimated cost of approximately $2,232 per facility to process applications for new and modified permits for 25 facilities. In addition, we estimated that it would cost approximately $246 per facility to conduct annual inspections and permit reviews for 18 facilities that currently do not have permits. The costs to the districts can be recovered under the fee provisions authorized by HSC sections 42311 and 40510. Therefore, the proposed ATCM imposes no costs on the districts that are required to be reimbursed pursuant to Section 6 of Article XIIIB of the California Constitution and Part 7 (commencing with section 17500), division 4, title 2 of the Government Code.

The proposed ATCM for thermal spraying facilities will not affect any State agency or program other than the ARB. Although the districts will have primary responsibility for enforcing the proposed ATCM, the ARB may, at the request of a district, provide technical expertise, legal support, or other enforcement support, as needed, to assist in the enforcement of the proposed ATCM. We do not expect requests for assistance on a regular basis. All costs incurred from this rulemaking action would be minimal and absorbable within the existing ARB budget.

13. Total Cost of the Proposed Airborne Toxic Control Measure

Based on information provided in the ARB's 2004 Thermal Spraying Facilities Survey and discussions with thermal spraying facilities and filter manufacturers, we estimated the total cost of the proposed ATCM. The total cost ranges from $672,000 to $1,195,000 in initial capital and permitting costs and $55,000 to $94,000 in annual recurring costs. This corresponds to a total annualized cost of $150,000 to $257,000 over the life of the regulation.

The cost ranges represent minimum and maximum costs associated with the one facility that would need to upgrade from water curtains to a HEPA filter. Based on information provided by the facility, we believe that one HEPA system for three spray booths would be sufficient to accommodate the quantities of chromium- and nickel-based materials being used at the facility and comply with the proposed ATCM. This situation is reflected in the lower end of the cost ranges provided above. If the business chose to install three HEPA systems for nine spray booths, to provide maximum operational flexibility, the costs would be greater, as represented by the upper end of the cost ranges provided above. However, the expenditure for upgrading nine spray booths would be a business decision that is not mandated by the proposed ATCM.

These cost estimates include the cost of purchasing and installing control equipment, as well as the cost of replacing the filters regularly. We also accounted for the operating costs for electricity, disposal, permitting, reporting and recordkeeping (see Appendix G).

REFERENCES

ARB, 2000a. Air Resources Board. "Staff Report for the Proposed Suggested Control Measure for Architectural Coatings." June, 2000.

ARB, 2000b. Air Resouces Board. "Initial Statement of Reasons for Proposed Amendments to the Vapor Recovery Certification and Test Procedures for Gasoline Loading and Motor Vehicle Gasoline Refueling at Service Stations." February, 2000.

ARB, 2004c. Air Resouces Board. "2004 Thermal Spraying Facility Survey, Draft Report." March 2004.

BOE, 2004. Board of Equalization. ."California City and County Sales and Use Tax Rates" Online, Internet at http://www.boe.ca.gov/sutax/pam71.htm. September, 2004.

BLS, 2004. U.S. Department of Labor, Bureau of Labor Statistics. "Consumer Price Index – Average Price Data: Electricity per KWH in Los Angeles and San Francisco" Online, Internet at http://data.bls.gov/labjava/outside.jsp?survey=ap, July 2004.

Cal/EPA, 1996. California Environmental Protection Agency. Memorandum from Peter M. Rooney, Undersecretary, to Cal/EPA Executive Officers and Directors. "Economic Analysis Requirements for the Adoption of Administrative Regulations." Appendix C ("Cal/EPA Guidelines for Evaluation Alternatives to Proposed Major Regulations"). December 6, 1996.

Donaldson, 2004. Donaldson Company Inc. Product Brochure, "Ultra-Web Cartridges." September, 2004.

Dun, 2003. Dun and Bradstreet. Industry Norms and Key Business Ratios, Desk-Top Editions, 2002-2003 and 1999-2000.

Gottes, 2004. Air Resources Board staff discussions with Janet Gottes, Clean Harbor. May 2004.

Hauck, 2004. Air Resources Board staff discussions with Bob Hauck, Spray Systems Inc. October 2004.

Jettan, 2004. Air Resources Board staff discussions with Steve Jettan, Farr APC. June 2004.

VIII. ENVIRONMENTAL IMPACTS OF PROPOSED AIRBORNE TOXIC CONTROL MEASURE

The intent of the proposed ATCM is to protect public health by reducing public exposure to emissions of hexavalent chromium and nickel. An additional consideration is the impact that the proposed ATCM may have on the environment. This chapter describes the potential impacts that the proposed ATCM may have on air quality, wastewater treatment, and hazardous waste disposal. Based upon available information, the ARB staff has determined that no significant adverse environmental impacts should occur as a result of adopting the proposed ATCM.

VIII.A. LEGAL REQUIREMENTS APPLICABLE TO THE ENVIRONMENTAL IMPACT ANALYSIS

The California Environmental Quality Act (CEQA) and ARB policy require an analysis to determine the potential environmental impacts of proposed regulations. ARB's program for adopting regulations has been certified by the Secretary of Resources, pursuant to Public Resources Code section 21080.5. Consequently, the CEQA environmental analysis requirements may be included in the Initial Statement of Reasons (ISOR) for this rulemaking. In the ISOR, the ARB must include a functionally equivalent document, rather than adhering to the format described in CEQA of an Initial Study, a Negative Declaration, and an Environmental Impact Report. In addition, staff will respond in the Final Statement of Reasons for the proposed ATCM to all significant environmental issues raised by the public during the 45-day public review period or at the Board hearing.

Public Resources Code section 21159 requires that the environmental impact analysis conducted by ARB include the following:

- An analysis of reasonably foreseeable environmental impacts of the methods of compliance;
- An analysis of reasonably foreseeable feasible mitigation measures; and
- An analysis of reasonably foreseeable alternative means of compliance with the proposed ATCM.

Compliance with the proposed ATCM is expected to directly affect air quality and potentially affect other environmental media as well. Our analysis of the reasonably foreseeable environmental impacts of the methods of compliance is presented below.

VIII.B. ANALYSIS OF REASONABLY FORESEEABLE ENVIRONMENTAL IMPACTS OF THE METHODS OF COMPLIANCE

1. Potential Air Quality Impacts

The proposed ATCM is expected to have a positive impact on air quality. The regulation will improve air quality by reducing emissions of hexavalent chromium and nickel throughout California, including urban areas and those areas that are non-attainment for the State and federal ambient air quality standards for PM_{10} and $PM_{2.5}$.

As previously discussed, hexavalent chromium and nickel are found in the particulate emissions from thermal spraying operations. Thus, thermal spraying should be performed inside a booth equipped with a ventilation system sufficient to draw the air from the booth through a control device that captures particulates. Most thermal spraying facilities exhaust the work area and booth air to the outside.

For the proposed thermal spraying ATCM, we estimated the potential emission reductions based on data from the ARB 2004 Thermal Spraying Facility Survey, the ARB 2003 Thermal Spraying Materials Survey, and the proposed ATCM control efficiency requirements. Implementation of this thermal spraying ATCM is expected to achieve significant emission reductions. For a facility with no existing control devices, the proposed ATCM would require at least a 99% reduction in emissions. For the largest facility in the State, the proposed ATCM would require that the control device efficiency be increased from a minimum of 81% to at least 99.97%. Overall, the proposed ATCM is expected to reduce hexavalent chromium emissions by approximately 80 percent (7 to 50 lbs/yr) and nickel emissions by approximately 50 percent (54 to 377 lbs/yr) from thermal spraying operations. These reductions will occur in six air districts, with the greatest benefits occurring in the SCAQMD and BAAQMD.

The proposed ATCM establishes emission standards that reflect the use of BACT and are designed to ensure that the potential cancer risk from hexavalent chromium and nickel does not exceed 10 in a million and the chronic hazard index does not exceed one. In addition, the proposed ATCM includes hourly emission limits for nickel that have been established to make sure that the acute hazard quotient does not exceed one.

The California Department of Industrial Relations, Division of Occupational Safety and Health Administration (Cal/OSHA) regulates the concentration of many TACs in the workplace environment. To protect worker safety, Cal/OSHA has established a permissible exposure limit (PEL) for many TACs. The PEL is the maximum, eight-hour, time-weighted average concentration for occupational exposure and is 0.1 mg/m^3 for hexavalent chromium, and 1 mg/m^3 for nickel (CCR, 2002). The proposed ATCM will require ventilation systems that will reduce worker exposure and will result in a reduction in hexavalent chromium and nickel emissions. Therefore, a decrease in workplace exposure and ambient air exposure from TAC emissions is expected.

2. Potential Wastewater Impacts

The Water Resources Control Board regulates wastewater in California. In California, it is illegal to dispose of wastewater containing hazardous substances in the sewer system. Discharge of wastewater from thermal spraying facilities to a sanitary sewer can result in metals such as hexavalent chromium and nickel accumulating in sewage treatment sludge, preventing its beneficial use. Some contaminants "pass through" and are discharged to lakes, rivers, bays, and oceans.

Although the practice is illegal, facility operators may introduce hazardous substances to the sewer system by washing down areas containing overspray and allowing that water to enter the sewer system. The requirement in the proposed ATCM to capture a greater percentage of these hazardous substances from thermal spraying operations should reduce the amount of these metals deposited into sewer systems and storm drains.

Most thermal spraying coating waste is a result of over spray and is collected primarily on the spray booth exhaust filter or in floor sweepings. However, thermal spraying facilities may also generate coating-contaminated masking supplies. These dry coating related wastes are potentially hazardous if they contain hexavalent chromium or nickel. If these wastes are landfilled, metals may leach out of the waste into the groundwater. While the proposed ATCM has no direct impact on waste disposal, it is anticipated that adoption and enforcement of the proposed ATCM will result in increased awareness of proper disposal methods by owners and operators of thermal spraying facilities, resulting in less hazardous wastes being landfilled.

3. Potential Hazardous Waste Impacts

Hazardous waste is regulated in California by federal and State laws. In California, all hazardous waste must be disposed of at a facility that is registered with the Department of Toxic Substances Control (DTSC). Under these programs, thermal spraying wastes would be classified as hazardous waste if they contain substances listed as toxic, such as hexavalent chromium and nickel.

Because TACs would otherwise be released into the air, this ATCM will benefit the environment by capturing a greater portion of these metallic particles. However, the particles collected by the control device must be removed periodically to maintain the effectiveness of the control device.

Thermal spraying facilities that have filter-type control systems also generate exhaust filters that may contain hexavalent chromium or nickel. Booth exhaust filters are typically changed once per year, but may be changed more or less often depending on the amount of thermal spraying being done. The waste filters may need to be tested for toxicity characteristics. The "*Toxicity Characteristic*

Leaching Procedure" (TCLP) is used to determine if the filters contain toxic metals. Hexavalent chromium and nickel are among the compounds for which testing is required. Filters containing these metals are typically disposed of as hazardous waste. While it is anticipated that there will be an increase in the amount of spray booth filters disposed of as hazardous waste, it is not expected to be a significant increase. This is due to the fact that most thermal spraying facilities already have control devices and are currently disposing of dry filters. The proposed ATCM would only require up to four facilities to install new dry filter systems, which would result in a new hazardous wastestream for these facilities. Of these four facilities, three facilities are expected to cease their thermal spraying operations that use chromium and nickel-containing materials, which would mean that no additional filters would need to be disposed at these facilities. The fourth facility currently operates water curtain booths that generate hazardous waste in the form of sludge. It is not expected that the quantity of filters being disposed will be substantially greater than the quantity of sludge currently being disposed.

Some thermal spraying facilities generate hazardous waste in the form of metal sludge from water curtain booths. The proposed ATCM is expected to result in a small decrease in the quantity of metal sludge disposed as hazardous waste, as some water curtain booths are upgraded to more efficient dry filter systems.

4. Reasonably Foreseeable Mitigation Measures

CEQA requires an agency to identify and adopt feasible mitigation measures that would minimize any significant adverse environmental impacts described in the environmental analysis. The ARB staff has concluded that no significant adverse environmental impacts should occur from adoption of and compliance with the proposed ATCM. Therefore, no mitigation measures would be necessary.

5. Reasonably Foreseeable Alternative Means of Compliance With the Proposed Airborne Toxic Control Measure

Alternatives to the Proposed ATCM are discussed in Chapter VI of this ISOR. The ARB staff has concluded that the proposed ATCM provides the most effective and least burdensome approach to reducing the public's exposure to hexavalent chromium and nickel emitted from thermal spraying operations.

VIII.C. COMMUNITY HEALTH AND ENVIRONMENTAL JUSTICE

Environmental Justice is defined as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. The ARB is committed to integrating environmental justice into all of our activities. On December 13, 2001, the Board approved "Policies and Actions for Environmental Justice," which formally established a framework for incorporating Environmental Justice into the ARB's programs, consistent with the directive of California state law. These policies apply to all communities in California. However, environmental justice issues have been raised specifically in the context of low-income areas and ethnically diverse communities.

The Environmental Justice Policies are intended to promote the fair treatment of all Californians and cover the full spectrum of the ARB's activities. Underlying these Policies is a recognition that the agency needs to engage community members in a meaningful way as it carries out its activities. People should have the best possible information about the air they breathe and what is being done to reduce unhealthful air pollution in their communities. The ARB recognizes its obligation to work closely with all communities, environmental and public health organizations, industry, business owners, other agencies, and all other interested parties to successfully implement these Policies.

During the ATCM development process, the ARB staff proactively identified and contacted representatives from thermal spraying materials manufacturers and thermal spraying operations, environmental organizations, and other parties interested in thermal spraying. These individuals participated by providing data, reviewing draft regulations, and attending public meetings in which staff directly addressed their concerns.

The proposed ATCM is consistent with our environmental justice policy to reduce health risks from toxic air pollutants in all communities, including those with low-income and ethnically diverse populations, regardless of location. Potential risks from thermal spraying can affect both urban and rural communities. Therefore, reducing emissions of toxic air pollutants from thermal spraying operations will provide air quality benefits to urban and rural communities in the State, including low-income areas and ethnically diverse communities.

To address environmental justice and general concerns about the public's exposure to hexavalent chromium emissions, the proposed ATCM establishes criteria for the operation of new thermal spraying facilities that use materials containing chromium or nickel. New facilities would be required to install HEPA filters (or equivalent). In addition, a new thermal spraying facility cannot operate unless it is located outside of a residential or mixed use zone and is located at least 500 feet from the border of a residential or mixed use zone. Also, new thermal spraying facilities would be required to undergo a site-specific analysis to ensure adequate protection of public health. These criteria will help ensure that new thermal spraying operations are not operated in environmental justice communities with residential areas. These operational limitations only apply to new thermal spraying operations that use materials containing chromium or nickel. We believe these criteria are necessary for new thermal spraying facilities because hexavalent chromium is a potent carcinogen, and short-term exposure to nickel can cause acute health impacts. While we believe these precautions are necessary for thermal spraying sources of hexavalent chromium and nickel, due to extreme toxicity and acute health effects, similar requirements may not be appropriate for sources of other TACs. Each TAC should be evaluated on a case by case basis to ensure public health protection.

REFERENCES

CCR, 2002. California Code of Regulations, Title 8, Division 1, Chapter 4, Subchapter 7, Group 16, Article 107, Section 5155, Airborne Contaminants, Table AC-1. 2002.

Appendix A

Proposed Regulation Order: Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying

PROPOSED REGULATION ORDER

AIRBORNE TOXIC CONTROL MEASURE TO REDUCE EMISSIONS OF HEXAVALENT CHROMIUM AND NICKEL FROM THERMAL SPRAYING

Adopt new section 93102.5, title 17, California Code of Regulations, to read as follows: Note: All of the following text is new language to be added to the California Code of Regulations. To improve readability, none of this language is shown in underline.

93102.5. Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying.

(a) Applicability

This Airborne Toxic Control Measure (ATCM) shall apply to each thermal spraying operation at a stationary source that uses materials containing chromium, chromium compounds, nickel, or nickel compounds. This ATCM does not apply to portable thermal spraying operations.

(b) Definitions

For the purposes of this section, the following definitions shall apply:

(1) *"Air Pollution Control System"* means equipment that is installed for the purpose of collecting and containing emissions of airborne particles from thermal spraying processes. "Air Pollution Control System" includes, but is not limited to, enclosures, exhaust hoods, ductwork, fans/blowers, particulate control devices, and exhaust stacks/vents.

(2) *"Control Device"* means a device that reduces emissions of particulate matter. "Control Device" includes, but is not limited to, dry filter cartridges, HEPA filters, water curtains, cyclones, baghouses, and scrubbers.

(3) *"Detonation Gun Spraying"* means a thermal spraying process in which the coating material is heated and accelerated to the workpiece by a series of detonations or explosions from oxygen-fuel gas mixtures.

(4) *"Dry Filter System"* means a dry particulate filter control system that uses filter media to remove particulate emissions from the exhaust air stream.

(5) *"Enclosure"* means a structure, such as a booth, that surrounds a thermal spraying process and captures and contains particulate emissions and vents them to a control device. Enclosures may have permanent or temporary coverings on open faces.

(6) *"Existing Thermal Spraying Operation"* means a thermal spraying operation that is in operation before January 1, 2005.

(7) *"Flame Spraying"* means a thermal spraying process in which an oxygen/fuel gas flame is the source of heat for melting the surfacing material.

(8) *"High Efficiency Particulate Air (HEPA) Filter"* means a disposable, dry filter that has a minimum particle collection efficiency of 99.97 percent when tested with a mono-disperse 0.3 um test aerosol.

(9) *"Hexavalent chromium"* means the form of chromium with a valence state of +6.

(10) *"High-Velocity Oxy-Fuel (HVOF) Spraying"* means a thermal spray process in which particles are injected into a high-velocity jet formed by the combustion of oxygen and fuel.

(11) *"Independent Tester"* means a person who engages in the testing of stationary sources to determine compliance with air pollution laws or regulations and who meets all of the following criteria:

(A) The independent tester is not owned in whole or in part by the owner/operator of the thermal spraying operation; and
(B) The independent tester has not received gross income from the owner/operator of the thermal spraying operation in excess of $100,000 or in excess of 10% of the tester's annual revenues, other than as a result of source test contracts; and
(C) The independent tester has not manufactured or installed any emission control device or monitor used in connection with the specific source to be tested; and
(D) When conducting the compliance test, the independent tester does not use any employee or agent who:
1. holds a direct or indirect investment of $1,000 or more in the owner/operator of the thermal spraying operation; or
2. has directly received income in excess of $250 from the owner/operator of the thermal spraying operation in the previous 12 months; or
3. is a director, officer, partner, employee, trustee, or holds any position of management in the owner/operator of the thermal spraying operation.

(12) *"Initial Startup"* means the first time a new thermal spraying operation begins production or the first time additional or modified thermal spraying operations begin operating at a modified source. If such production or operation occurs prior to the operative date of this section, "Initial Startup" means the operative date of this section. "Initial Startup" does not include operation solely for testing of equipment or subsequent startup of permit units following malfunction or shutdown.

(13) *"Intake Area"* means the area of the opening(s) in an enclosure from which make-up air is drawn from outside the enclosure during normal operations.

(14) *"Inward Face Velocity"* means the airflow in cubic feet per minute (cfm) divided by the open intake area in square feet, measured in accordance with Appendix 2. Inward face velocity is measured in feet per minute.

(15) *"Leak"* means the release of any particulate matter from any opening in the emission collection system/device other than the intended exhaust or emission point of that emission control system/device.

(16) *"Location"* means one or more contiguous or adjacent properties. Contiguous or adjacent properties are properties with two or more parcels of land in actual physical contact, or separated solely by a public roadway or other public right-of-way.

(17) *"Modification"* means:

(A) any existing thermal spraying operation that did not use materials containing chromium, chromium compounds, nickel or nickel compounds before January 1, 2005, but begins using any of these materials on or after January 1, 2005; or

(B) any physical change in, change in the method of operation of, or addition to an existing permit unit that requires an application for an authority to construct and/or a permit to operate issued by the permitting agency. Routine maintenance and/or repair is not considered a physical change. A "change in the method of operation" of equipment, unless previously limited by an enforceable permit condition, shall not include:

1. an increase in the production rate, unless such increase will result in an increase in emissions that causes a move from a lower tier to a higher tier in subsection (c)(1)(A) Table 1 or Table 2 of this regulation; or
2. an increase in the hours of operation; or
3. a change in ownership of a source; or

(C) the replacement of components for which the fixed capital cost exceeds 50 percent of the fixed capital cost that would be required to construct a comparable new source.

(18) *"Modified Thermal Spraying Operation"* means any thermal spraying operation which has undergone a modification.

(19) *"New Thermal Spraying Operation"* means any thermal spraying operation that begins initial operations on or after January 1, 2005. "New Thermal Spraying Operation" does not include the installation of a new permit unit at an existing thermal spraying operation.

(20) *"Operating Parameter"* means a parameter established for a control device or process parameter which, if achieved by itself or in combination with one or more other operating parameter values, determines that an owner or operator is in compliance with the applicable emission limitation or standard.

(21) *"Permit Unit"* means any article, machine, piece of equipment, device, process, or combination thereof, which may cause or control the release of air emissions of hexavalent chromium or nickel from a thermal spraying operation and which requires a permit to operate issued by a permitting agency.

(22) *"Permitting Agency"* means the local air pollution control or air quality management district.

(23) *"Plasma Spraying"* means a thermal spraying process in which an electric arc is used to ionize a gas and produce a plasma jet that melts and propels the coating material to the workpiece.

(24) *"Point Source"* means a permit unit that releases air pollutants through an intended opening such as, but not limited to, a stack, chimney, or vent.

(25) *"Portable Thermal Spraying Operation"* means a thermal spraying operation that is temporarily used for field applications at offsite locations. A thermal spraying operation is not a "Portable Thermal Spraying Operation" if the thermal spraying operation or its replacement resides at the same location for more than 30 consecutive days.

(26) *"Potential to Emit"* means the maximum capacity of a stationary source to emit a regulated air pollutant based on its physical and operational design. Any physical or operational limitation on the capacity of the stationary source to emit a pollutant, including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored, or processed, shall be treated as part of its design only if the limitations are listed as enforceable conditions in an air permit issued by the permitting agency.

(27) *"Sensitive Receptor"* means any residence including private homes, condominiums, apartments, and living quarters; education resources such as preschools and kindergarten through grade twelve (k-12) schools; daycare centers; and health care facilities such as hospitals or retirement and nursing homes. A sensitive receptor includes individuals housed in long term care hospitals, prisons, and dormitories or similar live-in housing.

(28) *"Stationary Source"* means any building, structure, facility or installation which emits any affected pollutant directly or as a fugitive emission. "Building, structure, facility, or installation" includes all pollutant emitting activities which meet all of the following criteria:

(A) are under the same ownership or operation, or which are owned or operated by entities which are under common control; and

(B) belong to the same industrial grouping either by virtue of falling within the same two-digit standard industrial classification code or by virtue of being part of a common industrial process, manufacturing process, or connected process involving a common raw material; and

(C) are located on one or more contiguous or adjacent properties.

(29) *"Thermal Spraying Operation"* means one or more of several processes in which metallic or nonmetallic surfacing materials are deposited in a molten or semi-molten condition on a substrate to form a coating. The surfacing material may originate in the form of powder, rod, or wire before it is heated, prior to spraying and deposition. Thermal spraying processes include: detonation gun spraying, flame spraying, high-velocity oxy-fuel spraying, plasma spraying, and twin-wire electric arc spraying. For the purposes of this section, "Thermal Spraying Operation" includes only those operations that are conducted at stationary sources and use materials containing chromium, chromium compounds, nickel, or nickel compounds. "Thermal Spraying Operation" does not include portable thermal spraying operations.

(30) *"Twin-Wire Electric Arc Spraying"* means a thermal spraying process where two electrically conducting wires are brought close together to create an electric arc. The molten material formed in the arc is then projected by a compressed gas stream towards a work piece on which it forms a coating.

(31) *"Volume Source"* means a permit unit, either controlled or uncontrolled, from which air pollutants undergo initial dispersion within a building or structure prior to their release into the outdoor ambient air. "Volume Source" also includes a thermal spraying process that is conducted outside of a building or structure and releases pollutants directly into the outdoor ambient air.

(32) *"Water Curtain"* means a particulate control system that utilizes flowing water (i.e., a conventional water curtain) or a pumpless system to remove particulate emissions from the exhaust air stream.

(c) Standards

(1) *Standards for Existing Thermal Spraying Operations*
Effective January 1, 2006, each owner or operator of an existing thermal spraying operation must control hexavalent chromium and nickel emissions by complying with the control efficiency requirements specified in subsection (c)(1)(A), the enclosure standards specified in subsection (c)(1)(B), and the ventilation system standards specified in subsection (c)(1)(C). Annual hexavalent chromium and nickel emissions and maximum hourly nickel emissions must be determined in accordance with the emission calculation methods in Appendix 1 or may be based on the results of an emissions source test. The use of data from an emissions source test must be approved by the permitting agency and the test must be conducted by an independent tester.

(A) *Control Efficiency Requirements for Existing Thermal Spraying Operations*
All existing thermal spraying operations must control hexavalent chromium and nickel emissions as follows:

1. All hexavalent chromium and nickel emissions from thermal spraying operations must be routed through an air pollution control system that meets the enclosure and ventilation standards in subsections (c)(1)(B) and (c)(1)(C).
2. For point sources, maximum hourly emissions of nickel from all thermal spraying operations at a stationary source must not exceed 0.1 lb. For volume sources, maximum hourly emissions of nickel from all thermal spraying operations must not exceed 0.01 lb.
3. For point sources, the air pollution control system must include a control device that is certified by its manufacturer to meet the minimum control efficiency requirements specified in Table 1 of this subsection (c)(1)(A). For volume sources, the air pollution control system must include a control device that is certified by its manufacturer to meet the minimum control efficiency requirements specified in Table 2 of subsection (c)(1)(A). Emissions of hexavalent chromium and/or nickel from all thermal spraying operations at a stationary source must be included when determining the annual emissions from thermal spraying under subsection (c)(1)(A). If an existing control device meets the minimum control efficiency requirements specified in subsection (c)(1)(A), no additional controls are required by this regulation, but the owner or operator must still comply with the enclosure standards in subsection (c)(1)(B), and the ventilation system standards in subsection (c)(1)(C). If a thermal spraying operation has an air permit that limits the use of chromium and nickel to specific thermal spraying permit units, the control efficiency requirements, enclosure standards, and ventilation system standards only apply to those specific thermal spraying permit units.

4. All thermal spraying operations that are subject to more than one minimum control efficiency requirement under subsection (c)(1)(A) must comply with the most stringent applicable requirement.

Table 1: Point Sources -
Control Efficiency Requirements for Existing Thermal Spraying Operations

Tier	Annual Hexavalent Chromium Emissions from Thermal Spraying [1]	Annual Nickel Emissions from Thermal Spraying [1]	Minimum Control Efficiency Requirements [2]
1	≥ 0.004 lbs/yr and ≤ 0.04 lbs/yr	≥ 2.1 lbs/yr and ≤ 20.8 lbs/yr	90% by weight (e.g., a water curtain)
2	> 0.04 lbs/yr and ≤ 0.4 lbs/yr	> 20.8 lbs/yr and ≤ 208 lbs/yr	99.999% @ 0.5 microns (e.g., a high-efficiency dry filter)
3	> 0.4 lbs/yr	> 208 lbs/yr	99.97% @ 0.3 microns (e.g., a HEPA filter)

1. Emissions are controlled emissions from all thermal spraying operations at a stationary source, if the thermal spraying operation is already equipped with a control device.
   a. For non-permitted sources, annual emissions must be determined in accordance with the emission calculation methods specified in Appendix 1 or based on the results of an emissions source test that has been reviewed and approved by the permitting agency.
   b. For permitted sources, annual emissions must be calculated based on the potential to emit or in accordance with the allowable limits set forth in the permit conditions. Emissions must be determined in accordance with the emission calculation methods specified in Appendix 1 or based on the results of an emissions source test that has been reviewed and approved by the permitting agency.
2. Control efficiency requirements must be certified by the manufacturer/supplier of the control device and/or filter media. Thermal spraying operations are not required to conduct an emissions source test to verify the control efficiency at the listed particle sizes.

Table 2: Volume Sources -
Control Efficiency Requirements for Existing Thermal Spraying Operations

Tier	Annual Hexavalent Chromium Emissions from Thermal Spraying [1]	Annual Nickel Emissions from Thermal Spraying [1]	Minimum Control Efficiency Requirements [2]
1	≥ 0.001 lbs/yr and ≤ 0.01 lbs/yr	≥ 0.3 lbs/yr and ≤ 3.1 lbs/yr	99% by weight (e.g., a dry filter)
2	> 0.01 lbs/yr and ≤ 0.1 lbs/yr	> 3.1 lbs/yr and ≤ 31 lbs/yr	99.999% @ 0.5 microns (e.g., a high-efficiency dry filter)
3	> 0.1 lbs/yr	> 31 lbs/yr	99.97% @ 0.3 microns (e.g., a HEPA filter)

1. Emissions are controlled emissions from all thermal spraying operations at a stationary source, if the thermal spraying operation is already equipped with a control device.
   a. For non-permitted sources, annual emissions must be determined in accordance with the emission calculation methods specified in Appendix 1 or based on the results of an emissions source test that has been reviewed and approved by the permitting agency.
   b. For permitted sources, annual emissions must be calculated based on the potential to emit or in accordance with the allowable limits set forth in the permit conditions. Emissions must be determined in accordance with the emission calculation methods specified in Appendix 1 or based on the results of an emissions source test that has been reviewed and approved by the permitting agency.
2. Control efficiency requirements must be certified by the manufacturer/supplier of the control device and/or filter media. Thermal spraying operations are not required to conduct an emissions source test to verify the control efficiency at the listed particle sizes.

(B) *Enclosure Standards*.

All existing thermal spraying operations that are subject to subsection (c)(1)(A) must use air pollution control systems that meet the following criteria by January 1, 2006. All modified or new thermal spraying operations that are subject to subsection (c)(2)(A)2. or (c)(3)(A)1., respectively, must use air pollution control systems that meet the following criteria upon initial startup.

1. Enclosures must be exhaust ventilated such that a continuous inward flow of air is maintained from all designed make-up air openings during thermal spraying operations.
2. To ensure good capture of airborne pollutants, the average inward face velocity of air through the enclosure must either be:
   a. a minimum of 100 feet per minute; or
   b. the minimum velocity for metal spraying facilities as established in "Industrial Ventilation, A Manual of Recommended Practice", 25th Edition or most recent version, published by the American Conference of Governmental Industrial Hygienists which is incorporated by reference herein.

   The inward face velocity must be confirmed by a velocity measuring device approved by the permitting agency (e.g., a pitot tube or anemometer.) Measurement of inward face velocity must be performed in accordance with the methods set forth in Appendix 2 or an alternative method approved by the permitting agency.
3. When thermal spraying is being performed, all air inlets and access openings must be covered to prevent the escape of dust or mist contaminants into areas outside the enclosure. This requirement does not apply to any designed or intended make-up air vents or openings. Coverings can be permanent (e.g., a door) or temporary (e.g., plastic flaps). Temporary coverings must be approved by the permitting agency.
4. Before the enclosure is opened, thermal spraying must cease and the exhaust system must be run for a sufficient period of time, as determined by the permitting agency, to remove contaminated air within the enclosure. A minimum of three air exchanges must be exhausted from the booth after thermal spraying ceases.

(C) *Ventilation System Standards*

1. *Installation of Ventilation System for Existing, New, and Modified Thermal Spraying Operations*

   For existing thermal spraying operations, the exhaust gas stream from the air pollution control system required by subsection (c)(1)(B) must be ducted to a particulate matter control device meeting the applicable control efficiency requirements of subsection (c)(1)(A) by January 1, 2006.

   For modified or new thermal spraying operations, the exhaust gas stream from the air pollution control collection system required by subsection (c)(1)(B) must be ducted to a particulate matter control device meeting the applicable control efficiency requirements of subsection (c)(2)(A)2. or (c)(3)(A)1., respectively, upon initial startup.

2. *Operating Requirements for Ventilation Systems at Existing, New, and Modified Thermal Spraying Operations*
   a. The ventilation system and control device must be properly maintained and kept in good operating condition at all times. Any leak, as determined by a visual leak inspection conducted in accordance with Appendix 3, is a violation of this section.
   b. Material collected by a particulate matter control system must be discharged into closed containers or an enclosed system that is completely sealed to prevent dust emissions.
   c. Dust collectors for control devices must be maintained in a manner that prevents emissions of particulate matter into the ambient air.

(D) Permit Requirements for Existing Thermal Spraying Operations
All unpermitted existing thermal spraying operations must submit a permit application to the permitting agency no later than October 1, 2005. This permitting requirement applies only to existing thermal spraying operations that use materials containing chromium, chromium compounds, nickel, or nickel compounds.

(E) Standards for Remotely Located Existing Thermal Spraying Operations
1. The requirements of subsections (c)(1)(A), (c)(1)(B), and (c)(1)(C) do not apply to existing thermal spraying operations that meet all of the following criteria:
   a. The thermal spraying operation is located at least 1,640 feet from a sensitive receptor, as determined by the permitting agency; and
   b. Annual emissions of hexavalent chromium from all thermal spraying operations do not exceed 0.5 lb; and
   c. The thermal spraying operation uses an air pollution control system that achieves a minimum control efficiency of 90 percent; and
   d. The thermal spraying operation complies with the permitting requirements of subsection (c)(1)(D); and
   e. The owner or operator of the thermal spraying operation has submitted an annual report to the permitting agency by March 1st of each calendar year, that quantifies emissions of hexavalent chromium and nickel from all thermal spraying operations during the previous calendar year; and
   f. The thermal spraying operation has undergone a site specific analysis from the permitting agency to ensure public health protection.

2. Thermal spraying operations that qualify for this standard must undergo an annual evaluation by the permitting agency to ensure that the thermal spraying operation still complies with the conditions of this standard. This

standard shall cease to apply if the permitting agency determines that the thermal spraying operation no longer meets all of the criteria in subsection (c)(1)(E)1. If the permitting agency determines that the standard ceases to apply, the owner or operator of the thermal spraying operation must submit a permit application to the permitting agency within 3 months of receipt of the permitting agency's determination. The owner or operator must achieve compliance with the requirements of this section within 9 months of receipt of the permitting agency's determination.

(F) Exemption for Existing Thermal Spraying Operations with Low Emission Levels

1. The requirements in subsections (c)(1)(A), (c)(1)(B), and (c)(1)(C) shall not apply to existing thermal spraying operations that meet all of the following criteria:
   a. For point sources, annual emissions of hexavalent chromium are less than 0.004 lb and annual emissions of nickel are less than 2.1 lbs. For volume sources, annual emissions of hexavalent chromium are less than 0.001 lb and annual emissions of nickel are less than 0.3 lb; and
   b. For point sources, maximum hourly emissions of nickel from all thermal spraying operations at a stationary source do not exceed 0.1 lb. For volume sources, maximum hourly emissions of nickel from all thermal spraying operations at a stationary source do not exceed 0.01 lb; and
   c. The thermal spraying operation complies with the permitting requirements of subsection (c)(1)(D); and
   d. The owner or operator of the thermal spraying operation has submitted an annual report to the permitting agency by March 1st of each calendar year, that quantifies emissions of hexavalent chromium and nickel from all thermal spraying operations during the previous calendar year.

(2) *Standards for Modified Thermal Spraying Operations*

(A) Upon initial startup, each owner or operator of a modified thermal spraying operation must comply with all of the following requirements:

1. Modified thermal spraying operations must control hexavalent chromium and nickel emissions by complying with the control efficiency requirements specified in subsection (c)(2)(A)2.

2. All thermal spraying operations that undergo a modification on or after January 1, 2005, must use a control device that is certified by the manufacturer to achieve 99.97 percent control efficiency for particles that are 0.3 micron in diameter. These thermal spraying operations must also comply with the enclosure standards specified in subsection (c)(1)(B) and the ventilation standards specified in subsection (c)(1)(C).

3. For point sources, the maximum hourly emissions of nickel from all thermal spraying operations at a stationary source must not exceed 0.1 lb. For

volume sources, the maximum hourly emissions of nickel from all thermal spraying operations at a stationary source must not exceed 0.01 lb. Maximum hourly nickel emissions must be determined in accordance with the emission calculation methods specified in Appendix 1 or may be based on the results of an emissions source test. The use of source test data must be approved by the permitting agency and the test must be conducted by an independent tester.

4. All thermal spraying operations that undergo a modification on or after January 1, 2005, must submit a permit modification application to the permitting agency, in accordance with permitting agency requirements. This permitting requirement only applies to thermal spraying operations that use materials containing chromium, chromium compounds, nickel, or nickel compounds.

(3) *Standards for New Thermal Spraying Operations*

(A) No person may operate a new thermal spraying operation unless it is located outside of an area that is zoned for residential or mixed use and is located at least 500 feet from the boundary of any area that is zoned for residential or mixed use.

(B) On and after initial startup, the new thermal spraying operation must use a control device that is certified by the manufacturer to achieve 99.97 percent control efficiency for particles that are 0.3 micron in diameter. These operations must also comply with the enclosure standards specified in subsection (c)(1)(B) and the ventilation standards specified in subsection (c)(1)(C).

(C) The maximum hourly emissions of nickel from all thermal spraying operations at a stationary source must not exceed 0.1 lb. Maximum hourly nickel emissions must be determined in accordance with the emission calculation methods specified in Appendix 1 or may be based on the results of an emissions source test. The use of source test data must be approved by the permitting agency and the test must be conducted by an independent tester.

(D) Prior to initial startup, the thermal spraying operation must undergo a site specific analysis from the permitting agency to ensure public health protection.

(E) *Permit Requirements for New Thermal Spraying Operations*
All new thermal spraying operations must submit a permit application to the permitting agency prior to initial startup, in accordance with permitting agency requirements. This permitting requirement only applies to new thermal spraying operations that use materials containing chromium, chromium compounds, nickel, or nickel compounds.

(d) Test Requirements and Test Methods

(1) Testing to Demonstrate Compliance with Enclosure and Ventilation Standards

(A) The owner or operator of an existing thermal spraying operation subject to the control efficiency requirements in subsection (c)(1)(A), must conduct a test to demonstrate compliance with the enclosure and ventilation standards specified in subsections (c)(1)(B) and (c)(1)(C). The test must include measurement of the inward face velocity (in accordance with Appendix 2) and a visual leak inspection (in accordance with Appendix 3.) This test must be conducted within 60 days of the operative date of this section. The owner or operator must notify the permitting agency at least 30 days prior to conducting a test. Although 60 days are allowed to conduct the test, all thermal spraying operations must comply with specified control efficiency requirements, enclosure standards, and ventilation standards by January 1, 2006, as specified in subsection (c)(1).

(B) The owner or operator of a modified or new thermal spraying operation subject to the control efficiency requirements in subsections (c)(2)(A)2. or (c)(3)(A)1., respectively, must conduct a test to demonstrate compliance with the enclosure and ventilation standards in subsections (c)(1)(B) and (c)(1)(C). The test must include measurement of the inward face velocity (in accordance with Appendix 2) and a visual leak inspection (in accordance with Appendix 3.) This test must be conducted within 60 days after initial startup. The owner or operator must notify the permitting agency at least 30 days prior to conducting a test. Although 60 days are allowed to conduct the test, all thermal spraying operations must comply with specified control efficiency requirements, enclosure standards, and ventilation standards upon initial startup.

(2) Verification of Control Efficiency

Existing thermal spraying operations that are subject to Tier 2 or Tier 3 control efficiency requirements specified in subsection(c)(1)(A), modified thermal spraying operations that are subject to the requirements of subsection (c)(2)(A)2., and new thermal spraying operations that are subject to the requirements of subsection (c)(3)(A)1., must use control devices with a control efficiency verified by the manufacturer. This verification must be provided to the permitting agency upon request. The control device manufacturer must verify the control efficiency using one of the following test methods, which are incorporated by reference herein:

(A) ASHRAE Standard 52.2-1999, "Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size", American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329. 1999.

(B) MIL-PRF-51526A(EA), "Filter, Particulate, 340 CMH (200 CFM), 13 March 2000, U.S. Army.

(C) ASME AG-1-2003, "Code on Nuclear Air and Gas Treatment", American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017. 2003.

(D) IEST-RP-CC001.3, "HEPA and ULPA Filters", Institute of Environmental Sciences and Technology, 5005 Newport Drive, Suite 506, Rolling Meadows, IL 60008-3841. 1993.

(3) *Source Tests to Determine Emissions of Hexavalent Chromium and Nickel*
Owners or operators of thermal spraying operations may choose to quantify hexavalent chromium and/or nickel emissions using data from a source test rather than using the calculation methods specified in Appendix 1. In addition, a permitting agency may require that a source test be performed to quantify hexavalent chromium and/or nickel emissions from thermal spraying operations. The use of source test data must comply with the requirements specified in this subsection (d)(3).

(A) *Use of Existing Source Tests*
A source test conducted prior to January 1, 2006, may be used to quantify emissions or demonstrate compliance with the standards in subsection (c)(1)(A), if the permitting agency approves the use of that test. The test must be conducted by an independent tester, in accordance with a test protocol that was reviewed and approved by the permitting agency.

(B) *Test Methods*
If the owner or operator of a thermal spraying operation conducts a source test to quantify emissions of hexavalent chromium and/or nickel, the testing must be conducted in accordance with the following listed test methods, which are incorporated by reference herein, or in accordance with alternative test methods approved by the permitting agency.

1. Testing to determine emissions of hexavalent chromium must be conducted in accordance with one of the following test methods:

ARB Test Method 425, "Determination of Total Chromium and Hexavalent Chromium Emissions from Stationary Sources", last amended July 28, 1997, section 94135, title 17, California Code of Regulations (CCR).

EPA Test Method 306, "Determination of Chromium Emissions From Decorative and Hard Chromium Electroplating and Chromium Anodizing Operations – Isokinetic Method", 40 CFR 63, Appendix A, as promulgated on January 25, 1995.

South Coast Air Quality Management District (SCAQMD) Test Method 205.1, "Determination of Hexavalent and Total Chromium from Plating", August 1991.

2. Testing to determine emissions of nickel must be conducted in accordance with one of the following test methods:

   ARB Test Method 433, "Determination of Total Nickel Emissions from Stationary Sources", last amended September 12, 1989, section 94145, title 17, California Code of Regulations (CCR).

   ARB Test Method 436, "Determination of Multiple Metals Emissions from Stationary Sources" (for nickel only), adopted July 28, 1997, section 94161, title 17, California Code of Regulations (CCR).

(C) The owner or operator of a thermal spraying operation that is conducting a source test must submit a pre-test protocol to the permitting agency, in accordance with permitting agency procedures, at least 60 days prior to conducting a source test. The pre-test protocol must include source test methods, planned sampling parameters, preliminary pollutant analytical data, calculated targets for testing the pollutant, and any proposed modifications to standardized methods. In addition, the pre-test protocol must include information on equipment, logistics, personnel, and any other information required by the permitting agency.

(e) Monitoring, Inspection, and Maintenance Requirements

(1) Monitoring Requirements

All thermal spraying operations with air pollution control systems must comply with the applicable monitoring requirements listed in Table 3 of this subsection (e)(1). In addition, any other operating parameters designated by the permitting agency must be monitored while conducting thermal spraying to ensure compliance with the requirements set forth in subsection (c).

Table 3 – Summary of Monitoring Requirements for Thermal Spraying Operations Using Add-on Air Pollution Control Devices

	Control Equipment	Monitoring Requirements
(A)	Dry particulate filter system (e.g., dry filter cartridge, HEPA filter)	1. Ensure that the pressure differential gauge continuously monitors pressure drop across the control device while conducting thermal spraying. 2. Record pressure drop once per shift while conducting thermal spraying.
(B)	Conventional Water Curtain	1. Ensure that the flow meter continuously monitors the water flow rate while conducting thermal spraying. 2. Monitor the water curtain continuity by visual observation to ensure that there are no gaps while conducting thermal spraying. 3. Record water flow rate and water curtain continuity once per week while conducting thermal spraying.

Table 3 – Summary of Monitoring Requirements for Thermal Spraying Operations Using Add-on Air Pollution Control Devices

	Control Equipment	Monitoring Requirements
(C)	Pumpless Water Curtain	1. Monitor parameters that indicate booth performance, per manufacturer's recommendations, while conducting thermal spraying. 2. Visually inspect the water curtain for continuity to ensure that there are no gaps while conducting thermal spraying. 3. Record recommended parameters and water curtain continuity once per week while conducting thermal spraying.

(2) Pressure Drop Monitoring Requirements

All dry particulate control devices (e.g., dry filter cartridges or HEPA filters) must have gauges that continuously monitor the pressure drop across each control device when thermal spraying is occurring. The gauge must have a high and low setting for the pressure drop and must trigger an alarm system when the high or low set points are exceeded or during the cleaning cycle when the high set point is exceeded. The gauge must be designed to accurately measure pressure drops within the expected range and have an accuracy of at least ± 5% of full scale. The gauge must be located so that it can be easily visible and in clear sight of the operation or maintenance personnel. The pressure drop must be maintained per manufacturer's specifications. If the pressure drop is outside of the acceptable limits, the owner or operator must shut down the thermal spraying operation immediately and take corrective action. The thermal spraying operation must not be resumed until the pressure drop is within the specified limit(s).

(3) Water Curtain Monitoring Requirements

For thermal spraying operations that are conducted in water curtain booths, the owner or operator must monitor booth operating parameters during thermal spraying to ensure compliance with the requirements specified in subsection (c). Water curtain booths must provide a continuous sheet of water down the rear wall of the booth. For all water curtain booths, the owner or operator must visually monitor the water curtain during thermal spraying to ensure that the sheet is continuous without any gaps or dry spots. The owner or operator of a conventional water curtain booth must continuously monitor the water flow rate with a flow meter during thermal spraying to ensure the water flow meets or exceeds the minimum flow rate recommended by the manufacturer. The owner or operator of a pumpless water curtain booth must monitor the parameters recommended by the booth manufacturer to ensure that these parameters meet or exceed the manufacturer's recommendations. If the water curtain fails the continuity and/or flow requirements, the owner or operator must shut down the thermal spraying operation immediately to take corrective action. The thermal spraying operation must not be resumed until the monitored parameters meet or exceed the manufacturer's recommendations.

(4) Inspection and Maintenance Requirements
All thermal spraying operations with air pollution control systems must comply with the applicable inspection and maintenance requirements listed in Table 4.

Table 4 - Summary of Inspection and Maintenance Requirements for Thermal Spraying Operations Using Add-on Air Pollution Control Devices

	Control Equipment	Inspection & Maintenance Requirements	Frequency
(A)	Dry particulate filter system (e.g., dry filter cartridge, HEPA filter)	1. Conduct a visual inspection to ensure there are no leaks in accordance with Appendix 3.	At least once every 90 days.
		2. Visually inspect ductwork from work area to the control device to ensure there are no leaks in accordance with Appendix 3.	At least once every 90 days.
		3. Replace filter.	Per manufacturer's specifications or permitting agency's requirement.
(B)	Water Curtain	1. Visually inspect ductwork from booth to the exhaust stack to ensure there are no leaks in accordance with Appendix 3.	At least once every 90 days.
(C)	All	1. Measure inward face velocity at each opening in accordance with Appendix 2.	At least once every 30 days

(f) Recordkeeping Requirements

(1) Monitoring Data Records
The owner or operator must maintain records of monitoring data required by subsection (e), including the date and time the data are collected. Recordkeeping logs must include the applicable acceptable limit(s) for: pressure drop (dry particulate control); water flow rate (conventional water curtain); or manufacturer's recommended parameter limits (pumpless water curtain).

(2) Inspection Records
The owner or operator must maintain inspection records that clearly document all inspections and maintenance activities to enable the permitting agency to determine whether the requirements of subsection (e)(4) have been met. The records may take the form of a checklist and must identify:

(A) the name of the device inspected;
(B) the date and time of inspection;
(C) a brief description of the working condition of the device during the inspection;
(D) all maintenance activities performed on the components of the air pollution control system (e.g., duct work replacement, filter replacement, fan replacement, leak repairs, etc.);
(E) the actions taken to correct deficiencies found during the inspection; and
(F) the person that conducted the inspection.

(3) *Material Usage Records*
For thermal spraying materials that contain chromium, chromium compounds, nickel, or nickel compounds, the owner or operator must record the name and quantity of material used during each month of the annual reporting period, and the total usage to date for that calendar year.

(4) *Source Test Records*
The owner or operator must maintain test reports documenting the conditions and results of all source tests.

(5) *Equipment Malfunctions and Failures*
The owner or operator must maintain records of the occurrence, duration, cause (if known), and action taken for each equipment malfunction and/or failure.

(6) *Records Maintenance and Retention*
All records required by this subsection (f) must be readily accessible for inspection and review at the thermal spraying operation for at least five years. If so requested by the permitting agency, the owner or operator must provide copies of the records to the permitting agency.

(g) Reporting Requirements

(1) *Initial Emission Inventory for Existing Thermal Spraying Operations*
All existing thermal spraying operations must submit an emission inventory for hexavalent chromium and nickel to the permitting agency no later than October 1, 2005. This inventory must quantify the emissions from thermal spraying operations conducted during the 12-month period between July 1, 2004 and July 1, 2005. The emission inventory must be prepared in accordance with Appendix 1 or must be based on an emissions source test approved by the permitting agency.

(2) *Annual Emission Inventory for Existing Thermal Spraying Operations Qualifying for the Standards for Remotely Located Operations or the Exemption for Operations with Low Emission Levels*
Existing thermal spraying operations that qualify for the standards specified in subsection (c)(1)(E) or the exemption specified in subsection (c)(1)(F) must submit an annual report to the permitting agency by March 1st of each calendar year that quantifies emissions of hexavalent chromium and nickel from thermal spraying operations during the previous calendar year.

(3) *Initial Notification*
Existing thermal spraying operations that intend to begin using materials containing chromium, chromium compounds, nickel, or nickel compounds on or after January 1, 2005, must notify the permitting agency at least 45 days prior to using any of these materials.

(4) Reports of Breakdowns, Equipment Malfunctions, and Failures
The owner or operator of a thermal spraying operation must report breakdowns, equipment malfunctions, and failures as required by the permitting agency.

(5) Source Test Documentation

(A) *Notification of Source Test*
The owner or operator of a thermal spraying operation must notify the permitting agency of his or her intention to conduct a source test to measure emissions of hexavalent chromium and/or nickel. The owner or operator must provide this notification to the permitting agency at least 60 days before the source test is scheduled. The notification must include a pre-test protocol and any other documentation required by the permitting agency.

(B) *Reports of Source Test Results*
The owner or operator of a thermal spraying operation must provide the source test results to the permitting agency no later than 60 days following completion of the testing.

(6) Adjustments to the Timeline for Submittal and Format of Reports
A permitting agency may change the timeline for submittal of periodic reports, allow consolidation of multiple reports into a single report, establish a common schedule for submittal of reports, or accept reports prepared to comply with other State or local requirements. Prior to allowing any of these changes, the permitting agency must determine that the change will provide the same information and will not reduce the overall frequency of reporting.

(h) Severability

Each part of this section is deemed severable, and in the event that any part of this section is held to be invalid, the remainder of this section shall continue in full force and effect.

Appendix 1 – Emission Calculation Method

Emissions of hexavalent chromium (Cr^{+6}) and nickel (Ni) from thermal spraying operations must be calculated in accordance with the procedures specified in this Appendix 1.

Step 1: Identify all thermal spraying materials that contain chromium (Cr) or nickel (Ni) at a concentration of at least 0.1% by weight (or less than 0.1%, if listed on the Material Safety Data Sheet.) Include materials that contain chromium or nickel in the form of a metallic compound or alloy. Examples of compounds and alloys include, but are not limited to, stainless steel; chromium carbide (Cr_3C_2); nichrome alloys (NiCr); and chromium oxide (Cr_2O_3).

Step 2: Determine the total percentage of chromium and/or nickel contained in each thermal spraying material. These data can be obtained from the material safety data sheet (MSDS) or by contacting the manufacturer. If the MSDS contains a range of percentages, use the upper value of the range. If the material contains a compound (e.g., Cr_3C_2), include only the portion that is chromium or nickel.

Step 3: For each thermal spraying operation, compile the annual usage for each thermal spraying material that contains chromium or nickel. For thermal spraying operations that have air permits, the annual usage is the maximum allowable under the permit.

Step 4: For each thermal spraying operation, calculate the annual usage quantities for chromium and nickel using the following equations:

Eqn. 1: [Annual Usage, lbs Cr/yr] = [Material Usage, lbs material used/yr][weight % Cr in Material]*

Eqn. 2: [Annual Usage, lbs Ni/yr] = [Material Usage, lbs material used/yr][weight % Ni in Material]*

Step 5. Identify the applicable emission factor(s) for each thermal spraying operation, based on the applicable control efficiency level. If a material was used for more than one type of thermal spraying operation, use the highest emission factor.

Table 1-1 specifies the applicable emission factors for thermal spraying operations using materials that contain chromium, chromium compounds, or chromium alloys.

Table 1-2 specifies the applicable emission factors for thermal spraying operations using materials that contain nickel, nickel compounds, or nickel alloys.

Appendix 1 – Emission Calculation Method

Table 1-1: Thermal Spraying Emission Factors for Hexavalent Chromium

Operation	Emission Factors (lbs Cr^{+6}/lb Cr sprayed)*			
	0% Control Efficiency (Uncontrolled)	90% Control Efficiency (e.g. Water Curtain)	99% Control Efficiency (e.g. Dry Filter)	99.97% Control Efficiency (e.g., HEPA Filter)
Single-Wire Flame Spray	4.68E-03	4.68E-04	4.68E-05	1.40E-06
Twin-Wire Electric Arc Spray	6.96E-03	6.96E-04	6.96E-05	2.09E-06
Flame Spray	6.20E-03	1.17E-03	6.20E-05	1.86E-06
HVOF	6.20E-03	1.17E-03	6.20E-05	1.86E-06
Plasma Spray	1.18E-02	6.73E-03	2.61E-03	2.86E-06
Other Thermal Spraying	7.17E-03	2.05E-03	5.70E-04	2.01E-06

*Some emission factors are based directly on stack test results while others are calculated values, derived from stack test results and control efficiencies.

Table 1-2: Thermal Spraying Emission Factors for Nickel

Operation	Emission Factors (lbs Ni/lb Ni sprayed)*			
	0% Control Efficiency (Uncontrolled)	90% Control Efficiency (e.g. Water Curtain)	99% Control Efficiency (e.g. Dry Filter)	99.97% Control Efficiency (e.g., HEPA Filter)
Twin-Wire Electric Arc Spray	6.0E-03	6.0E-04	6.0E-05	1.8E-06
Flame Spray	1.10E-01	4.64E-02	1.10E-03	3.30E-05
HVOF	1.10E-01	4.64E-02	1.10E-03	3.30E-05
Plasma Spray	1.5E-01	3.67E-02	1.5E-03	1.72E-05
Other Thermal Spraying	9.4E-02	3.25E-02	9.4E-04	2.13E-05

*Some emission factors are based directly on stack test results while others are calculated values, derived from stack test results and control efficiencies.

Step 6 – <u>Annual Emissions</u>. For each thermal spraying operation, calculate the annual emissions by multiplying the applicable emission factors by the annual usage rates, using the following equations:

Eqn. 3: [Annual Emissions, lbs Cr^{+6}/yr] = [Emission Factor, lbs Cr^{+6}/lb Cr][Annual Usage, lbs Cr/yr]]*

Eqn. 4: [Annual Emissions, lbs Ni/yr] = [Emission Factor, lbs Ni/lb Ni sprayed][Annual Usage, lbs Ni sprayed/yr]*

Appendix 1 – Emission Calculation Method

Step 7 – Maximum Hourly Nickel Emissions: For each thermal spraying operation that uses nickel, calculate the maximum hourly emissions by multiplying the applicable emission factors by the maximum hourly usage rates, using the following equations:

Eqn. 5:
[Max. Hourly Emissions, lbs Ni/hr] = [Emission Factor, lbs Ni/lb Ni sprayed][Max. Hourly Usage, lbs Ni sprayed/hr]*

Eqn. 6:
[Max. Hourly Usage, lbs Ni sprayed/hr] = [Max. Gun Spray Rate, lbs material sprayed/hr][Max. wt.% Ni in material]*

where

"Maximum Gun Spray Rate" is the highest material throughput rate that a thermal spraying gun can achieve, based on manufacturer specifications or actual user experience, whichever is greater. If multiple guns have the potential to be operated at the same time (e.g., in two separate booths), the maximum gun spray rate must include the total throughput from all guns.

"Maximum Weight % Nickel in Material" is the highest weight percentage of nickel for all of the thermal spraying materials that are used in thermal spraying operations at a facility.

Appendix 1 – Emission Calculation Method

Point Source Example:

Thermal Spraying Inc. operates two thermal spraying booths. One booth is used for plasma spraying and the other booth is used for flame spraying and twin-wire electric arc spraying. Listed below is information on the facility's operations:

Booth	Control Device	Operation	Materials Used	Quantity Used	% Total Chromium	% Nickel
Booth #1	HEPA Filter	Plasma Spray	Powder ABC	25 lbs/yr	25%	0%
			Powder XYZ	50 lbs/yr	20%	75%
Booth #2	Dry Filter (99% effic.)	Flame Spray	Powder 123	10 lbs/yr	0%	95%
			Powder XYZ	75 lbs/yr	20%	75%
		Twin-Wire	Wire #1	80 lbs/yr	20%	5%

An example calculation is provided below for Thermal Spraying Inc.:

Step 1: Identify all thermal spraying materials that contain at least 0.1% by weight of chromium (Cr) or nickel (Ni).

The following four products contain chromium or nickel: Powder 123; Powder ABC; Powder XYZ; Wire #1.

Step 2: Determine the total percentage of chromium and/or nickel.

Materials Used	% Total Chromium	% Nickel
Powder 123	0%	95%
Powder ABC	25%	0%
Powder XYZ	20%	75%
Wire #1	20%	5%

If a thermal spraying material contains a compound, include only the portion that is chromium or nickel. For example, if the material contains 95% chromium oxide (Cr_2O_3), the weight percent of chromium would be calculated as follows:

$$[\text{Chromium Weight \%}] = [\text{Weight \% } Cr_2O_3] * \frac{[\text{Molecular Weight of Chromium } (Cr_2)]}{[\text{Molecular Weight of Chromium Oxide } (Cr_2O_3)]}$$

Molecular Weight of Chromium (Cr_2) = (52 g/g-mol)*(2) = 104 g/g-mol
Molecular Weight of Chromium Oxide (Cr_2O_3) = (52 g/g-mol)*(2)+(16)*(3) = 152 g/g-mol

$$[\text{Chromium Weight \%}] = [95 \text{ \% } Cr_2O_3] * \frac{[104 \text{ g/g-mol}]}{[152 \text{ g/g-mol}]} = 65\%$$

Appendix 1 – Emission Calculation Method

Point Source Example (contd.):

Step 3: Compile the annual material usage.

Operation	Materials Used	Quantity Used
Plasma Spray	Powder ABC	25 lbs/yr
	Powder XYZ	50 lbs/yr
Flame Spray	Powder 123	10 lbs/yr
	Powder XYZ	75 lbs/yr
Twin-Wire	Wire #1	80 lbs/yr

Step 4: Calculate the annual usage quantities for chromium and nickel.

Materials Used	Quantity Used	% Total Chromium	% Nickel	Qty. of Total Chromium Used	Qty. of Nickel Used
Powder ABC	25 lbs/yr	25%	0%	[25 lbs/yr]x[25% Cr] = **6.25** lbs Cr/yr	[25 lbs/yr]x[0% Ni] = **0** lbs Ni/yr
Powder XYZ	50 lbs/yr	20%	75%	[50 lbs/yr]x[20% Cr] = **10.0** lbs Cr/yr	[50 lbs/yr]x[75% Ni] = **37.5** lbs Ni/yr
Powder 123	10 lbs/yr	0%	95%	[10 lbs/yr]x[0% Cr] = **0** lbs Cr/yr	[10 lbs/yr]x[95% Ni] = **9.5** lbs Ni/yr
Powder XYZ	75 lbs/yr	20%	75%	[75 lbs/yr]x[20% Cr] = **15.0** lbs Cr/yr	[75 lbs/yr]x[75% Ni] = **56.25** lbs Ni/yr
Wire #1	80 lbs/yr	20%	5%	[80 lbs/yr]x[20% Cr] = **16.0** lbs Cr/yr	[80 lbs/yr]x[5% Ni] = **4.0** lbs Ni/yr

Step 5: Identify the applicable emission factors.

Control Device	Operation	Emission Factor - Hexavalent Chromium (lb Cr^{+6}/lb Cr)	Emission Factor – Nickel (lb Ni/lb Ni sprayed)
HEPA Filter	Plasma Spray	2.86E-06	1.72E-05
Dry Filter	Flame Spray	6.20E-05	1.10E-03
(99% effic.)	Twin-Wire	6.96E-05	6.0E-05

Appendix 1 – Emission Calculation Method

Point Source Example (contd.):

Step 6: Calculate annual emissions (*[Annual Emissions] = [Emission Factor]*[Annual Usage].*)

For hexavalent chromium, the annual emissions are –

Booth	Control Device	Operation	Materials Used	Qty. of Total Chromium Used (lbs Cr/yr)	Emission Factor (lb Cr^{+6}/lb Cr)	Annual Emissions (lb Cr^{+6}/yr)
#1	HEPA Filter	Plasma Spray	Powder ABC	6.25	2.86E-06	[6.25]x[2.86E-06] = **1.79E-05**
			Powder XYZ	10.0	2.86E-06	[10.0]x[2.86E-06] = **2.86E-05**
#2	Dry Filter (99% effic.)	Flame Spray	Powder 123	0	6.20E-05	[0]x[6.20E-05] = **0**
			Powder XYZ	15.0	6.20E-05	[15.0]x[6.20E-05] = **9.30E-04**
		Twin-Wire	Wire #1	16.0	6.96E-05	[16.0]x[6.96E-05] = **1.11E-03**
					Total =	**0.002**

Based on this emission level, Thermal Spraying Inc. is below the Tier 1 threshold for hexavalent chromium. Therefore, no new control efficiency requirements would be imposed by this ATCM because of hexavalent chromium emissions.
However, Thermal Spraying Inc. will still need to comply with the permitting, monitoring, and recordkeeping requirements of the ATCM. In addition, if the workload increased and emissions exceeded Tier 1 thresholds, it would be necessary to upgrade the dry filter system or limit the usage of all chromium materials to the booth that has the HEPA filter.

For nickel, the annual emissions are –

Booth	Control Device	Operation	Materials Used	Qty. of Nickel Used (lbs Ni/yr)	Emission Factor (lb Ni/lb Ni sprayed)	Annual Emissions (lb Ni/yr)
#1	HEPA Filter	Plasma Spray	Powder ABC	0	1.72E-05	[0]x[1.72E-05] = **0**
			Powder XYZ	37.5	1.72E-05	[37.5]x[1.72E-05] = **6.45E-04**
#2	Dry Filter (99% effic.)	Flame Spray	Powder 123	9.5	1.10E-03	[9.5]x[1.10E-03] = **1.05E-02**
			Powder XYZ	56.25	1.10E-03	[56.25]x[1.10E-03] = **6.19E-02**
		Twin-Wire	Wire #1	4.0	6.0E-05	[4.0]x[6.0E-05] = **2.40E-04**
					Total =	**0.073**

Appendix 1 – Emission Calculation Method

Point Source Example (contd.):

Based on this emission level, Thermal Spraying Inc. is below the Tier 1 threshold for nickel. Therefore, no new control efficiency requirements would be imposed by this ATCM because of nickel emissions. However, Thermal Spraying Inc. will still need to comply with the permitting, monitoring, and recordkeeping requirements of the ATCM. In addition, if the workload increased and emissions exceeded Tier 1 thresholds, it would be necessary to upgrade the dry filter system or limit the usage of all nickel materials to the booth that has the HEPA filter.

Step 7: Calculate the maximum hourly emissions for nickel.

Powder 123 is the material that has the highest weight percentage of nickel (95%).
The maximum spray rate for the flame spraying gun is 10 lbs/hr.
The emission factor for flame spraying is 1.10E-03 lb Ni/lb Ni sprayed.

[Maximum Hourly Usage] = [Maximum Gun Spray Rate]*[Maximum Wt.% Nickel]
[Maximum Hourly Usage] = [10 lbs/hr]*[95% Ni] = 9.5 lbs Ni sprayed/hr

[Maximum Hourly Emissions] = [Emission Factor]*[Maximum Hourly Usage]
Maximum Hourly Emissions = [1.10E-03 lb Ni/lb Ni sprayed]*[9.5 lbs Ni sprayed/hr] = 0.01 lb Ni/hr

The maximum hourly emissions for nickel are 0.01 lbs Ni/hr, which is well below the compliance limit of 0.1 lb Ni/hr for point sources. Therefore, this thermal spraying operation complies with the maximum hourly limit for nickel.

Appendix 1 – Emission Calculation Method

Volume Source Example:

Machine Shop Inc. conducts flame spraying with powder on small parts. The parts are turned on a lathe while spraying is being performed. Since the lathe is not located in a booth, the shop uses a portable local exhaust fan to remove fumes from the worker's breathing area. This type of operation would be considered a volume source with 0% control efficiency. Listed below is information on the facility's operations:

Booth	Control Device	Operation	Materials Used	Quantity Used	% Total Chromium	% Nickel
None	None (uncontrolled)	Flame Spray	Powder 123	20 lbs/yr	0%	95%
			Powder XYZ	5 lbs/yr	20%	75%

An example calculation is provided below for Machine Shop Inc.:

Step 1: Identify all thermal spraying materials that contain at least 0.1% by weight of chromium (Cr) or nickel (Ni).

The following two products contain chromium or nickel: Powder 123 and Powder XYZ.

Step 2: Determine the total percentage of chromium and/or nickel.

Materials Used	% Total Chromium	% Nickel
Powder 123	0%	95%
Powder XYZ	20%	75%

Step 3: Compile the annual material usage.

Operation	Materials Used	Quantity Used
Flame Spray	Powder 123	20 lbs/yr
	Powder XYZ	5 lbs/yr

Step 4: Calculate the annual usage quantities for chromium and nickel.

Materials Used	Quantity Used	% Total Chromium	% Nickel	Qty. of Total Chromium Used	Qty. of Nickel Used
Powder 123	20 lbs/yr	0%	95%	[20 lbs/yr]x[0% Cr] = **0** lbs Cr/yr	[20 lbs/yr]x[95% Ni] = **19.0** lbs Ni/yr
Powder XYZ	5 lbs/yr	20%	75%	[5 lbs/yr]x[20% Cr] = **1.0** lbs Cr/yr	[5 lbs/yr]x[75% Ni] = **3.75** lbs Ni/yr

Appendix 1 – Emission Calculation Method

Volume Source Example (contd.):

Step 5: Identify the applicable emission factors.

Control Device	Operation	Emission Factor - Hexavalent Chromium (lb Cr^{+6}/lb Cr)	Emission Factor – Nickel (lb Ni/lb Ni sprayed)
Uncontrolled	Flame Spray	6.20E-03	1.10E-01

Step 6: Calculate annual emissions (*[Annual Emissions] = [Emission Factor]*[Annual Usage].*)

For hexavalent chromium, the annual emissions are –

Booth	Control Device	Operation	Materials Used	Qty. of Total Chromium Used (lbs Cr/yr)	Emission Factor (lb Cr^{+6}/lb Cr)	Annual Emissions (lb Cr^{+6}/yr)
None	None	Flame Spray	Powder 123	0	6.20E-03	[0]x[6.20E-03] = 0
			Powder XYZ	1.0	6.20E-03	[1.0]x[6.20E-03] = 6.20E-03
					Total =	**0.006**

Based on this emission level, Machine Shop Inc. is classified as Tier 1 for hexavalent chromium. Therefore, the thermal spraying operation would need to install a new booth with a control device that met the Tier 1 minimum efficiency requirement of 99%. In addition, Machine Shop Inc. would need to comply with the permitting, monitoring, and recordkeeping requirements of the ATCM. Machine Shop Inc. could avoid having to install a new booth and control device, if they eliminated the use of chromium-containing materials.

For nickel, the annual emissions are –

Booth	Control Device	Operation	Materials Used	Qty. of Nickel Used (lbs Ni/yr)	Emission Factor (lb Ni/lb Ni sprayed)	Annual Emissions (lb Ni/yr)
None	None	Flame Spray	Powder 123	19.0	1.10E-01	[19.0]x[1.10E-01] = 2.09
			Powder XYZ	3.75	1.10E-01	[3.75]x[1.10E-01] = 4.13E-01
					Total =	**2.50**

Appendix 1 – Emission Calculation Method

Volume Source Example (contd.):

Based on this emission level, Machine Shop Inc. is below the Tier 1 threshold for nickel. Therefore, no new control efficiency requirements would be imposed by this ATCM because of nickel emissions. However, this ATCM requires thermal spraying operations to comply with the most stringent control efficiency. Since the control efficiency requirement based on hexavalent chromium is the most stringent, they must comply with the 99% control efficiency.

Step 7: Calculate the maximum hourly emissions for nickel.

Powder 123 is the material that has the highest weight percentage of nickel (95%).
The maximum spray rate for the flame spraying gun is 10 lbs/hr.
The emission factor for flame spraying is 1.10E-01 lb Ni/lb Ni sprayed.

[Maximum Hourly Usage] = [Maximum Gun Spray Rate]*[Maximum Wt.% Nickel]
[Maximum Hourly Usage] = [10 lbs/hr]*[95 % Ni] = 9.5 lbs Ni sprayed/hr

[Maximum Hourly Emissions] = [Emission Factor]*[Maximum Hourly Usage]
Maximum Hourly Emissions = [1.10E-01 lb Ni/lb Ni sprayed]*[9.5 lbs Ni sprayed/hr] = 1.1 lb Ni/hr

The maximum hourly emissions for nickel are 1.1 lbs Ni/hr, which exceeds the compliance limit of 0.01 lb Ni/hr for volume sources. Therefore, this thermal spraying operation does not comply with the maximum hourly limit for nickel and it would be necessary to reduce emissions (e.g., install a control device, limit usage, etc.)

Appendix 2 –Method for Measuring Inward Face Velocity

Inward face velocity must be measured at least once every 30 days to ensure that the ventilation system is working properly. Measurements must be conducted in accordance with the procedures specified in this Appendix 2 or an alternative method approved by the permitting agency.

1. Hood Measurement:

Divide the face of the hood, the slot area, or the normal plane, at the capture velocity measurement point into equal area rectangles (see Figure 1). The side of each rectangular area should be no longer than 12 inches. Measure the air velocity (fpm) at the center of each rectangle using a calibrated anemometer or other measuring device approved by the permitting agency. The velocity measuring device must have an accuracy of at least ±10% of full scale. The measuring device must be in good condition, of proper velocity range, and operated according to the manufacturer's instructions. The measuring device must be calibrated in accordance with the manufacturer's recommendations. Do not block or disturb the airflow while taking the readings.

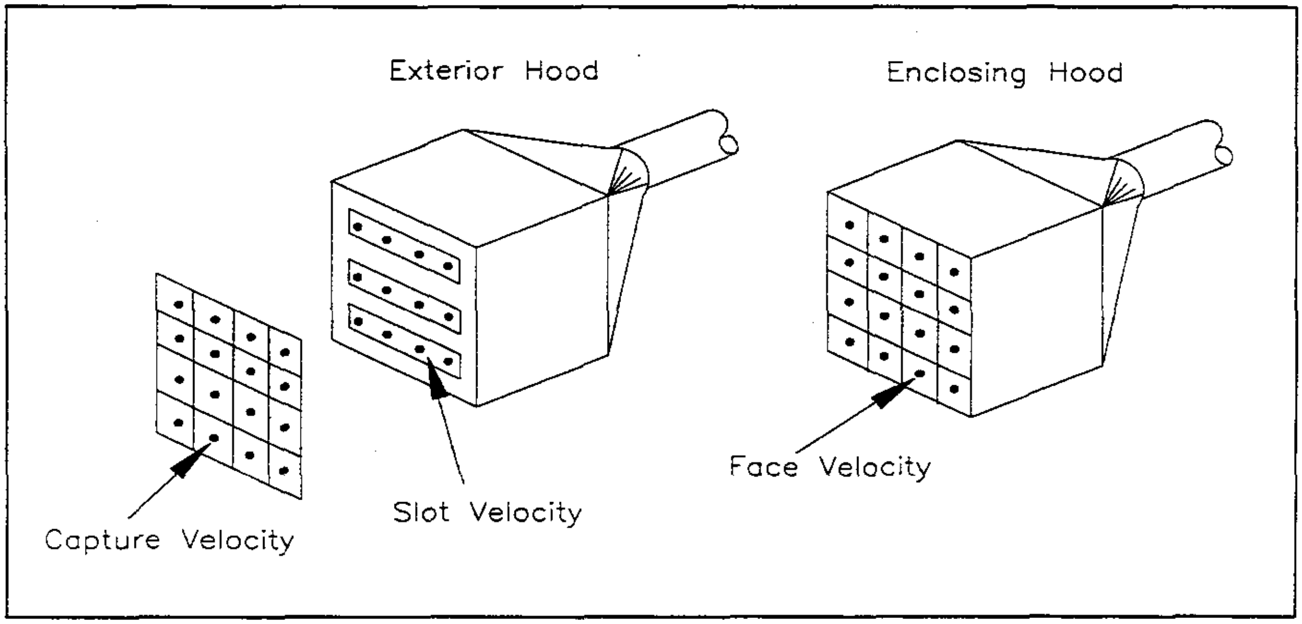


Figure 1: Airflow distribution measurement for an exterior hood and an enclosing hood

Measure the volumetric airflow rate through the hood by measuring the velocity at the center of each equal-sized rectangular area (i.e., by performing pitot traverses.) If no suitable location exists for performing complete pitot traverses, measure the slot velocity and use this data to estimate the volumetric airflow rate through a hood.

Appendix 2 –Method for Measuring Inward Face Velocity

2. Walk-in Booth Measurement:

For a cross-draft walk-in booth (i.e., air enters through filters in the front of the booth and leaves through filters in the back of the booth):

Empty the walk-in booth prior to the airflow distribution measurement. Divide the **length** of the booth into at least three cross-sectional areas to obtain the velocity profile in the booth. One cross-sectional area must be located near the exhaust plenum, one close to the supply plenum, and the other in the middle of the booth. Figure 2 illustrates the location of cross-sectional areas. Record the distance between each cross-sectional area and the exhaust or supply plenums. The distance between each cross-sectional area must not exceed ten feet.

Lay out imaginary grid lines through each cross sectional area. Use the intersections of the grid lines as locations to measure velocities inside the booth. The intersection points must be no more than six feet apart. Record the location of each point on the grid. Measure the air velocity (fpm) at each intersection point on the grid using a calibrated anemometer or other measuring device approved by the permitting agency. The velocity measuring device must have an accuracy of at least ±10% of full scale. The measuring device must be in good condition, of proper velocity range, and operated according to the manufacturer's instructions. The measuring device must be calibrated in accordance with the manufacturer's recommendations.

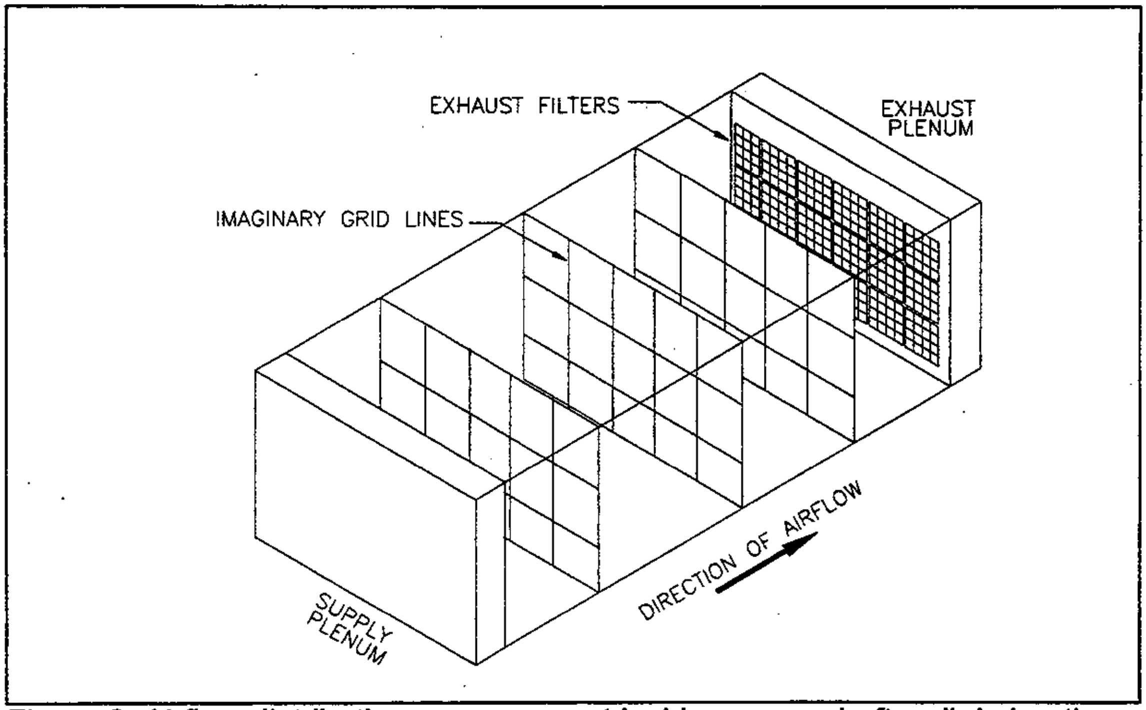


Figure 2: Airflow distribution measurement inside a cross-draft walk-in booth

Appendix 2 –Method for Measuring Inward Face Velocity

For a down-draft walk-in booth (i.e., air enters through filters in the ceiling of the booth and leaves through filters that cover trenches under a metal grate floor):

Empty the walk-in booth prior to the airflow distribution measurement. Divide the **height** of the booth into at least three cross-sectional areas to obtain the velocity profile in the booth. One cross-sectional area must be located near the exhaust plenum, one close to the supply plenum, and the other in the middle of the booth. Record the distance between each cross-sectional area and the exhaust or supply plenums. The distance between each cross-sectional area must not exceed ten feet.

Lay out imaginary grid lines through each cross sectional area. Use the intersections of the grid lines as locations to measure velocities inside the booth. The intersection points must be no more than six feet apart. Record the location of each point on the grid. Measure the air velocity (fpm) at each intersection point on the grid using a calibrated anemometer or other measuring device approved by the permitting agency. The velocity measuring device must have an accuracy of at least ±10% of full scale. The measuring device must be in good condition, of proper velocity range, and operated according to the manufacturer's instructions. The measuring device must be calibrated in accordance with the manufacturer's recommendations.

3. Average Value of Readings

Calculate the average value for all velocity readings, if all individual readings are within ± 20% of the average value. Do not include turbulent readings when calculating the average (turbulent airflow may be indicated by negative or zero velocity readings.) Record and make available for inspection by the permitting agency the entire velocity profile to show the airflow distribution.

Examples:

Hood A – Velocity Readings (fpm)		
100	90	110
85	115	100
105	95	100
Average Velocity = 900 fpm / 9 = 100 fpm		

Hood B – Velocity Readings (fpm)		
200	200	0
200	50	0
100	-5 *	-45 *
Average velocity = 750 fpm / 7 = 107 fpm **		

* Negative values indicate airflow in reverse direction and are not included in the average.
** This is not a valid average, because individual readings are not within ±20% of the average. The booth airflow needs to be adjusted and balanced before the velocity is measured again.

Appendix 3 – Leak Check Visual Inspection Checklist

Visual inspections must be conducted at least once every 90 days to ensure that no leaks are present in the control device or ventilation system. At a minimum, the inspection must include the items listed in the following checklist that are applicable. In addition to the items on this checklist, thermal spraying operations must inspect items in accordance with manufacturers' recommendations.

✓ Acceptable
✕ Unacceptable

Item to be Inspected	Look For -	Dates of Inspection:			
1. Hoods	Dents, holes, corrosion				
2. Ductwork	Dents, holes, corrosion				
	Blockages, plugging				
3. Dampers	Deterioration of seals/gaskets				
	Settings				
4. Access doors	Deterioration of seals/gaskets				
	Gaps when door is closed				
5. Fan housing	Deterioration of seals/gaskets				
	Gaps in connection to ductwork				
6. Dry filter media	Holes, gaps, abrasions				
	Does filter need to be changed?				
	Dust on clean side of filter?				
7. Dry filter mounting frame	Deterioration of seals/gaskets				
8. Other items inspected (provide descriptions):					
9. Corrective actions (provide descriptions & dates):					
10. Initials of person doing inspection:					

NOTE: Authority Cited: Sections 39600, 39601, 39650, 39658, 39659, 39666, and 41511, Health and Safety Code. Reference: Sections 39650, 39658, 39659, 39666, and 41511, Health and Safety Code

Appendix B

2003 Thermal Spraying Materials Survey

and

2004 Thermal Spraying Facility Survey

2003 Thermal Spraying Materials Survey

A.Survey for Sales of Thermal Spray Materials in California

PLEASE PROVIDE REQUESTED DATA BY OCTOBER 22, 2003:

CALIFORNIA AIR RESOURCES BOARD
STATIONARY SOURCE DIVISION
MEASURES ASSESSMENT BRANCH
P.O. BOX 2815
SACRAMENTO, CA 95812

?QUESTIONS?
CONTACT: MONIQUE DAVIS
(916) 324-8182
E-MAIL: mdavis@arb.ca.gov
FAX: (916) 324-8026

FORM I: GENERAL INFORMATION

Step 1: Please provide general company contact information.

Company Name: ______________________

Company Address: ______________________

Point of Contact: ______________________

Telephone Number: ______________________

Fax Number: ______________________

E-mail Address: ______________________

Step 2: Did you sell thermal spraying materials in California during 2002? ❑ YES ❑ NO
If "NO", please stop here and FAX this page to (916) 324-8026, Attn: Monique Davis.

Step 3: If you require the data submitted for this survey to be kept confidential, please complete the enclosed "Confidentiality Form". Clearly label all data submitted as confidential.

Step 4: Please provide an estimated breakdown, by category, for your annual thermal spraying materials sales in California (calendar year 2002).

____ % Aerospace	____ % Agriculture	____ % Automotive
____ % Computers	____ % Electronics	____ % Marine
____ % Medical	____ % Metal Working	____ % Military Working
____ % Offshore Applications	____ % Paper/Printing	____ % Petrochemicals
____ % Pumps/Motors	____ % Railroad	____ % Refineries
____ % Utilities	____ % Other ____________	

Legal authority and confidentiality. *This request for information is made pursuant to* sections 39607, 39701, and 41511 of the California Health and Safety Code, and Title 17, California Code of Regulations, section 91100. *These sections authorize the ARB to require the submission of information needed to estimate atmospheric emissions and to carry out its other statutory responsibilities. All survey data will be protected as confidential information, in accordance with* Title 17, California Code of Regulations, sections 91000 to 91022 and the California Public Records Act (Government Code section 6250 et seq.).

B.Survey for Sales of Thermal Spray Materials in California

FORM II: PRODUCT SALES DATA

*Step 5: Please report 2002 annual sales for all thermal spraying materials sold in California. Only include those products that contain at least **0.1%** (by weight) of the targeted compounds in the attached list (e.g., chromium, nickel, cobalt, copper). Make additional copies of this page, as needed, to submit data for additional products.*

Product Name: ______________________________

Product Code: ______________________________

Annual Sales in California: (by weight) CY 2002 ❑ Lbs ❑ Tons ❑ Kgs

Chemical Constituents: (Name, wt%)

Chemical Name	Weight Percentage (%)

SOLD TO:

Step 6: Please describe the customers for this product, by industry category. Check all that apply.

___ Aerospace
___ Agriculture
___ Automotive
___ Computers
___ **Electronics**
___ **Marine**
___ **Medical**
___ **Metal Working**
___ **Military**
___ Offshore Applications
___ Paper/Printing
___ Petrochemicals
___ Pumps/Motors
___ Railroad
___ Refineries
___ Utilities
Other: ____________

Step 7: Please identify the thermal spraying processes for this product. Check all that apply.

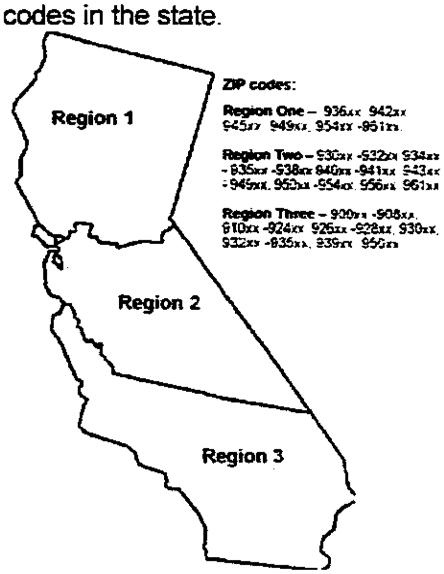
Powder	Wire/Rod
___ **High Velocity Oxy-Fuel (HVOF)**	___ Twin-Wire Electric Arc
___ **Flame Spray**	___ Single-Wire Flame
___ **Plasma Spray**	Other: ____________
___ Detonation Gun	

Step 8: Please estimate the number of customers in each region.

Region 1 : ______	Region 2 : ______	Region 3 : ______

REGION LOCATOR KEY

To better identify the number of facilities within California, we have divided the State into three regions and provided a Region Locator Key that lists all the prefixes for zip codes in the state.



C.Survey for Sales of Thermal Spray Materials in California

Ingredients of Interest

On Form II, please report 2002 sales of products that contain at least **0.1%** (by weight) of the targeted compounds in the following list:

Chemical Name	CAS Number
Antimony and Compounds	7440-36-0
Arsenic and Compounds	7440-38-2
Asbestos	1332-21-4
Beryllium and Compounds	7440-41-7
Bromine and Compounds	7726-95-6
Cadmium and Compounds	7440-43-9
Chromium and Compounds	7440-47-3
Chromium 6+ (hexavalent) and Compounds	18540-29-9
Chromium 3+ (trivalent) and Compounds	16065-83-1
Copper and Compounds	7440-50-8
Cyanide Compounds (Inorganic)	57-12-5
Fluoride Compounds (Inorganic)	16984-48-8
Lead and Compounds	7439-92-1
Manganese and Compounds	7439-96-5
Mercury and Compounds	7439-97-6
Nickel	7440-02-0
Phosphorus (white)	7723-14-0
Sodium Hydroxide	1310-73-2
Vanadium and Compounds	7440-62-2

This table is based on the data compiled by the Office of Environmental Health Hazard Assessment (OEHHA) in the "Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values".

2004 Thermal Spraying Facility Survey

THERMAL SPRAYING FACILITY SURVEY

I. GENERAL FACILITY INFORMATION

NAME OF FACILITY:

IS YOUR FACILITY A WHOLLY OWNED SUBSIDIARY OF ANOTHER COMPANY: ❑ YES ❑ NO

If "Yes", please provide parent company name:

CONTACT PERSON:

TITLE:

ADDRESS:

PHONE:

FAX:

E-MAIL:

II. EQUIPMENT INFORMATION

Type Of Thermal Spraying:	❑ Flame Spraying	❑ Electric Arc Spraying
	❑ Plasma Arc Spraying	❑ High-Velocity Oxy-Fuel (HVOF)
	❑ Detonation Gun	❑ Other (Describe)__________

Is Thermal Spraying Conducted In A Booth? ❑ YES ❑ NO

If YES, Please Describe Booths And Control Devices:

BOOTH #1:		
Type of Booth:	Control Device:	
❑ Complete Enclosure	❑ Dry Filter Cartridge	❑ HEPA Filter
❑ Partial Enclosure	❑ Water Curtain	❑ Wet Scrubber
Ventilation System?	❑ Other (Describe) __________	
❑ YES ❑ NO	Changeout Frequency __________	

BOOTH #2:		
Type of Booth:	Control Device:	
❑ Complete Enclosure	❑ Dry Filter Cartridge	❑ HEPA Filter
❑ Partial Enclosure	❑ Water Curtain	❑ Wet Scrubber
Ventilation System?	❑ Other (Describe) __________	
❑ YES ❑ NO	Changeout Frequency __________	

If NO, Do You Use Portable Thermal Spraying Equipment? ❑ YES ❑ NO

Complete Enclosure

Partial Enclosure

THERMAL SPRAYING FACILITY SURVEY

(cont'd)

III. MATERIALS INFORMATION

Type Of Materials Used: ❑ Powder ❑ Wire ❑ Other (Describe)____________

Metals Used: ❑ Chromium ❑ Nickel ❑ Cobalt ❑ Manganese

❑ Other (Describe) ____________________

Estimated Quantities Used Annually: ____________________ ❑ Lbs/yr ❑ Tons/yr ❑ Kgs/yr

IV. FACILITY OPERATING INFORMATION

Days of Operation: ____________________ Operating Hours: ____ a.m. to ____ p.m.

Hours Per Day Doing Thermal Spraying

❑ Less Than 1 Hour ❑ 1 – 4 Hours ❑ Greater Than 4 Hours

Total Number Of Employees: ______________

Number Of Employees Doing Thermal Spraying: ____________

Gross Annual Revenue For Facility:

❑ Less Than $100,000 ❑ $100,000 to $500,000 ❑ $500,000 to $1,000,000

❑ Greater Than $1,000,000

Percentage Of Revenue From Thermal Spray Operations: ________%

❑ Please check this box if you wish the survey data to be confidential*.

THANK YOU!

Please return completed survey by February 9, 2004, to:

FAX: 916-324-8026, Attention – Monique Davis

OR

MAIL:
Air Resources Board
Stationary Source Division, MAB
Attn: Monique Davis
P.O. Box 2815
Sacramento, CA 95812

Questions? Contact Monique Davis at 916-324-8182 or e-mail mdavis@arb.ca.gov

** In accordance with title 17, California Code of Regulations (CCR), sections 91000 to 91022, and the California Public Records Act (Government Code section 6250 et seq.), the information that a company provides to the Air Resources Board (ARB) may be released: (1) to the public upon request, except trade secrets which are not emissions data or other information which is exempt from disclosure or the disclosure of which is prohibited by law; (2) to the United States Environmental Protection Agency (U.S EPA), which protects trade secrets as provided in section 114(c) of the Clean Air Act and amendments thereto (42 USC 7401 et seq.) and in federal regulation; and (3) to other public agencies provided that those agencies preserve the protections afforded information which is identified as a trade secret, or otherwise exempt from disclosure by law (section 39660(e)).*

Appendix C

Methodology for Estimating Hexavalent Chromium Emissions from Thermal Spraying

C.1. Introduction

Hexavalent chromium emissions from thermal spraying can be estimated by direct measurement of facility exhaust gases or by performing calculations based on material usage. Measurement of exhaust gases is generally the preferred method for individual facilities, but conducting stack exhaust tests can be costly. Therefore, we have developed calculation methods that can be used to estimate hexavalent chromium emissions for different types of thermal spraying processes and the associated air pollution control devices. The following sections describe the process that was used to develop emission estimation methods for thermal spraying.

C.2. Hexavalent Chromium Fumes from Thermal Spraying

Hexavalent chromium and hexavalent chromium compounds are classified as toxic air contaminants, but hexavalent chromium compounds are not generally present in thermal spraying materials as a raw ingredient. The types of chromium that are listed as ingredients include:

- Chromium CAS # 7440-47-3
- Chromium +3 (trivalent) CAS # 16065-83-1
- Chromium Oxide CAS # 1308-38-9

Even though hexavalent chromium compounds are not originally present in thermal spraying materials, numerous stack tests have measured emissions of hexavalent chromium from thermal spraying facilities. This indicates that a conversion occurs during the thermal spraying process to change chromium from an elemental or trivalent state to a hexavalent state. A supplier of thermal spraying materials has found that hexavalent chromium may be produced when materials are exposed to the high temperatures that are involved in many thermal spraying processes (Praxair, 2002). In addition, a thermal spraying industry report states that vaporized metallic chromium can cause a small fraction of the chromium to oxidize and form chromates that contain a hexavalent form of chromium (Smith, 1994). This conversion to hexavalent chromium was measured during Sawatari's study of a plasma metal spraying process with chromium metal (Sawatari, 1986). Researchers used a METCO 7MC plasma metal sprayer and 99.9% chromium powder to generate fumes that were then analyzed to determine the hexavalent chromium content. Total chromium was determined with an atomic absorption spectrometer. Hexavalent chromium was determined by the colorimetric method, using an ultraviolet-visible (UV-Vis) spectrophotometer. Results indicated that metallic chromium was undetectable in the fumes (less than 0.5% of the total), but the fumes did contain 30% hexavalent chromium compounds as shown in Table C-1.

Table C-1:
Chromium Compounds in Plasma Spraying Fumes

Name of Compound	CAS #	MW*	% of Total
Dichromium Trioxide (Cr_2O_3) [corundum structure]	1308-38-9	152	25%
Chromium (VI) Trioxide (CrO_3)	1333-82-0	100	**3%**
Mixed Oxide Fraction Containing:			
Dichromium (III) Trioxide (Cr_2O_3)	1308-38-9	152	45%
Chromium (VI) Trioxide (CrO_3)	1333-82-0	100	**27%**
		Total =	100%

*MW = Molecular Weight, grams/mole

In another study, researchers used a plasma spraying gun to generate metal fumes from chromium powder. Total chromium was determined with an atomic absorption spectrometer. Hexavalent chromium was determined by the colorimetric method, using an ultraviolet-visible (UV-Vis) spectrophotometer. Chemical analysis determined that 26.4% of the total chromium was hexavalent and the residue was trivalent (Serita, 1990). These results are consistent with the values obtained from Sawatari's study.

The California Occupational Safety and Health Administration (Cal/OSHA) conducted additional research on plasma spraying activities (Gold, 2000). They conducted personal air sampling during two days of plasma spraying activities and measured the concentrations of hexavalent chromium, total chromium, and nickel. Hexavalent chromium was measured using the following analytical methods: NIOSH 7600 (visible absorption spectrophotometry), NIOSH 7604 (ion chromatography conductivity detection), and OSHA 215 (ion chromatography with UV-Vis detector). For the first day, the hexavalent chromium concentration was 0.074 mg/m^3 for two different samples, while the total chromium concentration was 0.110 mg/m^3 for one sample and 0.230 mg/m^3 for the other sample. On the second day, hexavalent chromium levels were much higher, measuring 0.646 mg/m^3 for one sample and 7.230 mg/m^3 for the other sample, while total chromium was 10.172 mg/m^3 and 27.258 mg/m^3, respectively. Based on these results, it is possible to estimate the percentage of total chromium that is in the hexavalent form (e.g., 0.074 /0.110 mg/m^3 = 67%). The average percentage of hexavalent chromium is 33%, which is consistent with the results from the Sawatari and Serita studies.

Hexavalent chromium emissions were also measured during a NIOSH Health Hazard Evaluation at a thermal spraying facility (NIOSH, 1989). Air samples were collected while workers conducted electric arc spraying with wires made of stainless steel, bronze, and alcro (aluminum, chromium, and iron). These samples were analyzed for a variety of metals, including hexavalent chromium, total chromium, and nickel. Hexavalent chromium was measured using the analytical method of NIOSH 7600 (visible absorption spectrophotometry.) During twelve sampling events, hexavalent chromium was detected in concentrations ranging from 0.12 to 0.34 mg/m^3 at the face of the ventilation hood. Total chromium concentrations ranged from 1.82 to 2.22 mg/m^3 and the average percentage of hexavalent chromium was 11%. These results confirm that hexavalent chromium is generated during electric arc spraying, but the percentage of hexavalent chromium in the fumes is lower than has been measured for plasma spraying. This may be because plasma spraying generates much higher temperatures and particle velocities than electric arc spraying.

As these studies demonstrate, the formation of hexavalent chromium during thermal spraying has been documented for a variety of sources, but the quantities that are emitted can vary widely, depending on the type of process and the type of control device. Some stack tests have found that more than 90% of the total chromium being measured consists of hexavalent chromium, while other tests have found less than 5%. The most conservative approach for estimating statewide emissions would be to assume maximum conversion to hexavalent chromium and complete consumption of all materials sold in California during 2002. However, ARB staff has developed a method that involves estimating emissions by compiling data from a variety of sources and a range of control devices. The following sections describe the different sources that were used to develop emission factors and estimate hexavalent chromium emissions on an annual basis and an hourly (average and maximum) basis.

C.2.1. Particle Sizes

Emissions and control device efficiencies are dependent on the size of the particles that are generated by thermal spraying processes. Some research has been done to measure particle sizes for thermal spraying processes and the results indicate that particle diameters can range from less than one micron to more than 100 microns. In Serita's study, fume particles from a plasma spraying gun were examined with a scanning electron microscope. The mass median aerodynamic diameter and the geometric standard deviation of the chromium fumes were 2.1 um and 2.00 um, respectively. Those of the nickel fumes were 3.7 um and 1.74 um, respectively (Serita, 1990). Chadwick's study also used a scanning electron microscope to examine fume particulate generated by electric arc, plasma and detonation gun spraying. This study found that particles were of two distinct types: crystalline/angular particles with diameters from 5 um to 20 um and smaller spherical particles ranging from <1 um to 10 um. Both plasma and detonation gun spraying produced a high proportion of particles with a diameter <2 um (Chadwick, 1997.) Both Chadwick's and Serita's studies indicate that metal fumes from thermal spraying contain a large portion of particles that are less than 5 um. We also found data on the "dust" that is generated by thermal spraying. Table C-2 contains particle size distributions for a variety of thermal spraying processes and the results indicate that 90% of the dust particles are larger than 5 microns (Smith, 1994). The analytical method that was used to measure these particles was not provided.

Table C-2:
Typical Particle Size Distributions in Dust of Thermal Spray Processes

Process	1 um	>1-5 um	5-10 um	10-50 um	50-100 um	>100 um
Flame/Wire Metallizing	2	8	10	20	40	20
Wire-Arc (Zinc)	-	1	2	21	-	76
Wire-Arc (Aluminum)	10	-	3	-	87	-
Powder/Flame	1	9	20	30	30	10
HVOF	1	9	30	55	5	-
Plasma	3	7	30	40	20	-

(Smith, 1994)

C.3. Hexavalent Chromium Emission Factors - Summary

The general approach for estimating emissions involves multiplying emission factors by usage rates. Emission factors were obtained from a variety of sources, based on the type of process, the form of material being used (i.e., powder or wire), and the type of control device. In some cases, emission factors were taken directly from stack test results, while other factors were derived from a combination of stack test results, research data, and data on control efficiencies. Table C-3 summarizes the emission factors that were used and Section C.4 describes how these factors were derived.

Table C-3:
Emission Factor Summary – Hexavalent Chromium

Process	Emission Factors (lbs Cr^{+6}/lb Cr sprayed)			
	0% Ctl. Eff. (Uncontrolled)	90% Ctl. Eff. [1] (e.g. Water Curtain)	99% Ctl. Eff. (e.g. Dry Filter)	99.97% Ctl. Eff. (e.g., HEPA Filter)
Single-Wire Flame Spray[2]	4.68E-03	4.68E-04	4.68E-05	1.40E-06
Twin-Wire Electric Arc Spray[2]	6.96E-03	6.96E-04	6.96E-05	2.09E-06
Flame Spray[3]	6.20E-03	1.17E-03	6.20E-05	1.86E-06
HVOF[3]	6.20E-03	1.17E-03	6.20E-05	1.86E-06
Plasma Spray[4]	1.18E-02	6.73E-03	2.61E-03	2.86E-06
Other Thermal Spraying[5]	7.17E-03	2.05E-03	5.70E-04	2.01E-06

1. Listed below the control efficiencies are examples of control devices that may meet the control efficiency.
2. Emission factors based on Battelle study.
3. Emission factors based on SDAPCD stack test data for flame spraying.
4. Emission factors based on stack test results compiled by CATEF, SCAQMD, and SDAPCD.
5. For "Other Thermal Spraying" processes, we used an average of the emission factors for the listed thermal spraying processes.

C.4. Emission Factor Development

The following sections describe how emission factors are derived from various sources for different types of thermal spraying processes and control devices. In each case, emission factors are developed for operations that had no air pollution control devices (i.e., uncontrolled) and for operations that had control devices (i.e., controlled).

C.4.1. Emission Factors: Flame Spraying & Electric Arc Spraying with Wire

Emission factors for wire spraying are based on a study that was conducted by Battelle for the American Welding Society. The study was primarily focused on measuring fumes from welding, but it also included using an enclosed fume collection chamber to measure the quantities of fumes generated by combustion flame spraying with stainless steel wire, and twin-wire electric arc spraying with stainless steel wire (AWS, 1979.) Results of the study are summarized in Table C-4.

Table C-4:
Fume Generation Rates - Flame Spraying & Electric Arc Spraying with Wire

Process	[wt. of fumes] / [wt. of metal sprayed] (grams/kg)	Total Chromium Content in Fumes (weight %)	Type of Wire
Single-Wire Flame Spray	16.6	8-15	316 Stainless Steel (16-18 % Cr)
Twin-Wire Electric Arc Spray	19.75	10-20	Proprietary Stainless Steel (17-18 % Cr)

(AWS, 1979)

The results of this study can be used to determine the maximum pounds of total chromium fumes that are generated for each pound of chromium sprayed.

[max. wt. of total chromium in fumes] = [wt. of fumes]*[max. total chromium content in fumes]
[min. wt. of total chromium sprayed] = [wt. of metal sprayed]*[min. chromium content of metal]

Flame Spray (wire):
[max. wt. of total chromium in fumes] = [16.6 grams]*[15%] = 2.49 grams
[min. wt. of total chromium sprayed] = [1 kg metal]*[16%] = 0.16 kg = 160 grams
max. wt. of total Cr in fumes per lb. of total Cr sprayed = [2.49 g]/[160 g] = 1.56E-02 g Cr/g Cr sprayed
= 1.56E-02 lb Cr/lb Cr sprayed

Electric Arc:
[max. wt. of total chromium in fumes] = [19.75 grams]*[20%] = 3.95 grams
[min. wt. of total chromium sprayed] = [1 kg metal]*[17%] = 0.170 kg = 170 grams
max. wt. of total Cr in fumes per lb. of total Cr sprayed = [3.95 g]/[170 g] = 2.32E-02 g Cr/g Cr sprayed
= 2.32E-02 lb Cr/lb Cr sprayed

Since the study only measured total chromium, we used the conclusions of the Sawatari study and other studies to estimate that 30% of the total chromium consists of hexavalent chromium. Listed below are the uncontrolled emission factors for wire spraying processes.

Flame Spray (wire): [1.56E-02]*[30%] = **4.68E-03** lb Cr^{+6}/lb chromium sprayed

Electric Arc: [2.32E-02]*[30%] = **6.96E-03** lb Cr^{+6}/lb chromium sprayed

To determine controlled emission factors, we used the following equation:

Eqn. 1: [Controlled Emission Factor] = [Uncontrolled Emission Factor][1 – Control Efficiency]*

Controlled emission factors for wire were developed for the following levels of control:

Control Efficiency Levels	
90%	(e.g., a water curtain)
99%	(e.g., dry filter)
99.97%	(e.g., a HEPA filter)

The actual control efficiency for a control device at a particular facility can depend on specific parameters (e.g., particle size, filter media, etc.), but the control efficiencies listed above are consistent with general industry estimates. Calculations for controlled emission factors are provided below:

Flame (wire) –

90% (e.g., water curtain): [4.68E-03 lb Cr^{+6}/lb wire]*[1 – 0.90] = **4.68E-04** lb Cr^{+6}/lb Cr
99% (e.g., dry filter): [4.68E-03 lb Cr^{+6}/lb wire]*[1 – 0.99] = **4.68E-05** lb Cr^{+6}/lb Cr
99.97% (e.g., HEPA filter): [4.68E-03 lb Cr^{+6}/lb wire]*[1 – 0.9997] = **1.40E-06** lb Cr^{+6}/lb Cr

Electric Arc –

90% (e.g., water curtain): [6.96E-03 lb Cr^{+6}/lb wire]*[1 – 0.90] = **6.96E-04** lb Cr^{+6}/lb Cr
99% (e.g., dry filter): [6.96E-03 lb Cr^{+6}/lb wire]*[1 – 0.99] = **6.96E-05** lb Cr^{+6}/lb Cr
99.97% (e.g., HEPA filter): [6.96E-03 lb Cr^{+6}/lb wire]*[1 – 0.9997] = **2.09E-06** lb Cr^{+6}/lb Cr

C.4.2. California Air Toxic Emission Factors – Thermal Spraying

ARB has developed a database of California Air Toxic Emission Factors (CATEF), based on source test data that were compiled for the Air Toxics Hot Spots Program. Source test reports were reviewed to verify the validity of the test methods and results. The validated report data were then used to develop the CATEF emission factors. The CATEF II database can be accessed on the ARB website (http://www.arb.ca.gov/emisinv/catef/catef.htm) and it includes a search function that enables users to identify emission factors for specific Source Classification Codes (SCCs). For thermal spraying, the CATEF II database contains emission factors for general thermal spraying of powdered metal (SCC 30904010) and plasma spraying of powdered metal (SCC 30904020).

CATEF contains thermal spraying emission factors for hexavalent chromium and total chromium, as shown in Table C-5. The factors are based on the quantity of material sprayed. To determine the emission factor based on the quantity of chromium metal sprayed, we used the following equation:

Eqn. 2:
$$\text{Emission Factor, } \frac{lbs\ Cr^{+6}}{lb\ chromium} = \text{Emission Factor, } \frac{lbs\ Cr^{+6}}{lb\ material} \times \frac{1}{wt\%\ chromium\ in\ material}$$

Different factors are provided based on the type of material that was sprayed and the air pollution control device (APC Device). In some cases, the APC Device is listed as an air filter, but no data were provided regarding control efficiency. Therefore, we have assumed that the air filters have a control efficiency of 99%, which is a low-end, conservative assumption for the efficiency of a dry filter system.

Table C-5:
Emission Factors – CATEF: Thermal Spraying Processes

Process*	APC Device	Material Type		Hexavalent Chromium Emission Factors		Total Chromium Emission Factors	
		Description	Wt % Cr	(lbs Cr^{+6}/lb matl used)	(lbs Cr^{+6}/lb Cr used)	(lbs total Cr/ lb matl used)	(lbs total Cr/ lb Cr used)
General Thermal Spray	None	8.5% Cr	8.5%	3.34E-05	3.93E-04	3.82E-03	4.49E-02
Plasma Spray	None	75%Cr_3C_2, 20%NiCr, 5% Cr	Unk.	1.63E-02	-	3.75E-01	-
Plasma Spray	None	80%Ni, 20%Cr	20%	2.58E-04	1.29E-03	1.86E-03	9.30E-03
Plasma Spray	None	100% Chromium Oxide	68%	8.90E-03	1.31E-02	1.42E-01	2.09E-01
Plasma Spray	Air Filter	70%Ni, 4%Cr	4%	1.81E-04	4.53E-03	1.86E-04	4.65E-03
Plasma Spray	Air Filter	49% Ni, 44%Cr	44%	3.01E-04	6.84E-04	4.03E-04	9.16E-04

* General Thermal Spraying of Powdered Metal – SCC 30904010
Plasma Arc Spraying of Powdered Metal – SCC 30904020
"Unk." – The total weight percent for chromium is unknown, because the chromium weight percentage in the Nickel-Chromium (NiCr) alloy was not specified.

Average CATEF hexavalent chromium emission factors were calculated as follows:

Plasma Spraying – Uncontrolled: (1.29E-03 + 1.31E-02)/2 = 7.20E-03 lbs Cr^{+6}/ lb Cr used
Plasma Spraying – Air Filter: (4.53E-03 + 6.84E-04)/2 = **2.61E-03** lbs Cr^{+6}/ lb Cr used

The uncontrolled CATEF value was then combined with factors from other sources to develop an overall average emission factor for plasma spraying (see Section C.4.5.)

C.4.3. SDAPCD Emission Factors for Plasma Spraying & Flame Spraying

The San Diego County Air Pollution Control District (SDAPCD) has compiled the following emission factors for various plasma spraying and flame spraying facilities, based on stack test data (SDAPCD, 1998).

Table C-6:
SDAPCD Emission Factors – Hexavalent Chromium and Nonhexavalent Chromium

SDAPCD Method #	Process	Control Device	Emission Factors (lb Cr^{+6}/lb Cr sprayed)	Emission Factors (lb non-hex Cr/lb Cr)
M01	Plasma Spray	HEPA	3.94E-06	3.31E-05
M02	Plasma Spray	HEPA	2.19E-06	1.35E-05
M03	Plasma Spray	HEPA	3.07E-06	2.32E-05
M04	Plasma Spray	Water Curtain	1.02E-03	2.70E-04
M05	Plasma Spray	Water Curtain	2.83E-03	2.08E-02
M06	Plasma Spray	Water Curtain	1.93E-03	1.05E-02
M08	Flame Spray	HEPA	**1.86E-06***	1.52E-04
M09	Flame Spray	Water Curtain	**1.17E-03***	7.15E-02

* Bold highlighting indicates a value that appears in the emission factor summary table.

For flame spraying facilities, the following controlled emission factors were used from SDAPCD Methods M08 and M09 –

HEPA Filter: **1.86E-06** lbs Cr^{+6}/lb chromium sprayed
Water Wash Booth: **1.17E-03** lbs Cr^{+6}/lb chromium sprayed

To determine an uncontrolled emission factor for a flame spraying facility, we used the following equation:

Eqn. 3: [Uncontrolled Emission Factor] = [Controlled Emission Factor]/[1 – Control Efficiency]

The uncontrolled emission factor for flame spraying was calculated as shown below:

Emission Factor for Flame Spraying with a HEPA Filter = 1.86E-06 lb Cr^{+6}/lb Cr sprayed
Estimated Control Efficiency for a HEPA Filter = 99.97%
[Uncontrolled Emission Factor] = [1.86E-06]/[1 – 0.9997] = **6.2E-03** lb Cr^{+6}/lb Cr sprayed

The emission factor for flame spraying with a dry filter was calculated as shown below:

Uncontrolled Emission Factor for Flame Spraying = 6.2E-03 lb Cr^{+6}/lb Cr sprayed
Control Efficiency = 99% (e.g., a dry filter)
[Controlled Emission Factor @ 99%] = [6.2E-03]*[1 – 0.99] = **6.2E-05** lb Cr^{+6}/lb Cr sprayed

The emission factors for flame spraying were also used to estimate emissions from HVOF processes, because they are both combustion-based operations that achieve comparable temperatures.

The emission factors in Table C-6 are based on stack test data from several thermal spraying facilities in the San Diego area. ARB staff reviewed these stack test results and selected tests that had the strongest staff evaluations. In addition to these tests, SDAPCD provided results from two stack tests that were conducted in 2002 at a plasma spraying facility. For plasma spraying, results from the following eight tests were selected to develop an average emission factor. All of the tests in Table C-6 used ARB Method 425 to measure hexavalent chromium emissions.

Table C-6:
Stack Test Results from Plasma Spraying Facilities in SDAPCD

Test #	Control Device	Material Sprayed During Test		Emissions	Emission Factor	
		Spray Rate (lb/hr)	Wt.% Chromium	(lbs Cr^{+6}/hr) per ARB Method 425	(lbs Cr^{+6}/ lb Cr sprayed)	(lbs total Cr/ lb Cr)
#1	HEPA	19.1	20.3%	1.037E-05	2.67E-06	2.36E-05
#2	Water Wash Booth	1.24	25.5%	5.23E-04	1.66E-03	1.64E-03
#3	HEPA	13.4	20%	1.03E-05	3.94E-06	3.70E-05
#4	Water Wash Booth	11.5	20%	6.15E-04	2.67E-04	6.72E-04
#5	HEPA	7.27	19%	8.19E-06	5.96E-06	2.02E-05
#6	HEPA	9.37	19%	6.59E-06	3.74E-06	1.62E-05
#7	HEPA	10.09	19%	8.28E-07	4.32E-07	6.42E-05
#8	HEPA	9.8	19%	8.29E-07	4.44E-07	1.06E-04
			Average:	HEPA	**2.86E-06**	4.45E-05
			Average:	Water Wash	9.64E-04	1.16E-03

(ERM, 1995; SCEC, 1998; SCEC, 1998a; SCEC, 2001; SDAPCD, 2002; SDAPCD, 2004)

The average value for the water wash booth in Table C-6 was combined with other data to develop an overall average emission factor for plasma spraying (see Section C.4.5.)

C.4.4. SCAQMD Emission Factors for Plasma Spraying

The South Coast Air Quality Management District (SCAQMD) worked with Pacific Environmental Services to develop an emission inventory for metal welding, cutting, and spraying operations. In May, 2000, Pacific Environmental Services completed an emission inventory report which contained metal spraying emission factors for total chromium (PES, 2000). The emission factors for total chromium were based on stack tests that were conducted at six facilities in the SCAQMD and the SDAPCD from 1987 to 1991. All of the facilities conducted plasma spraying during the stack tests. The report did not recommend an emission factor for hexavalent chromium, because the authors felt that the stack tests were conducted before improvements in laboratory methods allowed for reliable discrimination between total and hexavalent chromium. However, the report did refer to the previously cited Sawatari study which found that the fumes from plasma spraying contain approximately 30% hexavalent chromium (Sawatari, 1986).

The SCAQMD report concluded that the data could be reduced to two emission factors: one factor for a facility with a HEPA filter (1.0×10^{-5} lb total Cr/lb Cr sprayed), and another factor for all other facilities (5.1×10^{-2} lb total Cr/lb Cr sprayed). For the purposes of this report, we have reviewed the available stack test data and have used the results from 10 test runs at facilities with water curtains and 2 test runs at uncontrolled facilities to support development of our emission factors. The tests were conducted from 1989 to 1991. Listed below are average emission factors for total chromium and hexavalent chromium, based on the stack test data in the SCAQMD report (see Table C-7).

Table C-7:
Emission Factors – SCAQMD Plasma Spraying

Control Devices	Emission Factors		Test Methods
	(lb total chromium/ lb Cr sprayed)[1]	($lb\ Cr^{+6}$/ lb Cr sprayed)[2]	
Water Curtain	4.15E-02	1.25E-02	ARB Method 425 SCAQMD Method 205.1
Uncontrolled	5.44E-02	1.63E-02	Unknown

1. These values are based on stack test results in the SCAQMD report (PES, 2000.)
2. These values are based on the assumption that 30% of the total chromium is in the hexavalent form.

C.4.5. Summary of Average Plasma Spraying Emission Factors

CATEF, SDAPCD, and SCAQMD provided emission factors for plasma spraying processes. We used average values from these sources for our emission factor calculations, as shown below:

Table C-8:
Average Emission Factors – Plasma Spraying

Reference	Control Device	Emission Factor ($lb\ Cr^{+6}/lb\ Cr$)	Average Emission Factor ($lb\ Cr^{+6}/lb\ Cr$)
SDAPCD	Water Curtain	9.64E-04	**6.73E-03**
SCAQMD	Water Curtain	1.25E-02	
CATEF	Uncontrolled	7.20E-03	**1.18E-02**
SCAQMD	Uncontrolled	1.63E-02	

C.4.6. Thermal Spraying Emission Data from Other States

ARB staff contacted regulatory agencies in the following states to gather information on their methods for estimating emissions from thermal spraying sources:

Connecticut	Michigan	Pennsylvania
Florida	New Jersey	Texas
Georgia	New York	Virginia
Massachusetts	Ohio	Wisconsin

Most of the states that we contacted have permitting thresholds that allow smaller facilities to be exempt from obtaining an air permit. For example, some states do not require permitting or toxics screening for facilities that emit less than 1 ton/yr of hazardous air pollutants. Since many thermal spraying facilities fall below this threshold, the available permit data were generally restricted to relatively large thermal spraying operations. Stack testing was not required in most cases, so emissions were frequently estimated using the following equation:

Eqn. 4: Emissions, lbs PM/yr = [Material Usage, lbs/yr][1- T.E.]*[1 - Dropout]*[1 – C.E.]*

where

Emissions, lbs PM/yr = Pounds of particulate matter emissions per year

T.E. = Transfer Efficiency, which is the fraction of sprayed material that adheres to the part surface. Material that does not adhere to the surface is called overspray.

Dropout = The fraction of particles that drop out of the overspray before it is sent through the control device. This drop out can occur in the booth or the ductwork.

C.E. = Control Efficiency, which is the fraction of pollutants that are not emitted into the air due to the control device.

Equation #4 can be rearranged to yield an emission factor equation, as shown below:

Eqn. 5: $\text{Emission Factor, } \frac{\text{lbs PM}}{\text{lbs matl./yr}} = \frac{[\text{Emissions, lbs PM/yr}]}{[\text{Material Usage, lbs/yr}]} = [1 - T.E.]*[1 - \text{Dropout}]*[1 - C.E.]$

ARB has used this equation to compare the emission factors from other states with those developed by ARB. The following sections contain information that we obtained from other states for some of the thermal spraying facilities that were identified. We've also included some emission factor comparisons, which demonstrate that ARB's emission estimation methods are generally comparable to the methods used by other states.

Connecticut

Sources Identified - Staff members identified one Title V source that operates two thermal spraying booths, one for plasma spraying and one for HVOF spraying.

Control Devices – Both booths are equipped with HEPA filter systems, rated at 99.99% and 99.97% efficiency.

Permit Limits - Maximum application rates are 15 lb/hr for each booth. The permit contains mass limits for total suspended particulate (TSP) and concentration limits for hazardous air pollutants. For plasma spraying, the TSP emissions limit is 5.25E-04 lb TSP/hr while the HVOF process has no hourly limit. Both processes have annual TSP limits of 2.3E-03 tons per 12 consecutive months. To control toxic emissions, the permit contains maximum allowable stack concentrations that are equivalent to 150 ug Cr^{+6}/m^3 for the plasma spraying and 6.8 ug Cr^{+6}/m^3 for the HVOF process. These limits were determined in accordance with state air toxic regulations.

Stack Testing/Modeling - No stack testing or air dispersion modeling was required, because the facility emits less than 3 tpy of PM.

Emission Factors -

$$\text{Emission Factor, } \frac{\text{lbs TSP}}{\text{lbs matl./yr}} = \frac{[5.25\text{E-04 lb TSP/hr}]}{[15 \text{ lbs material/hr}]} = \frac{3.5\text{E-05 lb TSP}}{\text{lb material}}$$

Since total chromium is a component of the thermal spraying material, this emission factor also applies to total chromium emissions. If it is assumed that the total chromium contains 30% hexavalent chromium (i.e., 0.3 lbs Cr^{+6}/lb Cr), the following emission factor for hexavalent chromium can be derived:

Emission Factor = [3.5E-05 lbs total Cr/lb Cr sprayed]*[0.3 lbs Cr^{+6}/lb Cr] = [**1.05E-05** lbs Cr^{+6}/lb Cr]

This Connecticut emission factor lies between ARB's average HVOF/Plasma Spray emission factor for a control device with 99% efficiency and ARB's emission factors for a control device with 99.97% efficiency. Therefore, it appears that Connecticut's emission estimation methodology is reasonably consistent with ARB's methods.

Florida

Sources Identified - Staff members identified one thermal spraying facility that operated multiple booths.

Control Devices – The booths used two types of control devices – wet impingers (95% efficiency) and dry dust collectors (99% efficiency).

Permit Limits – ARB did not obtain a copy of the local permit.

Stack Testing/Modeling - No stack testing or air dispersion modeling was required.

Emission Factors - Emissions were calculated based on a 60% transfer efficiency (T.E.) and a 50% dropout rate. For a booth with a wet impinger (95% control efficiency), the emission factor would be -

$$\text{Emission Factor, } \frac{\text{lbs PM}}{\text{lbs matl./yr}} = [1-\text{T.E.}]*[1-\text{Dropout}]*[1-\text{C.E.}] = [1-0.6]*[1-0.5]*[1-0.95] = 1.00\text{E-02}$$

Since total chromium is a component of the thermal spraying material, this emission factor also applies to total chromium emissions. If it is assumed that the total chromium contains 30% hexavalent chromium, the following emission factor for hexavalent chromium can be derived:

Emission Factor = [1.00E-02 lbs Cr/lb Cr]*[0.3 lbs Cr^{+6}/lb Cr] = [**3.0E-03** lbs Cr^{+6}/lb Cr sprayed]

This value is between the ARB overall average emission factor for a control device with 90% efficiency and a control device with 99% efficiency, as summarized in Table C-3. Therefore, these results are consistent with ARB's methods.

New York

Sources Identified – Staff members identified one Title V source that operates four thermal spraying booths for a combination of HVOF and plasma spraying. One booth contains three thermal spraying units. The source is primarily a research facility, but it is permitted to conduct manufacturing, if needed.

Control Devices – Control devices include a baghouse/filter (99%+); fabric filter (95%)/Dollinger filter (98%); and a water curtain (90%).

Permit Limits – Maximum spray rates range from 10 lbs/hr to 1,050 lbs/hr for the highest capacity process. Annual usage limits range from 10,000 lbs/yr to 250,000 lbs/yr.

Stack Testing/Modeling - No stack testing or air dispersion modeling was required.

Emission Factors - Emissions were calculated based on transfer efficiencies (50% or 75%, depending on booth), a 90% dropout rate, the efficiencies of the control devices, and other assumptions. For the largest unit which vents to a baghouse/filter, 0.5% of quantity sprayed is emitted (i.e., the emission factor is 5.0E-03 lbs PM/lb matl.) Since the material being sprayed contains chromium, this 0.5% emission factor also applies to the chromium being sprayed (5.0E-03 lbs Cr/lb Cr sprayed). If it is assumed that the total chromium contains 30% hexavalent chromium, the following emission factor for hexavalent chromium can be derived:

Emission Factor = [5.0E-03 lbs Cr/lb Cr]*[0.3 lbs Cr^{+6}/lb Cr] = [**1.5E-03** lbs Cr^{+6}/lb Cr sprayed]

This value is between the ARB HVOF emission factor for a control device with 90% efficiency and a control device with 99% efficiency, as summarized in Table C-3. Therefore, these results are reasonably consistent with ARB's methods.

Ohio

Sources Identified – Staff members identified four permitted thermal spraying facilities, one of which was a Title V source with three plasma spraying booths.

Control Devices – The booths were vented to baghouses with 99% control efficiency.

Permit Limits – The maximum material usage rate is 8 lbs/hr and the annual operating limits are either 1,814 hours/yr or 3,267 hours/yr, depending on the booth. Hourly particulate emissions are limited to 0.551 lbs PM/hr for all of the booths. Maximum allowable annual emissions are either 0.5 tpy or 0.9 tpy, depending on the booth.

Stack Testing/Modeling - No stack testing or air dispersion modeling was required.

Emission Factors - Emissions were calculated based on a 65% transfer efficiency (T.E.) and a 99% control efficiency. No assumption was made regarding dropout percentage (i.e., dropout = 0.)

Emission Factor, $\frac{\text{lbs PM}}{\text{lbs matl./yr}}$ = [1- T.E.]*[1 – Dropout]*[1 – C.E.] = [1-0.65]*[1-0]*[1-0.99] = 3.50E-03

The primary pollutant of concern for this facility was nickel, but it is possible to develop an estimated emission factor for chromium as well. If total chromium was a component of the thermal spraying material, the emission factor would also apply to total chromium emissions. If it is assumed that the total chromium contains 30% hexavalent chromium, the following emission factor for hexavalent chromium can be derived:

Emission Factor = [3.50E-03 lbs Cr/lb Cr]*[0.3 lbs Cr^{+6}/lb Cr] = [**1.05E-03** lbs Cr^{+6}/lb Cr sprayed]

This value is between the ARB Plasma Spray emission factor for a control device with 99% efficiency and a control device with 99.97% efficiency, as summarized in Table C-3. Therefore, these results are consistent with ARB's methods.

Pennsylvania

Sources Identified – Staff members identified a Title V permit for a facility that conducted HVOF spraying on print rollers, using a nickel-chromium-copper material.

Control Devices – Emissions are controlled with a HEPA filter that has 99.97% control efficiency.

Permit Limits – Material usage is limited to 1,800 lbs/yr.

Stack Testing/Modeling – No stack testing or air dispersion modeling was required.

Emission Factors – Emissions were calculated based on 92% transfer efficiency, because the roller faces are flat and uniform. No assumption was made regarding dropout percentage (i.e., dropout = 0.)

Emission Factor, $\frac{\text{lbs PM}}{\text{lbs matl./yr}}$ = [1- T.E.]*[1 – Dropout]*[1 – C.E.]=[1-0.92]*[1-0]*[1-0.9997] = 2.40E-05

Since total chromium is a component of the thermal spraying material, this emission factor also applies to total chromium emissions. If it is assumed that the total chromium contains 30% hexavalent chromium, the following emission factor for hexavalent chromium can be derived:

Emission Factor = [2.40E-05 lbs Cr/lb Cr]*[0.3 lbs Cr^{+6}/lb Cr] = [**7.2E-06** lbs Cr^{+6}/lb Cr sprayed]

This value is slightly larger than ARB's HVOF emission factor for a control device with 99.97% control efficiency, as summarized in Table C-3.

C.5. Emission Calculations - Annual

This section describes how emission factors were used to estimate annual hexavalent chromium emissions from thermal spraying processes. The general approach involved multiplying emission factors by annual usage rates, as shown in the following equation:

Eqn. 6: $[\text{Emissions, lbs } Cr^{+6}/\text{year}] = [\text{Emission Factor, lbs } Cr^{+6}/\text{lb } Cr]*[\text{Usage, lbs } Cr/\text{year}]$

Emission factors were described in Section C.4 and were summarized in Table C-3.

ARB staff estimated annual emissions using two approaches: (1) potential to emit, based on manufacturer sales data, and (2) actual emissions, based on usage data as reported by individual facilities. When calculating the potential to emit, we used material sales data from ARB's 2003 Thermal Spraying Material Survey (ARB, 2004.) This survey collected sales quantities from thermal spraying materials manufacturers for calendar year 2002. The survey focussed on materials containing chemicals of concern (e.g., chromium and nickel). Based on this survey, more than 70 tons of thermal spraying materials containing chromium were sold or distributed in California during 2002. A report of the manufacturer survey results can be obtained on ARB's website (http://www.arb.ca.gov/coatings/thermal/thermal.htm). When calculating actual emissions, we used material throughput data from thermal spraying businesses, that was obtained from ARB's 2004 Thermal Spraying Facility Survey. The total estimated usage quantity provided by thermal spraying facilities was significantly less than the sales data provided by manufacturers. Since some facilities only provided rough estimates of their usage, we believe that the manufacturer's data are more accurate and yield a more reliable estimate of statewide usage for determining the potential to emit.

Data from ARB's 2003 Thermal Spraying Material Survey provided information on the annual material sales and ingredient percentages. We used these data to calculate the amount of chromium in each material and the potential annual usage of such materials, as shown in the following equations:

Eqn. 7: For products with Chromium

$$[\text{Chromium Qty}, \frac{\text{Lbs}}{\text{Yr}}] = [\text{Material Sales}, \frac{\text{lbs}}{\text{yr}}] * [\text{Wt\% Chromium}]$$

Eqn. 8: For products with Chromium Oxide (Cr_2O_3)

$$[\text{Chromium Qty}, \frac{\text{lbs}}{\text{yr}}] = [\text{Material Sales}, \frac{\text{lbs}}{\text{yr}}] * [\text{Wt\% } Cr_2O_3] * \frac{[104 \text{ g } Cr_2]}{[152 \text{ g } Cr_2O_3]}$$

The manufacturer survey also identified the types of thermal spraying processes associated with each product, which allowed us to select the appropriate emission factors. Some thermal spraying materials were designated as being suitable for two types of processes (e.g., flame spray and plasma spray).

For these multi-use products, an average emission factor value was used, as shown in the following example calculations:

Average Emission Factor Calculation - Uncontrolled Flame Spray & Plasma Spray:
(6.20E-03 + 1.18E-02)/2 = 9.00E-03 lbs Cr^{+6}/lb Cr sprayed

Example Annual Emissions Calculation - Uncontrolled Flame Spray & Plasma Spray:
[10,000 lbs Cr sprayed]* [9.00E-03 lbs Cr^{+6}/lb Cr sprayed] = 90 lbs Cr^{+6}/yr

To calculate potential emissions, we multiplied the applicable emission factor times the quantity of chromium sold. Table C-9 summarizes the California sales in 2002 for thermal spraying products that contain chromium and the associated quantity of chromium contained in those products. Table C-9 also contains the associated processes, emission factors, and emissions values. Potential statewide emissions of hexavalent chromium vary widely, depending on the type of control device used. For example, if all facilities used control devices with 99.97% control efficiency, statewide emissions would be only 0.1 lb/yr. However, statewide emissions would be almost 300 lbs/yr, if all facilities were uncontrolled. Therefore, it is important to identify a control effectiveness when estimating statewide emissions. ARB's 2004 Thermal Spraying Facility Survey provided information on the percentage of facilities that use control devices and the types of devices that were used. The results of this survey indicate that 87% of the thermal spraying facilities in California that use materials containing chromium have a control device. The most common type of control device at these facilities is the dry filter cartridge. Based on this information, the following assumptions were made:

- 87% of the thermal spraying material is used at controlled facilities with dry filters
- 13% of the thermal spraying material is used at uncontrolled facilities
- [Controlled Emissions] = [87%]*[Sales, lbs Cr]*[Emission Factor, lbs Cr^{+6}/lb Cr sold]
- [Uncontrolled Emissions] = [13%]*[Sales, lbs Cr]*[Emission Factor, lbs Cr^{+6}/lb Cr sold]

The survey data indicated that some facilities have HEPA filters (generally more efficient than dry filters) and some facilities have water curtains (usually less efficient than dry filters), so the assumption that controlled facilities use dry filters provides a reasonable representation of the average control efficiencies statewide.

Based on these assumptions, 18 tons of chromium were potentially used at thermal spraying facilities and the potential to emit is 66 pounds for hexavalent chromium statewide in 2002. Table C-9 provides details of potential material usage and potential to emit quantities, based on the manufacturer survey.

To calculate actual emissions, we multiplied the applicable emission factor times the quantity of chromium usage reported by individual facilities. Actual emissions were estimated to be 9.4 pounds, based on facility usage data, process descriptions, and control device information as provided by facilities. It is expected that our estimates of actual emissions and the potential to emit represent lower and upper boundaries for statewide emissions. Therefore, we estimate that annual hexavalent chromium emissions from thermal spraying are in the range of 9.4 – 66 pounds. The difference between estimates of maximum potential emissions and actual emissions may be due to the following factors: 1) materials sold in one year may be used over multiple years; 2) some materials sold to California distributors may be redistributed out of State; and 3) some businesses that conduct thermal spraying may not have been captured by the ARB facility survey.

For this thermal spraying ATCM, we estimated the potential emission reductions based on data from the ARB 2004 Thermal Spraying Facility Survey, the ARB 2003 Thermal Spraying Materials Survey, and the proposed ATCM control efficiency requirements. For a facility with no existing control devices, the proposed ATCM would require at least a 99% reduction in emissions. For the largest facility in the State, the proposed ATCM would require that the control device efficiency be increased from a minimum of 81% to at least 99.97%. Overall, the proposed ATCM is expected to reduce hexavalent chromium emissions by nearly 80 percent (7 to 50 lbs/yr.)

Table C-9:
Thermal Spraying Sales & Potential to Emit Summary - Hexavalent Chromium

Process	Material	Sales of Products Containing Chromium (lbs) [1]	Qty. of Chromium in Products (lbs Cr)	Potential to Emit (lbs Cr^{+6}/yr) [2]
Flame Spray	Powder	6,788	713.4	0.6
Flame Spray/Other	Powder	PD	2,415.0	2.8
Flame Spray/Plasma Spray	Powder	PD	736.5	1.7
HVOF	Powder	7,731	3,279.0	2.8
HVOF/Flame Spray/Plasma Spray	Powder	PD	2,860.7	5.3
HVOF/Plasma Spray	Powder	10,918	5,307.9	12.4
Plasma Spray	Powder	14,780	6,962.3	26.5
Plasma Spray/Other	Powder	PD	22.8	0.1
Powder Subtotal =		**63,612**	**22,298**	**52.1**
Single-Wire Flame Spray	Wire	PD	1,330.1	0.9
Twin-Wire Electric Arc	Wire	PD	13,036.6	12.6
Wire Subtotal =		**79,708**	**14,367**	**13.4**
GRAND TOTAL =		**143,320**	**36,664**	**65.6**

1. "PD": Protected data (fewer than three companies reported sales).
2. Assume 13% of products are used at Uncontrolled facilities and 87% of products are used at facilities with a dry filter control device.

C.6. Emission Calculations –Hourly

When performing health risk assessments, it is typically necessary to identify the average hourly emissions and the maximum hourly emissions. The average hourly emissions are used when calculating the possible impacts from long-term chronic exposure, while the maximum hourly emissions are used to calculate impacts from short-term acute exposures. Reference Exposure Levels (RELs) for short-term acute exposures have not yet been established for hexavalent chromium. Therefore, we did not estimate acute risk for hexavalent chromium, based on the maximum hourly emissions.

Annual average hourly emissions were estimated using the following equation:

Eqn. 5: $$[\text{Annual Avg. Hourly Emissions, lbs } Cr^{+6}/\text{hour}] = \frac{[\text{Annual Emissions, lbs } Cr^{+6}/\text{yr}]}{[350 \text{ days/yr}]*[\text{Daily Operating Hours, e.g., 8 hrs/day}]}$$

These values are converted into units of grams/second for the risk assessment calculations, using the following equation:

Eqn. 6: $$[\text{Hourly Emissions, g/s}] = \frac{[\text{Hourly Emissions, lb } Cr^{+6}]}{[\text{hr}]} * \frac{[453.59 \text{ g}]}{[1 \text{ lb}]} * \frac{[1 \text{ hr}]}{[60 \text{ min}]} * \frac{[1 \text{ min}]}{[60 \text{ sec}]}$$

C.6.1. Annual Average Hourly Emissions

Annual average hourly emissions vary, depending on individual facility operating schedules and other parameters. However, we can estimate statewide annual average hourly emissions, based on the total annual emissions statewide. According to the ARB 2004 Thermal Spraying Facility Survey, 30 facilities reported the use of materials that contain chromium.

$$[\text{Annual Avg. Hourly Emissions}] = \frac{[65.6 \text{ lbs } Cr^{+6}/\text{yr}]}{[350 \text{ days/yr}]*[8 \text{ hrs/day}]*[30 \text{ facilities statewide}]} = \frac{7.81\text{E-04 lbs } Cr^{+6}}{\text{hr}}$$

$$[\text{Hourly Emissions, g/s}] = \frac{[7.81\text{E-04 lbs } Cr^{+6}]}{[\text{hr}]} * \frac{[453.59 \text{ g}]}{[1 \text{ lb}]} * \frac{[1 \text{ hr}]}{[60 \text{ min}]} * \frac{[1 \text{ min}]}{[60 \text{ sec}]} = \frac{\mathbf{9.8E\text{-}05} \text{ grams } Cr^{+6}}{\text{second}}$$

This statewide average, based on manufacturer sales data, is at the high end of the values that are based on individual facility data, as reported in the 2004 ARB Thermal Spraying Facility Survey. For most facilities that reported chromium usage, the annual average emissions were between 1E-09 g/s and 1E-05 g/s, with one outlier at approximately 1E-03 g/s. Since the total sales reported by manufacturers was greater than the total usage reported by individual facilities, it is not surprising that annual average emissions based on manufacturer sales would be higher than emissions based on individual facility data.

REFERENCES

ARB, 2004. Air Resources Board. "2003 Thermal Spraying Materials Survey". 2004.

AWS, 1979. American Welding Society. "Fumes and Gases in the Welding Environment". 1979.

Chadwick, 1997. Chadwick, J.K., H.K. Wilson, M.A. White. "An investigation of occupational metal exposure in thermal spraying processes," The Science of the Total Environment 199, 115-124. 1997.

ERM, 1995. "Chemtronics Inc., Plasma-Arc Metal Spray Device, Emissions Testing of Associated Control Equipment". Test Date Oct. 25, 1994. Prepared by Environmental and Risk Management, Inc. for Chemtronics Inc. and submitted to the San Diego County Air Pollution Control District. 1995.

Gold, 2000. Gold, Deborah. "Chromium and Other Hazards in a Plasma Spray Operation", presented at the American Industrial Hygiene Conference and Exposition, May 2000.

NIOSH, 1989. National Institute for Occupational Safety and Health. "Health Hazard Evaluation Report, HETA 88-136-1945, Miller Thermal Technologies." January 1989.

PES, 2000. "Final Report, Development of Emission Inventory for Metal Welding, Cutting, and Spraying Operations". Prepared by Pacific Environmental Services for the South Coast Air Quality Management District. 2000.

Praxair, 2002. Praxair/TAFA. 2002. Material Safety Data Sheet #T122 (TAFA Bondarc Wire-75B) and #T124 (TAFA 88T UltraMachinable Stainless Wire).

Sawatari, 1986. Sawatari, K. and F. Serita. 1986. "Determination of Chromium Speciation in Fumes Prepared by a Plasma Metal Sprayer as a Model of Actual Welding Fumes," Industrial Health 24:51-61.

SCEC. 1998. "Emission Testing of a HEPA Filter System". Test Date Nov. 17, 19, 20, 1997. Prepared by SCEC for Flame Spray Inc. and submitted to the San Diego County Air Pollution Control District. 1998.

SCEC. 1998a. "Emission Testing of a Water Wash Booth". Results from Test Runs #1 and 3 only. Test Date Dec. 9, 1997. Prepared by SCEC for Flame Spray Inc. and submitted to the San Diego County Air Pollution Control District. 1998.

SCEC. 2001. "Toxic Air Contaminant Public Health Risk Assessment Testing of a Plasma Flame Spray Facility". Test Date Feb. 26-27, 2001. Prepared by SCEC for Chromalloy San Diego and submitted to the San Diego County Air Pollution Control District. 2001.

SDAPCD, 1998. San Diego County Air Pollution Control District. "Metal Deposition – Plasma and Flame Spray Operations." Updated October 1998. Online internet at http://www.sdapcd.co.san-diego.ca.us/toxics/emissions/metdep/metdep.html (July 12, 2004.)

SDAPCD, 2002. San Diego County Air Pollution Control District Audit Reports: Flame Spray Inc. - Compliance Source Tests conducted by SCEC on April 25-26, 2002. October 29, 2002.

SDAPCD, 2004. San Diego County Air Pollution Control District Audit Reports: Flame Spray Inc. - Compliance Source Tests conducted by SCEC on April 29-30, 2003. January 15, 2004.

Serita, 1990. F. Serita, K. Homma, K. Fukuda, K. Sawatari, Y. Suzuki, and T. Toya. 1990. "Development of an Inhalation System of High Melting Point Metal Fumes and Its Use for Exposure of Rats to Chromium and Nickel Fumes," Industrial Health 28:185-197.

Smith, 1994. Smith, R.W., P. Mathur, D. Sprigs. "Thermal Spray Industry Environmental Guideline". ASM International. 1994.

Appendix D

Methodology for Estimating Nickel Emissions from Thermal Spraying

D.1. Introduction

Estimating air emissions can be accomplished by direct measurement of facility exhaust gases or by performing calculations based on material usage. Measurement of exhaust gases is generally the preferred method for individual facilities, but conducting stack exhaust tests can be costly. Therefore, we have developed calculation methods that can be used to estimate nickel emissions for different types of thermal spraying processes and the associated air pollution control devices. The following sections describe the process that was used to develop emission estimation methods for thermal spraying.

D.2. Nickel Emission Factors - Summary

The general approach for estimating nickel emissions involves multiplying emission factors by usage rates. Emission factors were obtained from a variety of sources, based on the type of process and control device. In some cases, emission factors were taken directly from stack test results, while other factors were derived from a combination of stack test results and data on control efficiencies. Table D-1 summarizes the emission factors that were used and Section D.3 describes how these factors were derived.

Table D-1:
Emission Factor Summary – Nickel

Process	Emission Factors (lbs Ni/lb Ni sprayed)			
	0% Ctl. Eff. (Uncontrolled)	90% Ctl. Eff. [1] (e.g. Water Curtain)	99% Ctl. Eff. (e.g. Dry Filter)	99.97% Ctl. Eff. (e.g., HEPA Filter)
Twin-Wire Electric Arc Spray[2]	6.0E-03	6.0E-04	6.0E-05	1.8E-06
Flame Spray[3]	1.10E-01	4.64E-02	1.10E-03	3.30E-05
HVOF[3]	1.10E-01	4.64E-02	1.10E-03	3.30E-05
Plasma Spray[4]	1.5E-01	3.67E-02	1.5E-03	1.72E-05
Other Thermal Spraying[5]	9.4E-02	3.25E-02	9.4E-04	2.13E-05

1. Listed below the control efficiencies are examples of control devices that may meet the control efficiency.
2. Uncontrolled emission factor based on Wisconsin stack test data.
3. Emission factors based on SDAPCD stack test data for flame spraying.
4. Emission factors based on SCAQMD and SDAPCD stack test data.
5. For "Other Thermal Spraying" processes, we used an average of the emission factors for the listed thermal spraying processes.

D.3. Nickel Emission Factor Development

The following sections describe how emission factors were derived from various sources for different types of thermal spraying processes and control devices. In each case, emission factors were developed for operations that had no air pollution control devices (i.e., uncontrolled) and for operations that had control devices (i.e., controlled).

To determine controlled emission factors in the absence of stack test data, we used the following equation:

Eqn. D.1: [Controlled Emission Factor] = [Uncontrolled Emission Factor][1 – Control Efficiency]*

Controlled emission factors were developed for the following levels of control:

Control Efficiency Levels	
90%	(e.g., a water curtain)
99%	(e.g., a dry filter)
99.97%	(e.g., a HEPA filter)

The actual control efficiency for a control device at a particular facility can depend on specific parameters (e.g., particle size, filter media, etc.), but the control efficiencies listed above are consistent with general industry estimates.

D.3.2. SDAPCD Emission Factors for Plasma Spraying & Flame Spraying

The San Diego County Air Pollution Control District (SDAPCD) has compiled the following emission factors for various plasma spraying and flame spraying facilities, based on stack test data (SDAPCD, 1998.)

Table D-3:
SDAPCD Emission Factors – Nickel

SDAPCD Method #	Process	Control Device	Emission Factor (lb Ni/lb Ni sprayed)	Average (lb Ni/lb Ni sprayed)
M01	Plasma Spray	HEPA	3.73E-06	1.31E-05
M02	Plasma Spray	HEPA	2.24E-05	
M03	Plasma Spray	HEPA	1.31E-05	
M04	Plasma Spray	Water Curtain	8.10E-04	1.84E-02
M05	Plasma Spray	Water Curtain	3.59E-02	
M06	Plasma Spray	Water Curtain	1.84E-02	
M08	Flame Spray	HEPA	**3.30E-05***	
M09	Flame Spray	Water Curtain	**4.64E-02***	

* Bold highlighting indicates a value that appears in the emission factor summary table.

The emission factors in Table D-3 are based on stack test data from several thermal spraying facilities in the San Diego area. In addition to these tests, SDAPCD provided results from another stack test that was conducted in 2002 at a plasma spraying facility that was equipped with a HEPA filter. The emission factor from this test was 2.12E-05 lb Ni/lb Ni sprayed (SDAPCD, 2002a). The average emission factor for a plasma spraying facility with a HEPA filter was calculated as shown below:

[1.31E-05 + 2.12E-05]/2 = **1.72E-05** lb Ni/lb Ni sprayed

To determine an uncontrolled emission factor for a flame spraying facility, we used the following equation:

Eqn. D.3: [Uncontrolled Emission Factor] = [Controlled Emission Factor]/[1 – Control Efficiency]

The uncontrolled emission factor for flame spraying was calculated as shown below:

Emission Factor for Flame Spraying with a HEPA Filter = 3.30E-05 lb Ni/lb Ni sprayed
Estimated Control Efficiency for a HEPA Filter = 99.97%
[Uncontrolled Emission Factor] = [3.30E-05]/[1 – 0.9997] = **1.10E-01** lb Ni/lb Ni sprayed

The emission factor for flame spraying with a control device that achieves 99% control efficiency was calculated as shown below:

Uncontrolled Emission Factor for Flame Spraying = 1.10E-01 lb Ni/lb Ni sprayed
Control Efficiency = 99% (e.g., a dry filter)
[Controlled Emission Factor @ 99%] = [1.10E-01]*[1 – 0.99] = **1.10E-03** lb Ni/lb Ni sprayed

The emission factors for flame spraying were also used to estimate emissions from HVOF processes, because they are both combustion-based operations that achieve comparable temperatures.

D.3.3. SCAQMD Emission Factors for Plasma Spraying

The South Coast Air Quality Management District (SCAQMD) worked with Pacific Environmental Services to develop an emission inventory for metal welding, cutting, and spraying operations. In May 2000, Pacific Environmental Services completed an emission inventory report which contained metal spraying emission factors for nickel (PES, 2000). The emission factors for nickel were based on stack tests that were conducted at two facilities in the SCAQMD in 1987 to 1990. Both of the facilities conducted plasma spraying during the stack tests. Table D-4 lists the nickel emission factors from this study.

Table D-4:
Emission Factors - SCAQMD Plasma Spraying

Control Devices	Emission Factors (lb Ni/lb Ni sprayed)
Uncontrolled	**1.5E-01***
Water Curtain	5.5E-02

* Bold highlighting indicates a value that appears in the emission factor summary table.

The emission factor for plasma spraying with a control device that achieves 99% control efficiency was calculated as shown below:

Uncontrolled Emission Factor for Plasma Spraying = 1.5E-01 lb Ni/lb Ni sprayed
Control Efficiency = 99% (e.g., a dry filter)
[Controlled Emission Factor @ 99%] = [1.5E-01]*[1 – 0.99] = **1.5E-03** lb Ni/lb Ni sprayed

Both SDAPCD and SCAQMD provided emission factors for plasma spraying processes with water curtains. We used the average of these two values for our emission factor:

SDAPCD: 1.84E-02 lb Ni/lb Ni sprayed
SCAQMD: 5.5E-02 lb Ni/lb Ni sprayed
Average: (1.84E-02 + 5.5E-02)/2 = **3.67E-02** lb Ni/lb Ni sprayed

D.3.4. Wisconsin Data – Twin-Wire Electric Arc Spraying

ARB staff contacted regulatory agencies in other states to gather information on their methods for estimating emissions from thermal spraying sources. Wisconsin staff provided nickel emissions data for a facility that conducted electric arc spraying. The facility used nickel-based materials that do not contain chromium. Emissions were controlled by a baghouse and a HEPA filter. Based on stack test results, the control efficiency was 99.9% and the nickel emission factor was 6.0E-06 lbs Ni/lb Ni sprayed. The average spray rate during the stack testing was 31 lbs Ni/hr.

To determine an uncontrolled emission factor for a twin-wire electric arc spraying process, we used the following equation:

Eqn. D.4: [Uncontrolled Emission Factor] = [Controlled Emission Factor]/[1 – Control Efficiency]

The uncontrolled emission factor for twin-wire electric arc spraying was calculated as shown below:

Emission Factor for Twin-Wire Electric Arc Spraying = 6.0E-06 lb Ni/lb Ni sprayed
Control Efficiency, based on Wisconsin stack test data for this facility = 99.9%
[Uncontrolled Emission Factor] = [6.0E-06]/[1 – 0.999] = **6.0E-03** lb Ni/lb Ni sprayed

The emission factor for twin-wire electric arc spraying with a control device that achieves 90% control efficiency was calculated as shown below:

Uncontrolled Emission Factor for Twin-Wire Electric Arc Spraying = 6.0E-03 lb Ni/lb Ni sprayed
Control Efficiency = 90% (e.g., a water curtain)
[Controlled Emission Factor @ 90%] = [6.0E-03]*[1 – 0.9] = **6.0E-04** lb Ni/lb Ni sprayed

The emission factor for twin-wire electric arc spraying with a control device that achieves 99% control efficiency was calculated as shown below:

Uncontrolled Emission Factor for Twin-Wire Electric Arc Spraying = 6.0E-03 lb Ni/lb Ni sprayed
Control Efficiency = 99% (e.g., a dry filter)
[Controlled Emission Factor @ 99%] = [6.0E-03]*[1 – 0.99] = **6.0E-05** lb Ni/lb Ni sprayed

The emission factor for twin-wire electric arc spraying with a control device that achieves 99.97% control efficiency was calculated as shown below:

Uncontrolled Emission Factor for Twin-Wire Electric Arc Spraying = 6.0E-03 lb Ni/lb Ni sprayed
Control Efficiency = 99.97% (e.g., a HEPA filter)
[Controlled Emission Factor @ 99.97%] = [6.0E-03]*[1 – 0.9997] = **1.8E-06** lb Ni/lb Ni sprayed

D.4. Emission Calculations - Annual

This section describes how emission factors were used to estimate annual nickel emissions from thermal spraying processes. The general approach involved multiplying emission factors by annual usage rates, as shown in the following equation:

Eqn. D.5: [Emissions, lbs Ni/year] = [Emission Factor, lbs Ni/lb Ni sprayed][Usage, lbs Ni sprayed/year]*

Emission factors were described in Section D.3 and were summarized in Table D-1.

ARB staff estimated annual emissions using two approaches: (1) potential to emit, based on manufacturer sales data, and (2) actual emissions, based on usage data as reported by individual facilities. When calculating the potential to emit, we used material sales data from ARB's 2003 Thermal Spraying Material Survey (ARB, 2004b.) This survey collected sales quantities from thermal spraying materials manufacturers for calendar year 2002. The survey focussed on materials containing chemicals of concern (e.g., chromium and nickel). Based on this survey, more than 62 tons of thermal spraying materials containing nickel were sold or distributed in California during 2002. A report of the manufacturer survey results can be obtained on ARB's website (http://www.arb.ca.gov/coatings/thermal/thermal.htm). When calculating actual emissions, we used material throughput data from thermal spraying businesses, that was obtained from ARB's 2004 Thermal Spraying Facility Survey. The total estimated usage quantity provided by thermal spraying facilities was significantly less than the sales data provided by manufacturers. Since some facilities only provided rough estimates of their usage, we believe that the manufacturer's data are more accurate and yield a more reliable estimate of statewide usage for determining the potential to emit.

Data from the manufacturer survey provided information on the annual material sales quantities and ingredient percentages. We used these data to calculate the amount of nickel in each material and the potential annual usage of nickel, as shown in the following equations:

Eqn. D.6: $$[\text{Nickel Qty}, \frac{\text{lbs}]}{\text{yr}} = [\text{Material Sales}, \frac{\text{lbs}]}{\text{yr}} * [\text{Wt\% Nickel}]$$

The manufacturer survey also identified the types of thermal spraying processes associated with each product, which allowed us to select the appropriate emission factor. Some thermal spraying materials were designated as being suitable for two types of processes (e.g., flame spray and plasma spray). For these multi-use products, an average emission factor value was used, as shown in the following example calculations:

Average Emission Factor Calculation - Uncontrolled Flame Spray & Plasma Spray:
(1.10E-01 + 1.5E-01)/2 = 1.3E-01 lbs Ni/lb Ni sprayed

Example Annual Emissions Calculation - Uncontrolled Flame Spray & Plasma Spray:
[10,000 lbs Ni sprayed]* [1.3E-01 lbs Ni/lb Ni sprayed] = 1300 lbs Ni/yr

To calculate potential emissions, we multiplied the applicable emission factor times the quantity of nickel sold. Table D-5 summarizes the California sales in 2002 for thermal spraying products that contain nickel and the associated quantity of nickel contained in those products. Table D-5 also contains the associated processes, emission factors, and emissions values. Potential statewide emissions of nickel vary widely, depending on the type of control device used. For example, if all facilities used control devices with 99.97% control efficiency (e.g., HEPA filters), statewide emissions would be only 1 lb/yr. However, statewide emissions would be more than 4,700 lbs/yr, if all facilities were uncontrolled. Therefore, it is important to identify a control effectiveness when estimating actual statewide emissions. ARB's 2004 Thermal Spraying Facility Survey provided information on the percentage of facilities that use control devices and the types of devices that were used. The results of this survey indicate that 86% of the thermal spraying facilities in California that use materials containing nickel have a control device and the most common type of device is the dry filter cartridge. Based on this information, the following assumptions were made:

- 86% of the thermal spraying material would be used at controlled facilities with dry filters
- 14% of the thermal spraying material would be used at uncontrolled facilities
- [Controlled Emissions] = [86%]*[Sales, lbs]*[Emission Factor, lbs Ni/lb Ni sold]
- [Uncontrolled Emissions] = [14%]*[Sales, lbs]*[Emission Factor, lbs Ni/lb Ni sold]

The survey data indicated that some facilities had HEPA filters (generally more efficient than dry filters) and some facilities had water curtains (usually less efficient than dry filters), so the assumption that controlled facilities used dry filters provides a reasonable representation of the average control efficiencies statewide.

Based on these assumptions, 34 tons of nickel were potentially used at thermal spraying facilities and the potential to emit is 740 pounds for nickel statewide in 2002. Table D-5 provides details of potential material usage and potential to emit quantities, based on the manufacturer survey.

To calculate actual emissions, we multiplied the applicable emission factor times the quantity of chromium usage reported by individual facilities. Actual emissions were estimated to be 105 pounds, based on facility usage data, process descriptions, and control device information as provided by individual facilities. It is expected that our estimates of actual emissions and the potential to emit represent lower and upper boundaries for statewide emissions. Therefore, we estimate that annual hexavalent chromium emissions from thermal spraying are in the range of 105 – 740 pounds. The difference between estimates of maximum potential emissions and actual emissions may be due to the following factors: 1) materials sold in one year may be used over multiple years; 2) some materials sold to California distributors may be redistributed out of State; and 3) some businesses that conduct thermal spraying may not have been captured by the ARB facility survey.

For this thermal spraying ATCM, we estimated the potential emission reductions based on data from the ARB 2004 Thermal Spraying Facility Survey, the ARB 2003 Thermal Spraying Materials Survey, and the proposed ATCM control efficiency requirements.

For a facility with no existing control devices, the proposed ATCM would require at least a 99% reduction in emissions. For the largest facility in the State, the proposed ATCM would require that the control device efficiency be increased from a minimum of 81% to at least 99.97%. Overall, the proposed ATCM is expected to reduce nickel emissions by 51 percent (54 to 377 lbs/yr.)

Table D-5:
Thermal Spraying Sales & Potential to Emit Summary - Nickel

Process	Material	Sales of Products Containing Nickel (lbs) [1]	Qty. of Nickel in Products (lbs Ni)	Potential to Emit (lbs Ni/yr) [2]
Flame Spray	Powder	9,917	7,021.1	114.8
Flame Spray/Other	Powder	PD	8,429.3	162.8
Flame Spray/Plasma Spray	Powder	PD	9,567.7	184.8
HVOF	Powder	5,776	1,361.3	22.3
HVOF/Flame Spray/Plasma Spray	Powder	PD	828.0	15.2
HVOF/Plasma Spray	Powder	11,473	6,408.4	123.8
Plasma Spray	Powder	9,435	3,056.7	68.1
Plasma Spray/Other	Powder	PD	63.6	1.4
Powder Subtotal =		**67,911**	**36,736**	**693.1**
Single-Wire Flame Spray	Wire	PD	1,259.4	20.6
Twin-Wire Electric Arc	Wire	PD	29,320.2	26.1
Wire Subtotal =		**57,640**	**30,580**	**46.7**
GRAND TOTAL =		**125,550**	**67,316**	**739.9**

1. "PD": Protected data (fewer than three companies reported sales).
2. Assume 14% of products are used at Uncontrolled facilities and 86% of products are used at facilities with a dry filter control device.

D.5. Nickel Emission Calculations –Hourly

When performing health risk assessments, it is necessary to identify the average hourly emissions and the maximum hourly emissions. The average hourly emissions are used when calculating the possible impacts from long-term chronic exposure to nickel, while the maximum hourly emissions are used to calculate impacts from short-term acute exposures to nickel.

Hourly emissions were estimated using the following equations:

Eqn. D.7: [Max. Hourly Emissions, lbs Ni/hour] = [Emission Factor, lbs Ni/lb Ni sprayed]*[Usage, lbs Ni sprayed/hour]

Eqn. D.8: $$[\text{Annual Avg. Hourly Emissions, lbs Ni/hour}] = \frac{[\text{Annual Emissions, lbs Ni/yr}]}{[\text{350 days/yr}]*[\text{Daily Operating Hours, e.g., 8 hrs/day}]}$$

These values are converted into units of grams/second for the risk assessment calculations, using the following equation:

Eqn. D.9: $$[\text{Hourly Emissions, g/s}] = \frac{[\text{Hourly Emissions, lb Ni}]}{[\text{hr}]} * \frac{[453.59\text{ g}]}{[1\text{ lb}]} * \frac{[1\text{ hr}]}{[60\text{ min}]} * \frac{[1\text{ min}]}{[60\text{ sec}]}$$

D.5.1. Maximum Hourly Emissions

The maximum hourly emissions depend on the hourly spray rate for a given facility. To estimate maximum hourly emissions, we used emission factors and a range of spray rates (low, medium, and high) to cover a variety of scenarios. For most thermal spraying processes, the hourly spray rates for nickel were 0.5, 5, and 15 lbs/hr (or 0.063, 0.63, and 1.89 g/s), as shown in Table D-6. Twin-Wire Electric Arc spraying can achieve a substantially higher spray rate than flame spraying, according to information from manufacturers and technical literature. Therefore, the "high" estimated spray rate for electric arc spraying was 25 lbs/hr (or 3.15 g/s) instead of 15 lbs/hr (1.89 g/s). Since different products contain different nickel percentages, the amount of material that corresponds to these nickel spray rates will vary according to product. However, it is possible to get an estimated material spray rate, by using the sales-weighted average nickel percentage from the ARB 2003 Thermal Spraying Materials Survey (ARB, 2004), as shown below.

Table D-6:
Thermal Spraying Estimated Hourly Spray Rates

	Nickel Spray Rates, lbs Ni/hr (grams/second)			Material Spray Rates (lbs/hr)*		
	Low	Medium	High	Low	Medium	High
Flame, Plasma, HVOF, Detonation	0.5 (0.063)	5 (0.63)	15 (1.89)	0.9	9.2	27.7
Electric Arc Spraying	0.5 (0.063)	5 (0.63)	25 (3.15)	0.9	9.4	47.1

*Estimated values based on sales-weighted average nickel percentages from the *ARB 2003 Thermal Spraying Materials Survey*: 54.1% Ni for Powder, 53.1% Ni for Wire.

These usage levels are consistent with actual facility spray rates. Spray rates were examined for several thermal spraying facilities in the San Diego area and they ranged from 0.2 – 20 lbs/hr for materials that contain nickel.

Maximum hourly emission rates were estimated for uncontrolled facilities (Table D-7) and for facilities equipped with a control device that achieves 99% control efficiency (Table D-8). The maximum hourly values were calculated for low, medium, and high nickel spray rates. For the purposes of risk assessment, these data are presented in units of "grams/second", rather than units of "lbs/hr".

Table D-7:
Maximum Hourly Emissions, 0% Control Efficiency – Nickel

Process	Material	Emission Factor (g Ni/g Ni)	Estimated Emissions (grams Ni/sec) Low Spray Rate @ 0.063 g/s	Medium Spray Rate @ 0.63 g/s	High Spray Rate @ 1.89 g/s
Flame Spray	Powder	1.10E-01	6.93E-03	6.93E-02	2.08E-01
Flame Spray/Other	Powder	1.02E-01	6.43E-03	6.43E-02	1.93E-01
Flame Spray/Plasma Spray	Powder	1.30E-01	8.19E-03	8.19E-02	2.46E-01
HVOF	Powder	1.10E-01	6.93E-03	6.93E-02	2.08E-01
HVOF/Flame Spray/Plasma Spray	Powder	1.23E-01	7.77E-03	7.77E-02	2.33E-01
HVOF/Plasma Spray	Powder	1.30E-01	8.19E-03	8.19E-02	2.46E-01
Plasma Spray	Powder	1.50E-01	9.45E-03	9.45E-02	2.83E-01
Plasma Spray/Other	Powder	1.22E-01	7.69E-03	7.69E-02	2.31E-01
Single-Wire Flame Spray	Wire	1.10E-01	6.93E-03	6.93E-02	2.08E-01
			Low @ 0.063 g/s	**Medium** @ 0.63 g/s	**High** @ 3.15 g/s
Twin-Wire Electric Arc	Wire	6.00E-03	3.78E-04	3.78E-03	1.89E-02

Table D-8:
Maximum Hourly Emissions, 99% Control Efficiency – Nickel

Process	Material	Emission Factor (g Ni/g Ni)	Estimated Emissions (grams Ni/sec) Low Spray Rate @ 0.063 g/s	Medium Spray Rate @ 0.63 g/s	High Spray Rate @ 1.89 g/s
Flame Spray	Powder	1.10E-03	6.93E-05	6.93E-04	2.08E-03
Flame Spray/Other	Powder	5.85E-03	3.69E-04	3.69E-03	1.11E-02
Flame Spray/Plasma Spray	Powder	1.30E-03	8.19E-05	8.19E-04	2.46E-03
HVOF	Powder	1.10E-03	6.93E-05	6.93E-04	2.08E-03
HVOF/Flame Spray/Plasma Spray	Powder	1.23E-03	7.77E-05	7.77E-04	2.33E-03
HVOF/Plasma Spray	Powder	1.30E-03	8.19E-05	8.19E-04	2.46E-03
Plasma Spray	Powder	1.50E-03	9.45E-05	9.45E-04	2.83E-03
Plasma Spray/Other	Powder	6.05E-03	3.81E-04	3.81E-03	1.14E-02
Single-Wire Flame Spray	Wire	1.10E-03	6.93E-05	6.93E-04	2.08E-03
			Low @ 0.063 g/s	**Medium** @ 0.63 g/s	**High** @ 3.15 g/s
Twin-Wire Electric Arc	Wire	6.00E-05	3.78E-06	3.78E-05	1.89E-04

D.5.2. Annual Average Hourly Emissions

Annual average hourly emissions vary, depending on individual facility operating schedules. However, we can estimate the statewide average hourly emissions, based on the total annual emissions statewide. According to the ARB 2004 Thermal Spraying Facility Survey, 35 facilities reported the use of materials that contain nickel.

$$[\text{Annual Avg. Hourly Emissions}] = \frac{[740 \text{ lbs Ni/yr}]}{[350 \text{ days/yr}]*[8 \text{ hrs/day}]*[35 \text{ facilities statewide}]} = \frac{7.6\text{E-}03 \text{ lbs Ni}}{\text{hr}}$$

$$[\text{Hourly Emissions, g/s}] = \frac{[7.6\text{E-}03 \text{ lbs Ni}]}{[\text{hr}]} * \frac{[453.59 \text{ g}]}{[1 \text{ lb}]} * \frac{[1 \text{ hr}]}{[60 \text{ min}]} * \frac{[1 \text{ min}]}{[60 \text{ sec}]} = \frac{\mathbf{9.6E\text{-}04} \text{ g Ni}}{\text{sec}}$$

This statewide average is at the high end of values that are based on individual facility data, as reported in the 2004 ARB Thermal Spraying Facility Survey. For most facilities that reported nickel usage, the annual average emissions were generally between 4E-08 g/s – 5E-04 g/s, with one outlier that exceeded 2E-02 g/s. Since the total sales reported by manufacturers were greater than the total usage reported by individual facilities, it is not surprising that annual average emissions based on manufacturer sales would be higher than emissions based on individual facility data.

REFERENCES

ARB, 2004b. Air Resources Board. "2003 Thermal Spraying Materials Survey". 2004.

PES, 2000. "Final Report, Development of Emission Inventory for Metal Welding, Cutting, and Spraying Operations". Prepared by Pacific Environmental Services for the SCAQMD. 2000.

SDAPCD, 1998. San Diego County Air Pollution Control District. "Metal Deposition – Plasma and Flame Spray Operations." Updated October 1998. Online internet at http://www.sdapcd.co.san-diego.ca.us/toxics/emissions/metdep/metdep.html (July 12, 2004.)

SDAPCD, 2002a. SDAPCD Audit Report: Senior Flexonics - Compliance Source Test conducted by Air Quality Engineering, Inc. on January 10, 2002. March 28, 2002.

Appendix E

Air Quality Modeling of Emissions from Thermal Spraying Operations

Air Quality Modeling of Emissions from Thermal Spraying Operations

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Summary

It is requested to evaluate air quality impacts from emissions of hexavalent chromium from thermal spray operations. Four separate facilities are evaluated with meteorological data from different regions in the State. The emissions from the facilities range from 0.00011 lbs/yr to 0.023 lbs/yr. The maximum above ambient annual average concentration is estimated to be $2.8x10^{-4}$ $\mu g/m^3$ from the facility emitting 0.023 lbs/yr hexavalent chromium. Details of the analysis and additional results are described below.

Approach

Data from four separate facilities in the San Diego AQMD which have hexavalent chromium emissions are evaluated on an annual average basis for downwind air impacts. The stack parameters and building configurations are input to the US-EPA ISCST3 (Version 02035) air quality model to estimate downwind impacts. Urban dispersion coefficients are used in ISCST3. Receptor heights are set at 1.2 meters above ground level. Terrain is assumed to be flat. Meteorological data are considered from locations that are closest to each facility and as well as data from other places in the State such as Vernon, West Los Angeles, and South San Francisco.

Inputs

Tables 1 and 2 summarize the model inputs for the source configurations as derived from data provided by SSD staff.

Table 1 – Volume Sources

ID	H (m)	Syo (m)	Szo (m)	Bw (m)	Bh (m)
Src1	1.8	9.9	2.3	42.6	4.9

Syo=L/4.3, Szo=H/2.15.
Bw is taken as the length of the shortest side of the building.

Table 2 – Point Sources							
ID	Hs (m)	Ts (K)	Vs (m/s)	Ds (m)	Bw (m)	Bh(m)	Notes
Src2	5.5	299.8	23.96	0.549	43	4.0	(a)
Src3	10.7	294.3	19.01	0.811	100	9.2	(b)
Src4	13.7	293.2	12.92	0.884	181	12.2	(c)

(a) Bh estimated at 1.5 meters below Hs. Bw is estimated as the diameter of equivalent area to footprint.
(b) Bh estimated at 1.5 meters below Hs. Bw is estimated as the average of the other three facilities. Source next to Magnolia School.
(c) Bh is given. Bw is estimated as the diameter of equivalent area to footprint.

The annual average emissions are uniformly distributed over all hours when emissions may result. Even though facilities may only emit hexavalent chromium during certain periods (e.g., two hours per day), it is assumed that emissions may occur anytime the facility is in operation. Provided emissions result throughout the operating period over the year, this assumption should not bias the results. Table 3 below shows the annual inventory and the hours over which the annual average emissions are uniformly distributed based on data obtained on the operations of each facility.

Table 3 – Annual Inventory and Hourly Distribution			
ID	Annual Inventory (lbs/yr)	Hours when Emissions may Occur	
		Hours per day	Beginning at
Src1	2.27E-02	9	8 am
Src2	2.85E-04	6	6 am
Src3	2.78E-03	24	-
Src4	1.10E-04	9	8 am

Meteorological data are obtained from various locations. Table 4 summarizes the meteorological data used in this analysis. While representative meteorological data is preferred, it is not always possible to determine which station is the most representative of the project site. In these cases meteorological data from two nearest stations are used and results from both are presented. US-EPA Guidelines recommend the latest five years of consecutive meteorological data for these types of analyses. Five years of data are used where available. In addition, it is requested to simulate air dispersion with meteorological data from South San Francisco, West Los Angeles, and Vernon. In this case, the model results only reflect simulations from the facility with the highest emissions.

Table 4 – Meteorological Data Summary						
Station	Abbreviation	Year	Anemometer Height Input to Model (m)	Avg. WS (m/s)	% Calms	Notes
Barrio Logan	BL	2000	7	2.0	1 %	Data gathered at Logan Memorial for special study.
Lindbergh Airport	Lind	1985-1989	10	3.6	7 %	San Diego Airport
Miramar Naval Air Station	Mir	1967-1971	10	2.8	17 %	San Diego
Vernon	Vern	1981	10	2.3	7 %	SCAQMD
West Los Angeles	WLA	1981	10	1.5	19 %	SCAQMD
San Francisco Airport	SFO	1985-1989	10	5.4	5 %	

Results

The maximum above ambient annual average concentration is estimated to be 2.8×10^{-4} µg/m^3 from the facility emitting 0.023 lbs/yr hexavalent chromium. Figure 1 is a log-log plot showing the estimated above ambient annual average concentration of hexavalent chromium from all the facilities, as a function of downwind distance. The downwind direction is selected as the direction of the maximum annual impact. Table 5 shows the data presented in Figure 1.

Figure 1 – Above Ambient Annual Average Hexavalent Chromium Concentrations

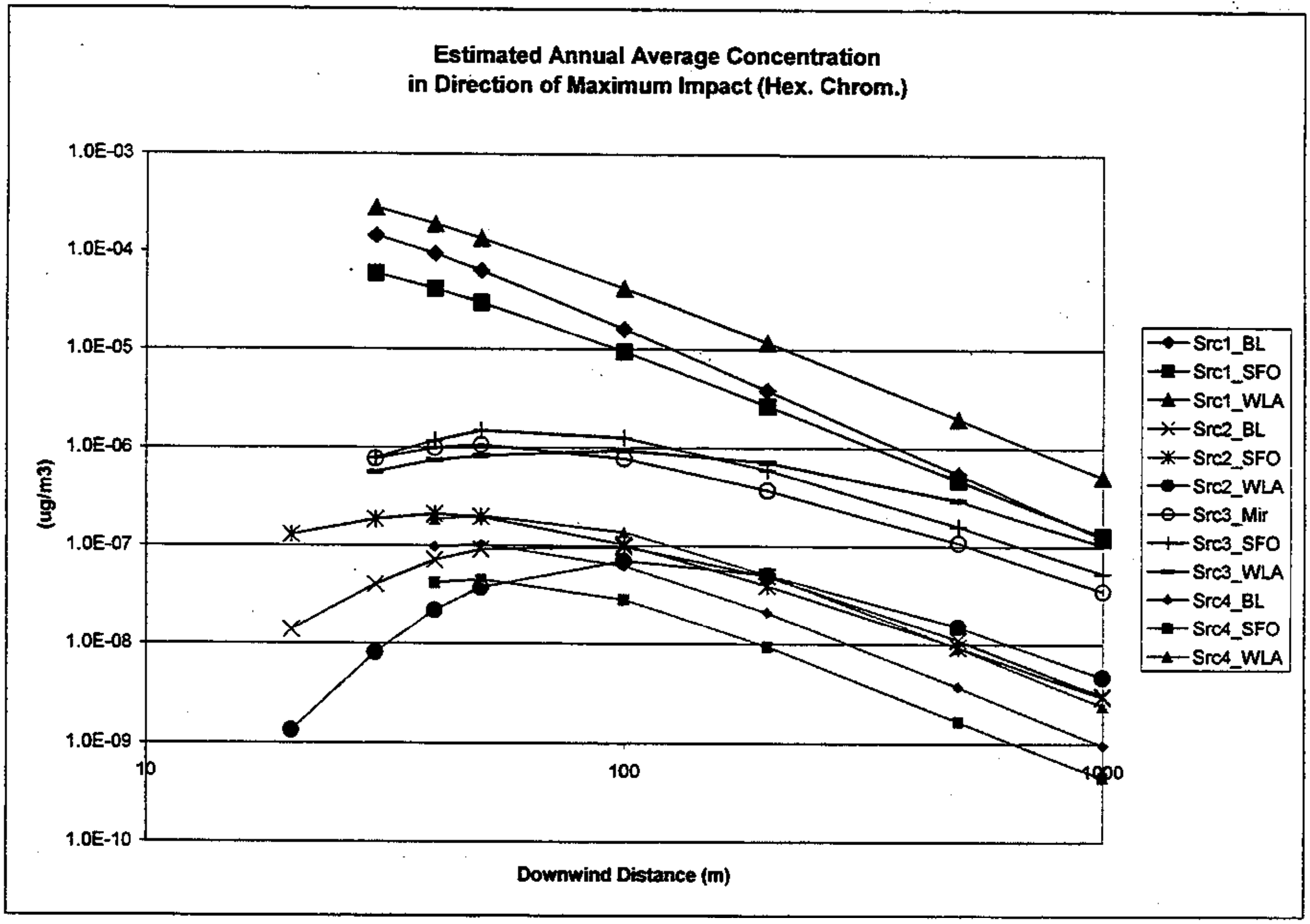


Table 5 – Summary Table of Above Ambient Annual Average Concentration of Hexavalent Chromium ($\mu g/m^3$)

Source ID	Met. Data	Dir (deg)	Distance from source (m)							
			20	30	40	50	100	200	500	1000
Src1	BL	70		1.4E-04	9.5E-05	6.3E-05	1.6E-05	3.8E-06	5.5E-07	1.2E-07
Src1	SFO	110		5.9E-05	4.2E-05	3.0E-05	9.4E-06	2.7E-06	4.7E-07	1.3E-07
Src1	WLA	40		2.8E-04	1.9E-04	1.4E-04	4.2E-05	1.2E-05	2.0E-06	5.1E-07
Src2	BL	40	1.4E-08	4.0E-08	7.1E-08	9.2E-08	9.8E-08	5.0E-08	1.1E-08	3.0E-09
Src2	SFO	120	1.3E-07	1.9E-07	2.1E-07	2.0E-07	1.0E-07	4.0E-08	9.4E-09	2.9E-09
Src2	WLA	40	1.3E-09	8.1E-09	2.2E-08	3.8E-08	7.0E-08	5.1E-08	1.5E-08	4.7E-09
Src3	Mir	120		7.7E-07	9.9E-07	1.1E-06	7.8E-07	3.7E-07	1.1E-07	3.5E-08
Src3	SFO	120		7.8E-07	1.2E-06	1.5E-06	1.3E-06	6.0E-07	1.6E-07	5.3E-08
Src3	WLA	50		5.7E-07	7.5E-07	8.3E-07	9.4E-07	7.1E-07	2.9E-07	1.0E-07
Src4	BL	100			9.7E-08	1.0E-07	6.3E-08	2.1E-08	3.7E-09	9.6E-10
Src4	SFO	220			4.2E-08	4.5E-08	2.8E-08	9.5E-09	1.7E-09	4.5E-10
Src4	WLA	50			1.8E-07	2.0E-07	1.4E-07	5.1E-08	9.3E-09	2.4E-09

A blank cell indicates plume has yet to touchdown or the receptor is near the building wake effects and no calculation is made.

Appendix F

Health Risk Assessment Estimation Methods

F.1. Risk Assessment Estimation Methods

This appendix describes the methods used to estimate the potential cancer and non-cancer risk from thermal metal spraying operations. These risk estimates were used to support the development of the proposed Thermal Spraying Airborne Toxic Control Measure (ATCM).

The risk estimates were based on air dispersion modeling results from four actual facilities in the San Diego County Air Pollution Control District (SDAPCD). The modeling results from these four facilities were used to estimate health risks from all of the thermal spraying facilities in California that use chromium or nickel containing compounds.

Exposures were estimated at varying receptor distances, including the point of maximum impact (PMI), as determined by air dispersion modeling at the actual facilities. The estimated risk levels are intended to provide an estimate of the potential health risks near thermal spraying facilities. Actual risks will vary due to site-specific parameters, including material usage, exhaust flowrate, control device efficiency, and distance to receptors.

The risk assessment was conducted using the following approach:

Step 1 - Hazard Identification	The risk assessor determines if a hazard exists, and if so, identifies the pollutant(s) and the type of effect, such as cancer or respiratory effects.
Step 2 - Dose-Response Assessment	The risk assessor characterizes the relationship between a person's exposure to a pollutant and the occurrence of an adverse health effect.
Step 3 - Exposure Assessment	The risk assessor estimates the extent of public exposure by looking at who is likely to be exposed, how exposure will occur, and the magnitude of exposure (e.g., the airborne concentration of a pollutant.)
Step 4 - Risk Characterization	The risk assessor combines airborne pollutant concentrations with cancer potency factors (for cancer risk) and reference exposure levels (for non-cancer effects) to quantify the potential cancer risk and non-cancer health impacts.

The methods used in this risk assessment are consistent with the Tier 1 analysis, presented in the OEHHA Air Toxics "Hot Spots" Program Risk Assessment Guidelines, the Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (OEHHA, 2003). Health and exposure information was obtained from the following references:

(1) The OEHHA Air Toxics "Hot Spots" Program Risk Assessment Guidelines, Part I, The Determination of Acute RELs for Airborne Toxicants (OEHHA, 1999);

(2) The OEHHA Air Toxics "Hot Spots" Program Risk Assessment Guidelines, Part II, Technical Support Document for Describing Available Cancer Potency Factors (OEHHA, 2002);
(3) The OEHHA Air Toxics Hot Spots Program Risk Assessment Guidelines, Part III, Technical Support Document for the Determination of Noncancer Chronic Reference Exposure Levels (OEHHA, 2000a);
(4) The OEHHA Air Toxics Hot Spots Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Analysis and Stochastic Analysis (OEHHA, 2000); and
(5) "Recommended Interim Risk Management Policy for Inhalation–Based Residential Cancer Risk" (ARB, 2003a)

Table F-1 summarizes the key parameters that were used when conducting the air dispersion modeling and the health risk assessment.

Table F-1:
Key Parameters for Air Dispersion Modeling and Health Risk Assessment

Air Dispersion Model:	U.S. EPA, Industrial Source Complex Short Term (ISCST3), Version 02035
Source Type:	Volume and Point
Dispersion Setting:	Urban
Receptor Height:	1.2 meters
Stack Information (Point Sources):	
Stack Diameters	0.55, 0.81, and 0.88 meters
Stack Heights	5.5, 10.7, and 13.7 meters
Stack Temperatures	300, 294, and 293 degrees Kelvin
Stack Exhaust Velocities	24, 19, and 13 meters/second
Volume Source Information:	
Release Height	1.8 meters
Lateral Dimension	9.9 meters
Vertical Dimension	2.3 meters
Meteorological Data:	Los Angeles area – Vernon, West LA San Francisco Bay area – San Francisco Airport San Diego area – Barrio Logan, Miramar Naval Air Station, Lindbergh Airport
Exposure Duration, Exposure Frequency	70 yrs, 350 days/year
Adult Daily Breathing Rates:	393 liters/kg body weight-day (high-end) 302 liters/kg body weight-day (80th percentile) 271 liters/kg body weight-day (mean)
Adult Body Weight:	70 kg
Cancer Inhalation Potency Factors:	Hexavalent Chromium – 510 $(mg/kg\text{-}day)^{-1}$ Nickel – 0.91 $(mg/kg\text{-}day)^{-1}$
Non-Cancer Acute Reference Exposure Levels (RELs) – Inhalation:	Hexavalent Chromium – not established Nickel – 6.0 ug/m^3
Non-Cancer Chronic RELs - Inhalation:	Hexavalent Chromium – 0.20 ug/m^3 Nickel – 0.05 ug/m^3
Non-Cancer Chronic RELs - Oral:	Hexavalent Chromium – 0.02 mg/kg-day Nickel – 0.05 mg/kg-day

F.2. Multi-Pathway Health Risk Assessment

In evaluating the potential health effects of a pollutant, it is important to identify the different routes by which an individual could be exposed to the pollutant. The appropriate pathways to include in a HRA are dependent on the specific toxic air pollutant that a person (receptor) is exposed to, and can include inhalation, dermal exposure, and the ingestion of soil, water, crops, fish, meat, milk, and eggs. However, hexavalent chromium and nickel are only considered to be carcinogenic via inhalation exposure (OEHHA, 2003.) In addition, our analysis indicates that the inhalation pathway and the potential impacts on the respiratory endpoint would present the most significant non-cancer chronic health impacts. Therefore, this health risk assessment focused upon the impacts of exposure to hexavalent chromium and nickel via the inhalation pathway.

F.3. Hazard Identification

Thermal spraying is a process in which metals are deposited in a molten or nearly molten condition to form a coating. The process generates air emissions of metal fumes and dust. These emissions can include chemicals that are classified as toxic air contaminants (e.g. hexavalent chromium and nickel.) The primary hazard from thermal spraying is related to air emissions of hexavalent chromium, followed by nickel.

Both hexavalent chromium and nickel are classified as carcinogens. Exposure to hexavalent chromium may cause lung and nasal cancers, respiratory irritation, severe nasal and skin ulcerations and lesions, perforation in the nasal septum, liver and kidney failure and birth defects. Exposure to nickel may cause lung and nasal cancers, allergic sensitization, asthma, and other respiratory ailments. It is possible to have significant potential acute health impacts from nickel, even though the potential for cancer health impacts from nickel is very low.

In 2003, the Air Resources Board (ARB) staff conducted a survey of thermal spraying materials that were sold in California during 2002. The survey focused on gathering data for products that contained toxic air contaminants. It also gathered data on products that contained copper, due to potential acute health risks. Based on the survey results, the primary chemicals of concern were: Hexavalent chromium, nickel, and cobalt. Cobalt has not yet been assigned a cancer potency factor or any non-cancer health factor; therefore, cobalt is not included in the risk assessment calculations for this report. Hexavalent chromium and nickel are the two chemicals that were evaluated for potential cancer and non-cancer health impacts.

F.4. Dose Response Assessment

OEHHA develops dose-response factors to characterize the relationship between a person's exposure to a pollutant and the occurrence of an adverse health effect. A cancer potency factor is used when estimating potential cancer risks and reference exposure levels (RELs) are used to assess potential non-cancer health impacts (OEHHA, 1999; OEHHA, 2002; OEHHA, 2003).

Table F-2 contains inhalation cancer potency factors, non-cancer RELs, and non-cancer toxicological endpoints for hexavalent chromium and nickel. No acute REL has been established for hexavalent chromium. Therefore, we did not estimate acute health impacts from hexavalent chromium.

Table F-2:
Health Effects Values Used in Health Risk Assessment

	Hexavalent Chromium	Nickel
Cancer Inhalation Potency Factor (mg/kg-day)$^{-1}$	510	0.91
Non-Cancer Reference Exposure Levels (ug/m^3)		
Acute - Inhalation	N/A	6.0
Chronic – Inhalation	0.20	0.05
Chronic - Oral	0.02	0.05
Toxicological Endpoints		
Acute - Inhalation	N/A	Immune System and Respiratory System
Chronic – Inhalation	Respiratory system	Hematopoietic System and Respiratory System
Chronic - Oral	Hematologic	Alimentary

(OEHHA, 2003)

F.5. Exposure Assessment

Hexavalent chromium and nickel are only considered to be carcinogenic when exposure occurs by the inhalation route (OEHHA, 2003.) In addition, non-cancer chronic health impacts can occur through multiple pathways, including inhalation, soil ingestion, and dermal (skin) exposure. Non-cancer acute health impacts occur by inhalation only.

For thermal spraying activities, the persons that are most likely to be exposed include off-site workers located near the facility and nearby residents. On-site workers could be impacted by the emissions; however, they are not included in this health risk assessment (HRA) because Cal/OSHA has jurisdiction over on-site workers.

The magnitude of exposure was assessed through the following process. ARB staff conducted air dispersion modeling to provide downwind airborne concentrations of hexavalent chromium and nickel in the ambient air. The downwind concentration is a function of the quantity of emissions, release parameters at the source, and appropriate meteorological conditions. Results of the air dispersion modeling are detailed in Appendix E.

Air dispersion modeling was conducted using the U.S. EPA, Industrial Source Complex Short Term (Version 02035) air dispersion model (ISCST3 model). The ISCST3 model estimates concentrations at specific locations around each facility, directly caused by each facility's emissions. Facility operating parameters are provided in Table F-3 and exhaust parameters are contained in Table F-4.

Table F-3:
Air Dispersion Modeling - Facility Parameters

Facility	Stack Height (m)	Stack Diameter (m)	Stack Gas Temp. (°K)	Stack Gas Velocity (m/s)	Hours When Emissions May Occur		Hexavalent Chromium Emissions	
					Hours Per Day	Beginning At	Average Rate (g/s)	Annual (lbs/yr)
1	1.8	0.3	-*	-*	9	8 am	8.71E-07	2.27E-02
2	5.5	0.549	299.8	23.96	6	6 am	1.64E-08	2.85E-04
3	10.7	0.811	294.3	19.01	24	-	4.00E-08	2.78E-03
4	13.7	0.884	293.2	12.92	9	8 am	4.23E-09	1.10E-04

* Volume Source (i.e., no exhaust stack)
Glossary of Acronyms:
(m) = Meters
(°K) = Degrees Kelvin
(m/s) = Meters Per Second
(g/s) = Grams Per Second
(lbs/yr) = Pounds Per Year

Table F-4:
Air Dispersion Modeling – Exhaust Parameters

Facility	Type of Source	Exhaust Parameters		
1	Volume	H = 1.8 m	Syo = 9.9 m	Szo = 2.3 m
2	Point	Hs = 5.5 m	Ds = 0.55 m	Vs = 23.96 m/s
3	Point	Hs = 10.7 m	Ds = 0.81 m	Vs = 19.01 m/s
4	Point	Hs = 13.7 m	Ds = 0.88 m	Vs = 12.92 m/s

H = Source Release Height, meters
Syo = Initial Lateral Dimension of the Volume, meters
Szo = Initial Vertical Dimension of the Volume, meters
Hs = Stack Height, meters
Ds = Stack Diameter, meters
Vs = Stack Gas Velocity, meters/second

Facility #1 was modeled as a volume source, because emissions were exhausted through a horizontal vent at breathing zone height. Volume sources can result in higher health risks, because the pollutant discharge is more concentrated near the breathing zone, rather than being dispersed through a vertical exhaust stack. Facilities #2, #3, and #4 were modeled as point sources with vertical exhaust stacks. All four facilities were equipped with air pollution control devices.

The majority of the thermal spraying facilities in California are located in three areas: Los Angeles, San Diego, and the San Francisco Bay Area. This conclusion is based on the results of ARB's 2004 Thermal Spraying Facility Survey, ARB's 2003 Thermal Spraying Materials Survey, and air permit data from local districts (ARB, 2004c; ARB, 2004b). Meteorological data from these three areas were used to conduct air dispersion modeling for all four facilities. The modeling analyzed airborne concentrations for potential receptor distances that ranged from 30 to 5000 meters (or 100 – 16,400 feet) away from the thermal spraying facilities. The detailed results from this modeling are contained in Appendix E.

Air dispersion modeling results are expressed as an air concentration or in terms of (CHI/Q) for each receptor distance. (CHI/Q is the modeled downwind concentration based on an emission rate of one gram per second.) Table F-5 lists the (CHI/Q) values that resulted from the air dispersion modeling. These values represent the high-end results from the air dispersion modeling. For each of the four actual facilities, we evaluated results from the three meteorological areas and selected the set of results from the one meteorological area that yielded the highest annual average concentrations. The table contains the annual average (CHI/Q) values and the corresponding maximum 1-hour (CHI/Q) values for the selected meteorological areas.

Table F-5:
Facilities –CHI/Q Values (ug/m^3)/(g/s)

Facility	Receptor Distance from source (meters)									Max. 1-Hr CHI/Q
	30	40	50	100	200	500	1000	2000	5000	
1	321.50	220.16	156.63	48.54	13.51	2.28	0.59	0.20	0.07	5671
2	11.37	12.78	12.07	6.33	2.41	0.57	0.18	0.06	0.02	708
3	19.60	29.36	37.40	31.48	15.06	4.00	1.33	0.44	0.11	453
4	N/A	43.62	47.63	32.68	12.04	2.20	0.57	0.19	0.07	333

N/A: Plume has yet to touch down or the receptor is near the building wake effects.

The ARB 2004 Thermal Spraying Facility Survey gathered data on the locations of active thermal spraying businesses in California. ARB staff used this location data and local zoning information to estimate the distance from a business to the nearest sensitive receptor. Sensitive receptors that were identified included schools, hospitals, and residential areas. Most (>70%) thermal spraying facilities are located more than 100 meters (or 330 feet) from sensitive receptors. The (CHI/Q) values and corresponding health risks decrease significantly beyond 100 meters. Figures F-1 and F-2 illustrate the number of facilities at each receptor distance and the corresponding (CHI/Q) value.

Figure F-1:
Point Sources - Number of Facilities in Each Receptor Distance Range & Corresponding (CHI/Q)

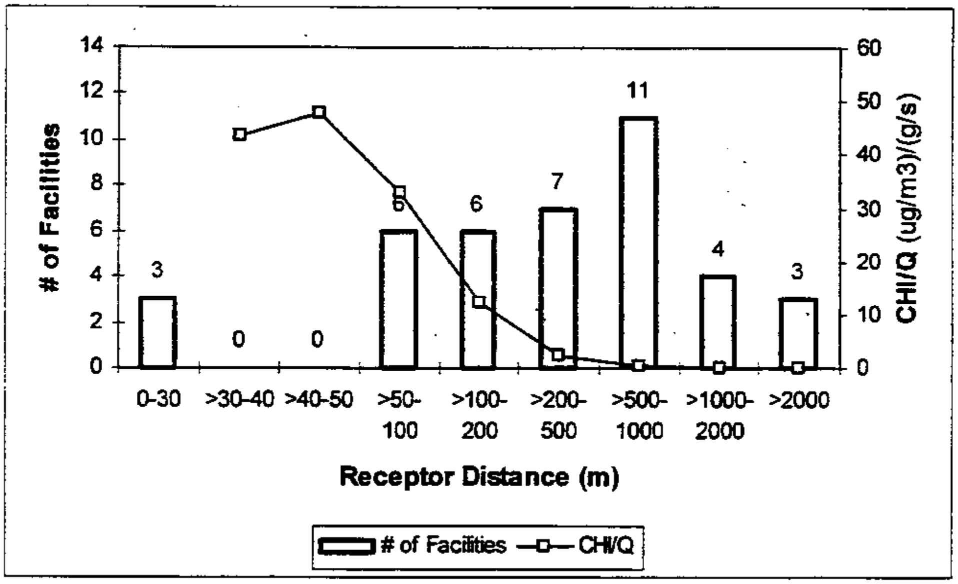
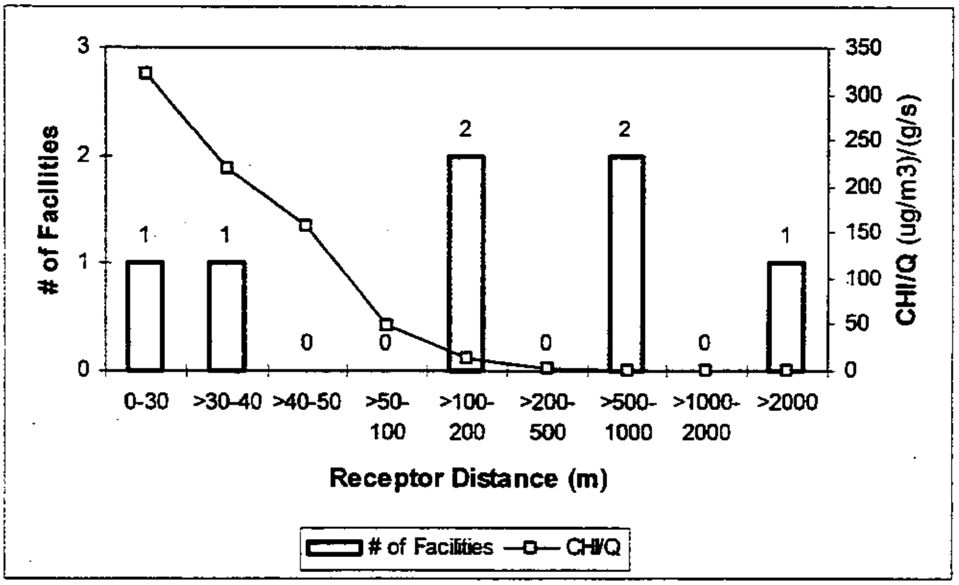


Figure F-2:
Volume Sources - Number of Facilities in Each Receptor Distance Range & Corresponding (CHI/Q)



Different thermal spraying processes can cause different emission rates. The health risk assessment included an evaluation of the health risks associated with emissions from the following processes: flame spraying; plasma spraying; and twin-wire electric arc. These processes were selected because they were the top three most common types identified in ARB's 2004 Thermal Spraying Facility Survey.

Ground-level concentrations (GLCs) for pollutants were calculated using the following equation and the [CHI/Q] values in Table F-5.

Eqn. F.1.: [GLC] = [CHI/Q][Q]* (OEHHA, 2003)

where
GLC = Ground Level Concentration of Pollutant, ug/m^3
CHI/Q = Modeled Downwind Air Concentration of Pollutant, $(ug/m^3)/(g/s)$

$$Q = \text{Average Emission Rate of Pollutant (g/s)} = \frac{[\text{Annual Emissions, lb/yr}]*453.59\ \text{grams/lb}]}{[365\ \text{days/yr}]*[\text{Operating Hours, hrs/day}]*[3600\ \text{sec/hr}]}$$

Equation F.1 allowed us to evaluate how different emission rates could impact the concentration of pollutants in the air. Ground level concentrations were estimated for each of the three thermal spraying processes, at each of the generic facilities. The calculated GLCs represent a conservative estimate of the pollutant concentrations at each facility.

F.6. Cancer Risk Characterization

Cancer risk characterization involves calculating the potential health risks, based on exposure and cancer potency factors. We evaluated the cancer and non-cancer health impacts and found that the potential cancer health impacts were more significant than non-cancer impacts. Therefore, the following section focuses on cancer risk thresholds and a correlation to emission rates. Section F.6 contains a discussion of non-cancer health impacts.

For the purposes of this risk assessment, we determined the threshold emission rates that would likely result in potential cancer risk levels of up to 1 in a million and up to 10 in a million.

To estimate the cancer risk from inhalation exposure, we used the following equations (OEHHA, 2003):

Eqn. F.2: $[\text{Cancer Risk}] = [\text{Inhalation Dose, mg/kg-day}]*[\text{Cancer Potency, } (\text{mg/kg-day})^{-1}]$

Note: To convert this to chances per million, multiply the cancer risk by 10^6.

Eqn. F.3: $$[\text{Inhalation Dose, mg/kg-day}] = \frac{[C_{air}]*[DBR]*[A]*[EF]*[ED]*[10^{-6}]}{AT}$$

where

	Definitions	Values
C_{air}	= Concentration in Air, ug/m^3	Based on air dispersion modeling or calculated GLC
DBR	= Adult Daily Breathing Rate, L/kg body weight-day	Defaults = 393 (70-yr exposure, high-end) = 302 (70-yr exposure, 80th percentile) = 271 (70-yr exposure, mean)*
A	= Inhalation Absorption Factor, unitless	Default = 1
EF	= Exposure Frequency, days/year	Default = 350
ED	= Exposure Duration, years	Default = 70
AT	= Averaging Time Period for Exposure, days	Default = 25,550 (70 yrs * 365 days/year)
10^{-6}	= Micrograms to Milligrams conversion and Liters to Cubic Meters conversion	

For each of the facilities listed in Table F-3, we estimated the annual emissions of hexavalent chromium that would likely result in potential cancer risks of up to 1 in a million and up to 10 in a million. Staff also calculated the usage quantities of chromium that corresponded to these emission levels. Emissions were estimated using emission factors, as discussed in Appendix C and Appendix D.

Equations F.1, F.2, and F.3 are generally used to evaluate the risk based on a given set of operating parameters. However, these equations can also be used to determine the emission rates that are likely to result in potential cancer risks at a given level. As shown below, Equations F.1, F.2, and F.3 can be reorganized to calculate the emission rates that that would likely result in potential cancer risks of up to 1 in a million and up to 10 in a million.

$$[Inhalation\ Dose] = \frac{[C_{air}]*[DBR]*[A]*[EF]*[ED]*[10^{-6}]}{AT}$$

$$[Cancer\ Risk,\ chances\ per\ million] = [Inhalation\ Dose]*[Cancer\ Potency]*10^6$$

Therefore, the inhalation dose that would likely result in a potential cancer risk at a given level is –

$$Eqn.\ F.4:\quad [Inhalation\ Dose\ @\ risk\ level,\ mg/kg/day] = \frac{[Cancer\ Risk]}{[Cancer\ Potency]*10^6}$$

The airborne concentration (C_{air}) that would likely result in a potential cancer risk at a given level is –

$$Eqn.\ F.5:\quad [C_{air}\ @\ risk\ level,\ ug/m^3] = \frac{[Inhalation\ Dose\ @\ risk\ level,\ mg/kg/day]*[AT][10^6]}{[DBR]*[A]*[EF]*[ED]}$$

$[C_{air}] = [CHI/Q]*[Q]$ and
$[Q] = [C_{air}]/[CHI/Q]$

Therefore, the emission rate (Q) that would likely result in a potential cancer risk at a given level is –

Eqn. F.6: $$[Q, \text{Emission Rate @ risk level, g/s}] = \frac{[\text{Cair @ risk level}]}{[CHI/Q]}$$

The annual emissions level that would likely result in a potential cancer risk at a given level is –

Eqn. F.7: $$[\text{Annual Emissions @ risk level, lb/yr}] = \frac{[\text{Q @ risk level, g/s}]*[\text{Operating Hours, hrs/yr}]*[3600 \text{ sec/hr}]}{[453.59 \text{ g/lb}]}$$

"Operating Hours" are the annual hours of operation that were used in the air dispersion modeling and which correspond to the (CHI/Q) value.

For example, to determine the hexavalent chromium emission rate that would likely result in a potential cancer risk that does not exceed 10 in a million –

Assumptions:
- Point Source
- Receptor distance = 50 meters (164 feet)
- CHI/Q (from air dispersion modeling) = 47.63 (ug/m^3)/(g/s)
- Operating Hours (from air dispersion modeling) = 9 hrs/day, 365 days/yr
- Daily Breathing Rate = 393 L/kg body weight-day), 95th percentile value
- Cancer Potency Factor, Hexavalent Chromium = 510 (mg/kg-day)$^{-1}$

The inhalation dose that would likely result in a potential cancer risk up to 10 in a million is –

$$[\text{Inhalation Dose @ 10 in a million risk, mg/kg/day}] = \frac{[10]}{[510]*10^6} = 1.96E\text{-}08 \text{ mg/kg/day}$$

The airborne concentration that would likely result in a potential cancer risk that does not exceed 10 in a million is –

$$[\text{Cair @ risk level, ug/m3}] = \frac{[1.96E\text{-}08 \text{ mg/kg/day}]*[25550 \text{ days}]*[10^6]}{[393 \text{ l/kg-day}]*[1]*[350 \text{ days/yr}]*[70 \text{ yrs}]} = 5.20E\text{-}05 \text{ ug/m}^3$$

The emission rate (Q) that that would likely result in a potential cancer risk that does not exceed 10 in a million is –

$$[Q, \text{Emission Rate @ risk level, g/s}] = \frac{[5.20E\text{-}05 \text{ ug/m}^3]}{[47.63 (\text{ug/m}^3)/(\text{g/s})]} = 1.09E\text{-}06 \text{ g/s}$$

To calculate annual emissions that would likely result in a potential cancer risk that does not exceed 10 in a million –

$$[\text{Annual Emissions @ risk level, lb/yr}] = \frac{[1.09E\text{-}06 \text{ g/s}]*[3285 \text{ hrs/yr}]*[3600 \text{ sec/hr}]}{[453.59 \text{ g/lb}]} = 0.028 \text{ lb/yr}$$

Table F-6 summarizes the minimum emission rates that that would likely result in a potential cancer risk of up to 10 in a million for hexavalent chromium. Table F-5 represents a conservative scenario for potential cancer risks that corresponds to the point of maximum impact for health effects. Emissions from facilities that are located at different receptor distances may result in lower potential cancer risk estimates.

Table F-6:
Minimum Cr^{+6} Emission Rates That Would Likely Result in Potential Cancer Risks Up to 10 in a Million

Facility	Type of Source	Receptor Distance Where Minimum Occurs (m)	Minimum Emission Rate (lbs Cr^{+6}/yr)	
			High-End *	Mean *
1	Volume Source	30	0.004	0.006
4	Point Source	50	0.028	0.041

* The potential cancer risk was calculated using the following daily breathing rates (DBRs):

High-End (95th percentile) = 393 L/kg body weight-day
Mean (65th percentile) = 271 L/kg body weight-day

Table F-7:
Minimum Nickel Emission Rates That Would Likely Result in Potential Cancer Risks Up to 10 in a Million

Facility	Type of Source	Receptor Distance Where Minimum Occurs (m)	Minimum Emission Rate (lbs Ni/yr)	
			High-End	Mean
1	Volume Source	30	2	3
4	Point Source	50	16	23

If a facility has performed a stack test, they may be able to use the results of that stack test to determine whether their annual emissions exceed the levels in Tables F-6 and F-7. For facilities that have not performed a stack test, they can calculate their emissions using the emission calculation methods described in Appendix C and Appendix D.

Figures F-3 and F-4 illustrate the potential cancer risk ranges for set emission levels and different receptor distances. The shaded areas indicate potential cancer risk ranges that are less than or equal to 10 in a million, based on the 95^{th} percentile breathing rate. Both figures show that there are two situations which would likely result in potential cancer risks that do not exceed 10 in a million:

(1) Limiting hexavalent chromium emissions to 0.01 lbs Cr^{+6}/yr (for point sources) and 0.004 lbs Cr^{+6}/yr (for volume sources); or
(2) Locating thermal spraying facilities at least 1640 feet (500 meters) from sensitive receptors.

Figure F-3: Hexavalent Chromium - Estimated Risk Range vs. Receptor Distance for Point Sources

Emissions (lbs Cr^{+6}/yr)								
0.004	A	A	A	A	A	A	A	A
0.01	A	A	A	A	A	A	A	A
0.05	B	B	B	A	A	A	A	A
0.1	B	B	B	A	A	A	A	A
0.5	C	C	C	B	A	A	A	A
	40	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**
	Receptor Distance (meters)							

KEY A: ≤ 10 in a million
B: >10 and ≤ 100 in a million
C: >100 in a million

Figure F-4: Hexavalent Chromium – Estimated Risk Range vs. Receptor Distance for Volume Sources

Emissions (lbs Cr^{+6}/yr)									
0.004	A	A	A	A	A	A	A	A	A
0.01	B	B	B	A	A	A	A	A	A
0.05	B	B	B	B	A	A	A	A	A
0.1	C	C	C	B	A	A	A	A	A
0.5	C	C	C	C	B	A	A	A	A
	30	**40**	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**
	Receptor Distance (meters)								

KEY A: ≤ 10 in a million
B: >10 and ≤ 100 in a million
C: >100 in a million

Figures F-5 and F-6 illustrate the potential cancer risk ranges for set emission levels of nickel at different receptor distances. Figures F-5 and F-6 are based on nickel emission levels that are much higher than the hexavalent chromium emission levels shown in Figures F-3 and F-4. Even though the nickel emissions are higher than the emissions of hexavalent chromium, the potential health risks from nickel are much lower than the potential risks from hexavalent chromium. This is due to the fact that nickel is less toxic than hexavalent chromium.

Figure F-5: Nickel – Estimated Risk Range vs. Receptor Distance for Point Sources

Emissions (lbs Ni/yr)								
2	A	A	A	A	A	A	A	A
5	A	A	A	A	A	A	A	A
10	A	A	A	A	A	A	A	A
50	B	B	B	A	A	A	A	A
100	B	B	B	B	A	A	A	A
	40	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**
	Receptor Distance (meters)							

KEY A: ≤ 10 in a million
B: >10 and ≤ 100 in a million

Figure F-6: Nickel - Estimated Risk Range vs. Receptor Distance for Volume Sources

Emissions (lbs Ni/yr)									
2	A	A	A	A	A	A	A	A	A
5	B	B	B	A	A	A	A	A	A
10	B	B	B	A	A	A	A	A	A
50	C	C	C	B	A	A	A	A	A
100	C	C	C	B	B	A	A	A	A
	30	**40**	**50**	**100**	**200**	**500**	**1000**	**2000**	**5000**
	Receptor Distance (meters)								

KEY A: ≤ 10 in a million
B: >10 and ≤ 100 in a million
C: >100 in a million

The ARB 2004 Thermal Spraying Facility Survey gathered data on the total annual material usage quantities and the types of toxic air contaminants contained in thermal spraying materials. These data were used to estimate the potential health risks for each facility. In addition, some facilities provided more detailed information on material usage and product composition. If detailed product composition data was not available, we used data from the ARB 2003 Thermal Spraying Manufacturer Survey to estimate the weight percentages of chromium and nickel contained in the thermal spraying materials. According to the Manufacturer Survey, thermal spraying powders contained 30.7% of chromium and 54.1% nickel, while wires contained 20.1% chromium and 53.1% nickel, based on sales-weighted averages. When estimating emissions for individual facilities, it was assumed that all of the reported material contained 30.7% of chromium and 54.1% nickel, to be conservative. Table F-8 summarizes the maximum estimated cancer risks from hexavalent chromium emitted by small, medium, and large thermal spraying facilities. Small facilities are those that reported an annual usage quantity of 500 lbs/yr or less for thermal spraying materials. Medium facilities reported annual usage quantities between 500 – 5000 lbs/yr. Large facilities reported more than 5,000 lbs/yr of thermal spraying materials.

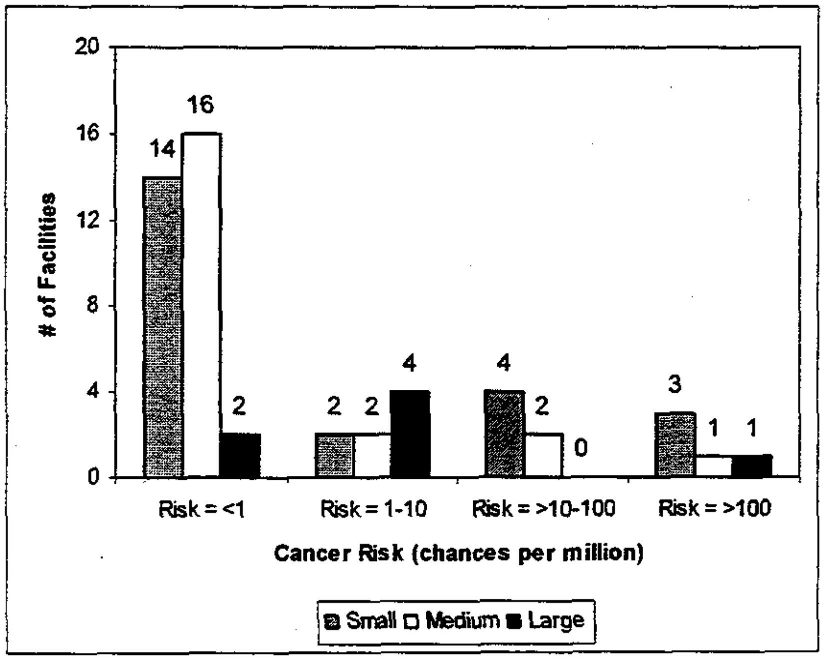
Table F-8:
Distribution of Maximum Potential Cancer Risks from Thermal Spraying - Hexavalent Chromium

Maximum Potential Cancer Risk	Small (500 lbs/yr or less of total material usage)	Medium (>500 – 5,000 lbs/yr of total material usage)	Large (>5,000 lbs/yr of total material usage)
Risk = <1	14	16	2
Risk = 1-10	2	2	4
Risk = >10-100	4	2	0
Risk = >100	3	1	1
Totals:	**23**	**21**	**7**

1. High-end daily breathing rate of 393 L/kg body weight-day was used to estimate cancer risk.
2. Assume that thermal spraying materials contain the sales-weighted average value of chromium (30.7 wt.%), as identified in ARB 2003 Thermal Spraying Manufacturer Survey, if detailed facility usage data was not available.
3. Average emission factors were established for each facility, based on the reported thermal spraying processes and reported control devices.

Figure F-7 illustrates the distribution of maximum potential cancer risks from thermal spraying hexavalent chromium emissions, based on facility size (i.e. the quantity of thermal spraying materials used annually.) This figure includes 21 thermal spraying facilities that pose a health risk <1 because they do not use materials containing chromium.

Figure F-7:
Maximum Estimated Potential Cancer Risk from Hexavalent Chromium Based on Facility Size



Small - 500 lbs/yr or less; Medium - > 500 - 5000 lbs/yr; Large - > 5000 lbs/yr

Table F-9 summarizes the maximum potential cancer risks from nickel emitted by thermal spraying facilities.

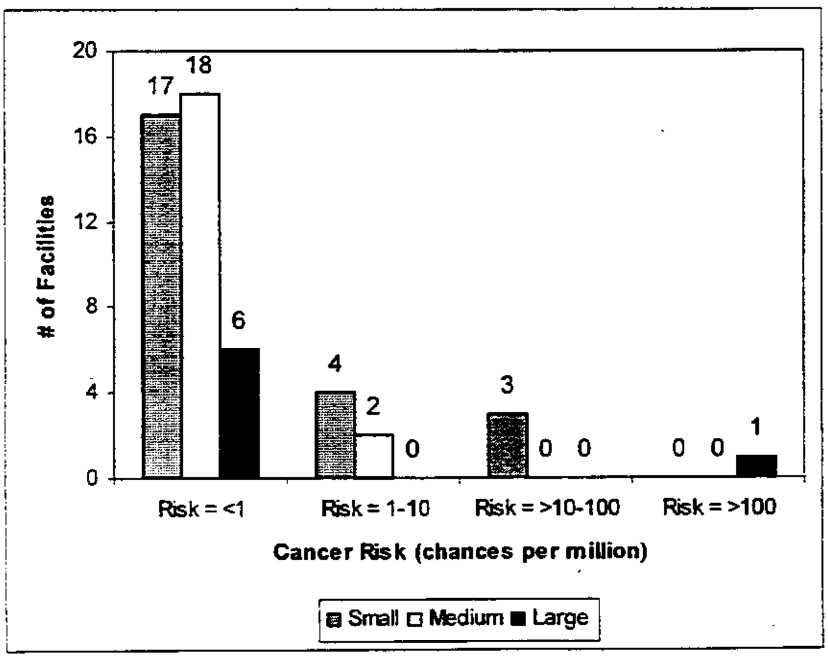
Table F-9:
Distribution of Maximum Potential Cancer Risks from Thermal Spraying – Nickel

Maximum Potential Cancer Risk	Small (500 lbs/yr or less of total material usage)	Medium (500 – 5,000 lbs/yr of total material usage)	Large (>5,000 lbs/yr of total material usage)
Risk = <1	17	18	6
Risk = 1-10	4	2	0
Risk = >10-100	3	0	0
Risk = >100	0	0	1
Totals:	**24**	**20**	**7**

1. High-end daily breathing rate of 393 L/kg body weight-day was used to estimate cancer risk.
2. Assume that thermal spraying materials contain the sales-weighted average values of nickel (54.1 wt.%), as identified in ARB 2003 Thermal Spraying Manufacturer Survey.
3. Average emission factors were established for each facility, based on the reported thermal spraying processes and reported control devices.

Figure F-8 illustrates the distribution of maximum potential cancer risks from thermal spraying nickel emissions, based on facility size (i.e. the quantity of thermal spraying materials used annually). This figure includes 16 thermal spraying facilities that pose a health risk <1 because they do not use materials containing nickel.

Figure F-8:
Maximum Estimated Potential Cancer Risk from Nickel Based on Facility Size



Small - 500 lbs/yr or less; Medium - > 500 - 5000 lbs/yr; Large - > 5000 lbs/yr

Potential health impacts are based on pollutant emission rates, but facilities generally track material usage, rather than emissions. Therefore, we've also estimated the minimum chromium usage rates that would likely result in potential cancer risks that do not exceed 10 in a million. Facilities could then compare their chromium usage rates with these levels to determine whether their operations might present a potential risk of approximately 10 in a million. To calculate the quantity of chromium used, facilities would need to identify the percentage of total chromium that is contained in their thermal spraying materials and then multiply that percentage by the quantity of material used. Table F-10 lists the minimum annual usage quantities for total chromium that would likely result in potential cancer risks that do not exceed 10 in a million for different processes and control devices. These values are based on the emission calculation methods described in Appendix C and Appendix D.

Table F-10:
Minimum Usage Rates That Would Likely Result in Potential Cancer Risks Up to 10 in a Million *

Type of Source / Control Efficiency	Receptor Distance Where Minimum Occurs (m)	Minimum Chromium Usage (lbs Cr/yr)		
		Flame Spraying	Plasma Spraying	Twin-Wire Electric Arc
Volume Source	30			
0%		1	<1	1
90%		4	1	6
99%		68	2	61
Point Source	50			
0%		5	2	4
90%		24	4	41
99%		459	11	409

*Cancer risk estimates were based on the high-end daily breathing rate of 393 L/kg body weight-day.

As shown above, a volume source that performs plasma spraying and uses products containing only 1 lb/yr of chromium could potentially result in cancer risks of up to 10 in a million for nearby receptors. The results from the other facilities also indicate that using small quantities of chromium can lead to cancer risks that exceed 10 in a million. To reduce the cancer risk from an uncontrolled operation, a facility would either need to install a control device or limit the usage of chromium-containing products to very low levels.

The results of the risk assessment indicate that a device which achieves 99.97% control efficiency will provide adequate control to keep potential cancer risks below 10 in a million, even if large quantities of chromium and nickel are used. The proposed ATCM is designed to ensure that potential cancer risk does not exceed 10 in a million for any thermal spraying facility that uses chromium or nickel.

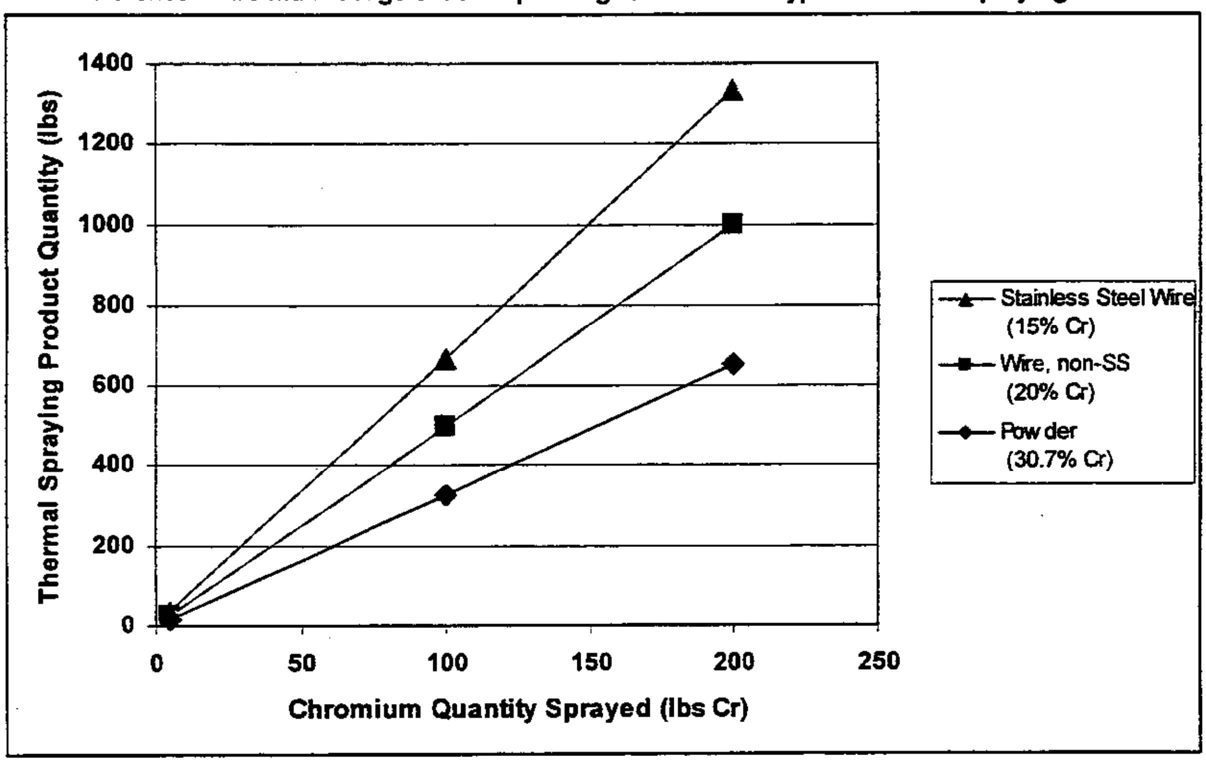
Emissions calculations and risk analyses were based on the quantity of pure chromium used. However, most shops use thermal spraying materials that contain only a percentage of chromium. Therefore, it's useful to provide a cross-reference for the amount of thermal spraying material that would correspond to a given amount of pure chromium. Table F-11 provides this information, based on the sales-weighted average chromium percentages from ARB's 2003 Thermal Spraying Materials Survey. Figure F-9 is a graphical cross-reference.

Table F-11:
Quantity of Pure Chromium in Thermal Spraying Products

This Quantity of Elemental Chromium (lbs Cr/yr):	Is equivalent to these amounts for thermal spraying products (lbs/yr):		
	Powder (30.7% Cr)	*Wire (non-stainless steel) (20% Cr)*	*Stainless Steel Wire (15% Cr)*
1	3	5	7
5	16	25	33
25	81	125	167
50	163	250	333
100	326	500	667

For example, spraying 25 pounds of chromium is equivalent to spraying 81 pounds of a typical thermal spraying powder (containing 30.7% of chromium).

Figure F-9:
Cross Reference: Chromium Usage & Corresponding Quantities of Typical Thermal Spraying Products



F.7. Non-Cancer Chronic Risk Characterization

Non-cancer chronic risk characterization involves estimating the maximum potential health impacts, based on long-term chronic exposure and reference exposure levels. Non-cancer health impacts are estimated by calculating a hazard quotient (single pollutant) or a hazard index (multiple pollutants). For the purposes of this risk assessment, we performed a multi-pathway risk assessment for non-cancer health impacts. Based on this analysis, we determined that the inhalation pathway and the potential impacts on the respiratory endpoint would present the most significant non-cancer chronic health impacts. Therefore, we determined the threshold emission rates that would likely result in a potential hazard index that does not exceed 1.0 for hexavalent chromium and nickel, based on the inhalation pathway only.

To estimate the non-cancer hazard indices from long-term chronic inhalation exposure, we used the following equation for each chemical, then added the impacts together when both chemicals impacted the same toxicological endpoint (e.g., the respiratory tract) (OEHHA, 2003):

Eqn. F.8: $$[\text{Hazard Quotient}] = \frac{[\text{Annual Average Concentration, } ug/m^3]}{[\text{Chronic Reference Exposure Level, } ug/m^3]}$$

Annual average concentrations can be obtained from air dispersion modeling or they can be calculated (*[GLC] = [CHI/Q]*[Q]*). Table F-2 contains reference exposure levels (RELs).

For each of the facilities listed in Table F-3, we calculated the annual emissions that would likely result in a potential hazard index that does not exceed 1.0. Equation F.5 is generally used to evaluate the hazard quotient based on a given concentration. However, this equation can also be used to determine the emission rates that would likely result in a given hazard quotient. As shown below, Equation F.8 can be reorganized to calculate the emission rates that would likely result in a potential chronic hazard quotient that does not exceed 1.0.

$$[\text{Hazard Quotient}] = \frac{[\text{Annual Avg. Concn.}]}{[\text{Chronic REL}]} = \frac{GLC}{[\text{Chronic REL}]} = \frac{[CHI/Q]*[Q]}{[\text{Chronic REL}]}$$

Therefore, the emission rate that would likely result in a given hazard quotient is –

Eqn. F.9: $$[Q] = \text{Avg. Emission Rate (g/s)} = \frac{[\text{Hazard Quotient}]*[\text{Chronic REL}]}{[CHI/Q]}$$

Our chronic risk analysis was based on the assumption that both hexavalent chromium and nickel could be emitted simultaneously. We determined the minimum emission rates that would likely result in a potential chronic hazard index that does not exceed 1.0 for hexavalent chromium and nickel combined.

For hexavalent chromium, the emission rates that would likely result in a chronic hazard quotient of up to 1.0 are much higher than the emission rates that would trigger the need for additional controls to protect against cancer risk. Therefore, the controls that would be required to protect against cancer impacts would keep emission rates well below the level that could result in chronic health impacts from either hexavalent chromium or nickel.

If nickel was the only pollutant being emitted, the emission rates that would likely result in a chronic hazard quotient of up to 1.0 are higher than the emission rates that would trigger the need for additional controls to protect against cancer risk. Therefore, the controls that would be required to protect against cancer impacts would keep emission rates below the level that could result in chronic health impacts.

Our analysis indicated that long-term exposure to hexavalent chromium and nickel emissions from a small number of high-use thermal spraying facilities could result in a chronic hazard index greater than one. All but a few of the thermal spraying facilities in the State are expected to have hazard indices less than one. The highest estimated hazard index for a specific thermal spraying facility was approximately two. The proposed ATCM is designed to ensure that the chronic hazard index does not exceed 1.0 for any thermal spraying facility that uses chromium or nickel.

F.8. Non-Cancer Acute Risk Characterization

Non-cancer acute risk characterization involves calculating the maximum potential health impacts, based on short-term acute exposure and reference exposure levels. Non-cancer acute impacts are estimated by calculating a hazard quotient (single pollutant) or a hazard index (multiple pollutants). For the purposes of this risk assessment, we determined the threshold emission rates that would likely result in a potential hazard quotient that does not exceed 1.0. Hexavalent chromium does not have an established acute reference exposure level. Therefore, our evaluation only included nickel.

To estimate the non-cancer health impacts from short-term acute inhalation exposure, we used the following equation (OEHHA, 2003):

Eqn. F.10:

$$[\text{Hazard Quotient}] = \frac{[\text{Maximum Hourly Concentration, } ug/m^3]}{[\text{Acute Reference Exposure Level, } ug/m^3]}$$

Maximum hourly concentrations can be obtained from air dispersion modeling. Table F-2 contains reference exposure levels (RELs).

For each of the facilities listed in Table F-3, we calculated the maximum hourly emissions that would likely result in a potential acute hazard quotient of up to 1.0. Equation F.5 is generally used to evaluate the hazard quotient based on a given concentration. However, this equation can also be used to determine the emission rates that would likely result in a given hazard quotient. As shown below, Equation F.8 can be reorganized to calculate the emission rates that would likely result in a potential chronic hazard quotient of up to 1.0.

$$[\text{Hazard Quotient}] = \frac{[\text{Max. Hourly Concn.}]}{[\text{Acute REL}]} = \frac{[\text{1-Hr GLC}]}{[\text{Acute REL}]} = \frac{[\text{Max. 1-Hr CHI/Q}]*[Q]}{[\text{Acute REL}]}$$

Therefore, the emission rate that would likely result in a given hazard quotient is –

Eqn. F.11:

$$[Q] = \text{Emission Rate (g/s)} = \frac{[\text{Hazard Quotient}]*[\text{Acute REL}]}{[\text{Max. 1-Hr CHI/Q}]}$$

For example, the emission rate that would likely result in a hazard quotient of up to 1.0, for a source that emits nickel, is calculated as shown below –

$$[Q], \text{Emission Rate} = \frac{[1.0]^* [6.0\ ug/m^3]}{[333\ (ug/m^3)/(g/s)]} = \frac{0.018\ grams}{sec} = \frac{\mathbf{0.14}\ lbs}{hour}$$

Table F-12 summarizes the key results from the acute risk analysis. It contains the minimum hourly emission rates that would likely result in potential acute hazard quotients that do not exceed 1.0. Table F-12 represents a conservative scenario for potential acute risks. Emissions from facilities that are located at different receptor distances may result in lower acute hazard quotients.

Table F-12:
Minimum Emission Rates That Would Likely Result in a Potential Acute Hazard Quotient Up To 1.0

Type of Source	Receptor Distance Where Minimum Occurs (m)	Minimum Emission Rate (lbs/hour)
		Nickel
Volume Source	22	0.01
Point Source	57	0.1

The primary non-cancer health impacts from thermal spraying are potential acute impacts from short-term exposure to nickel. Our analysis indicated that hourly nickel emissions from thermal spraying facilities could result in a hazard quotient that is greater than 1.0. The peak hourly nickel emission rates that would likely result in a potential acute hazard quotient of up to 1.0 are lower than the annual average hourly emission levels that would likely result in a potential cancer risk of up to 10 in a million or chronic hazard quotient of 1.0. Therefore, it is possible to have a potential acute hazard quotient that is greater than 1.0, even though the potential cancer risk from nickel is less than 10 in a million. For that reason, the proposed ATCM would include an hourly emission limit for nickel to protect against acute health risks. This hourly limit is designed to ensure that the acute hazard quotient does not exceed 1.0.

F.9. Workplace Exposure

Hexavalent chromium and nickel are human carcinogens. As such, the California Department of Industrial Relations, Division of Occupational Safety and Health Administration (Cal/OSHA) regulates these compounds in the workplace environment. To protect worker safety, Cal/OSHA has established permissible exposure limits (PEL) for these compounds. The PEL is the maximum, eight-hour, time-weighted average concentration for occupational exposure and is 0.01 mg/ m^3 for hexavalent chromium and 0.1 mg/ m^3 for nickel (CCR, 2002.) Since the proposed ATCM will require ventilation systems for certain uncontrolled facilities, worker exposure to hexavalent chromium and nickel from the use of these products will be reduced.

REFERENCES

ARB, 2003a. Air Resources Board. "Recommended Interim Risk Management Policy for Inhalation–Based Residential Cancer Risk". October 2003.

ARB, 2004b. Air Resources Board. "2003 Thermal Spraying Materials Survey". 2004.

ARB, 2004c. Air Resources Board. "2004 Thermal Spraying Facility Survey". 2004.

CCR, 2002. California Code of Regulations, Title 8, Division 1, Chapter 4, Subchapter 7, Group 16, Article 107, Section 5155, Airborne Contaminants, Table AC-1. 2002.

OEHHA, 1999. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots. Program Risk Assessment Guidelines, Part I, The Determination of Acute Reference Exposure Levels for Airborne Toxicants". March 1999.

OEHHA, 2000. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Assessment and Stochastic Analysis". September 2000.

OEHHA, 2000a. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots Program Risk Assessment Guidelines, Part III, Technical Support Document for the Determination of Noncancer Chronic Reference Exposure Levels". February 2000.

OEHHA, 2002. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II, Technical Support Document for Describing Available Cancer Potency Factors". December 2002.

OEHHA, 2003. Office of Environmental Health Hazard Assessment. "Air Toxics Hot Spots Program Risk Assessment Guidelines, the Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments". August 2003.

Appendix G

Summary of Cost Analysis Methodology

Summary

The cost of the proposed ATCM to affected businesses is estimated to be $672,000 to $1,195,000 in initial capital and permitting costs and $55,000 to $94,000 in annual recurring costs. This equates to $150,000 to $257,000 dollars annually over the useful life of the control equipment. This cost represents the capital cost of equipment, annualized over its useful life, plus the annual recurring costs in 2004 dollars. The annual cost for facilities that would not be required to install additional controls ranges from $600 to $850 per facility. The annual cost for facilities that would be required to install additional controls ranges from about $5,000 to $55,000 (or $162,000 if the largest facility installs three HEPA systems) per facility.

The cost ranges represent minimum and maximum costs associated with the one facility that would need to upgrade from water curtains to a HEPA filter system. Based on information provided by the facility, we believe that one HEPA system for three spray booths would be sufficient to accommodate the quantities of chromium- and nickel-based materials being used at the facility and comply with the proposed ATCM. This situation is reflected in the lower end of the cost ranges provided above. If the business chose to install three HEPA systems for nine spray booths, to provide maximum operational flexibility, the costs would be greater, as represented by the upper end of the cost ranges provided above. However, the expenditure for upgrading nine spray booths would be a business decision that is not mandated by the proposed ATCM.

The cost for 31 of the 37 facilities that would not need to install control devices is summarized in Table G-1. All 31 facilities would need to initially report their emissions, and meet monitoring and recordkeeping requirements, which is estimated to cost $600 per year. Seventeen of the 31 facilities would need to modify or obtain a permit, which the ARB estimates will cost $2,232. Of the 17 facilities that will incur permit application fees, 12 do not have an existing permit, and will incur additional annual permit fees.

Table G-1:
Costs for Affected Facilities Not Installing Control Devices

Requirement	Cost	Number of Affected Facilities	Total Initial Capital Cost	Total Annual Recurring Cost
Reporting, Monitoring and Recordkeeping	$600	31	$0	$18,600
Permit Application Fee	$2,232	17	$0	$37,944
Annual Permit Fee	$246	12	$2,952	$0

The following discussion deals primarily with the methodology used to determine the cost to the six facilities that would need to install new control devices to meet the requirements of the proposed ATCM. A summary of the costs and assumptions used for each of the six facilities is shown in Tables G–2 and G-3.

Table G-2:
Cost Estimates and Assumptions Used for Four Facilities Needing New Control Devices to Meet the 99.999% or 99.97% Control Efficiency Requirement*

	Facility 1**	Facility 2	Facility 3	Facility 4	Total
Size of Filter System (in square feet of filter media)	15,000	6,000	6,000	6,000	
HEPA Filter Unit	Yes	No	No	No	
Dry Filter Unit	Yes	Yes	Yes	Yes	
Booth Needed	Yes	No	Yes	Yes	
Hood Needed	Yes	Yes	Yes	Yes	
Filter Replacement Frequency	One Year	Two Years	Two Years	Two Years	
Existing Permit	Yes	No	No	No	
Cost of Equipment	$213,172 - $639,517	$66,997	$87,440	$87,440	$455,049 - $881,394
Installation, Freight and Permit Fees	$50,868 - $148,139	$22,047	$22,047	$22,047	$117,009 - $214,280
Initial Capital Cost (fixed)	$264,040 - $787,656	$89,045	$109,488	$109,488	$572,061 - $1,095,677
Annualized Fixed Cost	$35,059 - $104,147	$12,230	$14,878	$14,878	$77,045 - $146,133
Annual Recurring Cost	$19,799 - $58,196	$3,815	$3,815	$3,815	$31,244 - $69,641
Total Annual Cost	$54,858 - $162,343	$16,046	$18,693	$18,693	$108,290 - $215,775

** The high end of the range assumes the facility would install three HEPA systems and three cyclones to control emissions from nine spray booths.

Table G-3:
Cost Estimate Used for Two Facilities Needing New Control Devices to Meet the 90% Control Efficiency Requirement*

	Facility 5	Facility 6	Total
Water Wash Spray Booth	$17,320	$17,320	$34,640
Installation, Freight and Permit Fees	$11,232	$11,232	$22,464
Disposal	$214	$214	$428
Electricity	$154	$154	$308
Recordkeeping	$600	$600	$1,200
Annual Permit Fee	$246	$246	$492
Initial Capital Cost (fixed)	$28,552	$28,552	$57,104
Annualized Fixed Cost	$3,698	$3,698	$7,396
Annual Recurring Cost	$1,214	$1,214	$2,428
Total Annual Cost	$4,912	$4,912	$9,824

* Estimates are based on discussions with manufacturers, information from the 2004 Thermal Spray Facility Survey, and confidential discussions with industry representatives. (ARB, 2004c; BOE, 2004; Gansert, 2004; Huack, 2004; Walters, 2004).

The cost to install a filter system can vary significantly depending on the configuration and layout of the existing facility and spray booths. Based on discussions with air filter manufacturers and confidential discussions with the thermal spray industry, we assumed the installation costs to be 50% of the total cost of the blower, dust collector, control panel, other miscellaneous equipment and the HEPA filter unit, if applicable. The estimate for installation represents typical installation costs and assumes that the six facilities needing new control devices will not have special circumstances, such as a structure that needs to be heavily modified, that would increase this cost.

Tables G-4 and G-5 present the estimated initial capital cost of various components of control systems that facilities would install to meet the proposed ATCM requirements. In Table G-4 are estimates for control system components for a dry cartridge filter system with 6,000 square feet of filter media. In Table G-5 are estimates for control system components for a dry cartridge filter system with 15,000 square feet of filter media and a HEPA unit.

Table G–4:
Estimated Equipment Costs for a Dry Cartridge Filter System with 6,000 Square Feet of Filter Media*

Item	**Estimated Cost**
20 hp Blower	$4,654
Control Panel	$3,635
Dust Collector	$24,436
Other Equipment	$3,248
Duct Work	$21,650
Dry Cartridge Filters, 24 filters at $90 each	$2,338
Hood	$7,036
Booth	$20,443
Installation	$16,616
Freight	$3,200
Permit Fee	$2,232
Total	**$109,488**

* Estimates are based on discussions with filter manufacturers, information from the 2004 Thermal Spray Facility Survey, product literature and confidential discussions with industry representatives. (ARB, 2004c; BOE, 2004; Fontaine, 2004; Gansert, 2002; Gansert, 2004; Jettan, 2004; Mills, 2002; Walters, 2003; Walters, 2004).

Table G–5:
Estimated Equipment Costs for a Single Dry Cartridge Filter System with 15,000 Square Feet of Filter Media and a HEPA Filter Unit*

Item	Estimated Cost
50 hp Blower	$6,291
Control Panel	$4,092
Dust Collector	$62,714
HEPA Filter Unit	$6,868
Cyclone	$12,990
Other Miscellaneous Equipment	$5,413
Duct Work	$21,650
Dry Cartridge Filters, 60 filters at $90 each	$5,845
HEPA Filters, 15 filters at $300 each	$4,871
Hood X 3	$21,109
Booth X 3	$61,329
Installation	$45,436
Freight	$3,200
Permit Fee	$2,232
Total	**$264,040**

* Estimates are based on discussions with filter manufacturers, information from the 2004 Thermal Spray Facility Survey, product literature and confidential discussions with industry. representatives. (ARB, 2004c; BOE, 2004; Fontaine, 2004; Gansert, 2002; Gansert, 2004; Jettan, 2004; Mills, 2002; Walters, 2003; Walters, 2004).

Table G-6 shows the estimated recurring cost for the facilities that would be required to install filter controls to meet the 99.999% or 99.97% control efficiency requirements. These estimates are based on the assumption that facility 1 installs a HEPA filter, and facilities 2-4 install dry cartridge filters.

Table G-6:
Recurring Costs for Four Facilities Needing New Control Devices to Meet the 99.999% or 99.97% Control Efficiency Requirement *

	Facility 1**	Facility 2	Facility 3	Facility 4
Operating Hours/Year	1000	250	250	250
Filter Change out Frequency	Every Year	Every 2 Years	Every 2 Years	Every 2 Years
Disposal Cost	$6,420 - $19,260	$1,284	$1,284	$1,284
Replacement Filters	$5,846 - $17,537	$1,169	$1,169	$1,169
Replacement HEPA Filters	$4,871 - $14,614	$0	$0	$0
Electrical Cost	$2,062 - $6,186	$516	$516	$516
Recordkeeping, Monitoring and Reporting	$600	$600	$600	$600
Annual Permit Fees	$0	$246	$246	$246
Total	**$19,799 - $58,197**	**$3,815**	**$3,815**	**$3,815**

* Estimates are based on discussions with filter manufacturers, information from the 2004 Thermal Spray Facility Survey, product literature, disposal companies and confidential discussions with industry representatives (BLS, 2004; Donaldson, 2004; Gottes, 2004; Jettan, 2004).

** The high end of the range assumes the facility would install three HEPA systems and three cyclones to control emissions from nine spray booths.

Electrical cost was calculated as follows:

Electrical Cost = (motor hp) X (.75 kilowatts/hp) X ($0.1375/kilowatt-hour) X (annual hours of operation)

If the facility had an existing control device, their current electrical cost was calculated in the same fashion, and the incremental increase in electrical cost was used in the cost estimate.

Annualized Costs

We annualized non-recurring fixed costs using the Capital Recovery Method. Using this method, we multiplied the non-recurring fixed costs by the Capital Recovery Factor (CRF) to convert these costs into equal annual payments over a project horizon at a discount rate. The Capital Recovery Method for annualizing fixed costs is recommended by Cal/EPA (Cal/EPA, 1996), and is consistent with the methodology used in previous cost analyses for ARB regulations (ARB, 2000a; ARB, 2000b).

The CRF is calculated as follows:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

where,

CRF = *Capital Recovery Factor*

i = *discount interest rate (assumed to be 5%)*
n = *project horizon or useful life of equipment*

All costs of the control devices were annualized over 10 years, except the cost of the blower, which was annualized over five years. These values are based on a conservative estimate of the expected lifetime of the equipment. The permit application or renewal fees were annualized over five years. The total annualized cost was obtained by adding the annual recurring costs to the annualized fixed costs derived by the Capital Recovery Method.

REFERENCES

ARB, 2000a. Air Resources Board. "Staff Report for the Proposed Suggested Control Measure for Architectural Coatings." 2000.

ARB, 2000b. Air Resources Board. "Initial Statement of Reasons for Proposed Amendments to the Vapor Recovery Certification and Test Procedures for Gasoline Loading and Motor Vehicle Gasoline Refueling at Service Stations." 2000.

ARB, 2004c. Air Resources Board. "2004 Thermal Spraying Facility Survey, Draft Report." 2004.

BOE, 2004. Board of Equalization, "California City and County Sales and Use Tax Rates" Online, Internet at http://www.boe.ca.gov/sutax/pam71.htm. (18 September 2004)

BLS, 2004. U.S. Department of Labor, Bureau of Labor Statistics, "Consumer Price Index – Average Price Data: Electricity per KWH in Los Angeles and San Francisco" Online, Internet at http://data.bls.gov/labjava/outside.jsp?survey=ap, (18 September 2004)

Cal/EPA, 1996. California Environmental Protection Agency. "Economic Analysis Requirements for the Adoption of Administrative Regulations." Appendix C ("Cal/EPA Guidelines for Evaluation Alternatives to Proposed Major Regulations"). Memorandum from Peter M. Rooney, Undersecretary, to Cal/EPA Executive Officers and Directors. December 6, 1996.

Donaldson, 2004. Donaldson Company Inc. Product Brochure, "Ultra-Web Cartridges." September, 2004.

Fontaine, 2004. Air Resources Board staff discussions with Mike Fontaine, Donaldson Company Inc., May 2004.

Gansert, 2002. Air Resources Board staff discussions with Robert Gansert, Hardface Alloys Inc., November 2002.

Gansert, 2004. Air Resources Board staff discussions with Robert Gansert, Hardface Alloys Inc., May 2004.

Gottes, 2004. Air Resources Board staff discussions with Janet Gottes, Clean Harbor, May 2004.

Hauck, 2004. Air Resources Board staff discussions with Bob Hauck, Spray Systems Inc. October 2004.

Jettan, 2004. Air Resources Board staff discussions with Steve Jettan, Farr APC, June 2004.

Mills, 2002. Air Resources Board staff discussions with David Mills, Sulzer Metco, November 2002.

Walters, 2003. Air Resources Board staff discussions with Robert Walters, Donaldson Company Inc. March 2003.

Walters, 2004. Air Resources Board staff discussions with Robert Walters, Donaldson Company Inc. June 2004.

TITLE 13. CALIFORNIA AIR RESOURCES BOARD

. NOTICE OF PUBLIC HEARING TO CONSIDER AMENDMENTS TO THE CALIFORNIA OFF-ROAD EMISSIONS REGULATION FOR 2005 AND LATER COMPRESSION-IGNITION ENGINES AND EQUIPMENT

The Air Resources Board (ARB or Board) will conduct a public hearing at the time and place noted below to consider adopting amendments to the off-road compression-ignition (diesel) regulations and test procedures for new engines and equipment. These amendments would harmonize the requirements of California's off-road diesel program with those of the United States Environmental Protection Agency (U.S. EPA) regarding exhaust emission standards, compliance procedures, and testing methods. Manufacturers of new off-road, compression-ignition engines and equipment would be subject to and have responsibilities under the regulation. This notice summarizes the proposed regulatory amendments. The staff report presents the proposed amendments in greater detail.

DATE: December 9, 2004

TIME: 9:00 a.m.

PLACE: California Environmental Protection Agency
Air Resources Board
Central Valley Auditorium
1001 I Street
Sacramento, California 95814

This item will be considered at a two-day meeting of the Board, which will commence at 9:00 a.m., December 9, 2004, and may continue at 8:30 a.m., December 10, 2004. This item may not be considered until December 10, 2004. Please consult the agenda for the meeting, which will be available at least 10 days before December 9, 2004, to determine the day on which this item will be considered.

If you have a disability-related accommodation need, please go to http://www.arb.ca.gov/html/ada/ada.htm for assistance or contact the ADA Coordinator at (916) 323-4916. If you are a person who needs assistance in a language other than English, please contact the Bilingual Coordinator at (916) 324-5049. TTY/TDD/Speech-to-Speech users may dial 7-1-1 for the California Relay Service.

INFORMATIVE DIGEST OF PROPOSED ACTION AND POLICY STATEMENT OVERVIEW

Sections Affected: Proposed adoption of amendments to sections 2420, 2421, 2423, 2424, 2425, and 2427, title 13, California Code of Regulations (CCR), and to the following documents incorporated by reference therein: "California Exhaust Emission Standards and Test Procedures for New 2000 and Later Off-Road Compression-Ignition

Engines, Part I-B," as last amended January 28, 2000; and "California Exhaust Emission Standards and Test Procedures for New 1996 and Later Off-Road Compression-Ignition Engines, Part II," as last amended January 28, 2000. Proposed adoption of the following document incorporated by reference therein: "California Exhaust Emission Standards and Test Procedures for New 2008 and Later Tier 4 Off-Road Compression-Ignition Engines."

Background: Health and Safety Code sections 43013 and 43018 direct ARB to achieve the maximum feasible and cost effective emission reductions from all mobile source categories, including off-road diesel engines and equipment, through the setting of emission control requirements. In January 2000, ARB adopted amendments to the off-road emissions regulation for 2000 and later compression-ignition (diesel) engines and equipment. Those amendments established more stringent exhaust standards for particulate matter (PM), oxides of nitrogen (NOx), and non-methane hydrocarbon (NMHC) than were previously required. Further, they harmonized California's off-road diesel requirements with those of the U.S. EPA at that time.

Despite the significant improvements to air quality resulting from the 2000 and later requirements, commonly referred to as Tier 2 and Tier 3, many regions in California still routinely experience unhealthful air quality. Over 50 percent of the State's air basins currently violate the federal eight hour ambient air quality standard for ozone (see http://www.epa.gov/air/oaqps/greenbk/ca8.html), and many will be in violation beyond attainment due-dates if additional measures are not taken.

Off-road diesel engines are similar to on-road diesel engines in design; however, off-road emission control capability typically lags behind on-road capability because of the added complexity in designing systems that will function reliably for the many different applications of off-road engines. With advanced exhaust aftertreatment standards now required for heavy-duty on-road diesel engines beginning in 2007, staff believes it is appropriate to set similar standards for California's off-road diesel engines.

Description of the Proposed Regulatory Action: Staff is proposing to amend California's existing off-road diesel regulations to harmonize with the U.S. EPA requirements for nonroad diesel engines and equipment as set forth on June 29, 2004, in Title 40, Code of Federal Regulations, Part 1039 (40 CFR 1039). This would ensure a greater degree of emission reductions from non-preempted off-road diesel engines in California (i.e., those which the ARB has authority to regulate under the federal Clean Air Act), by enabling the ARB to independently enforce compliance with the regulation, as necessary.

The proposed amendments require new off-road diesel engines to meet more stringent exhaust emission standards for PM, NOx, NMHC, and CO than are currently required. Enhancements to test procedures and the certification process are proposed to ensure meaningful compliance with the new standards and to provide compliance flexibility without sacrificing air quality benefits. A full description of the proposed amendments is presented in the Staff Report: Initial Statement of Reasons, available as described below.

The proposed standards are based on the use of advanced aftertreatment technologies and will reduce PM and NOx emissions from new engines by up to 95 percent, as compared to previous emission requirements. Furthermore, harmonization serves the interest of the off-road industry in that resources would not have to be invested to comply with separate State and federal requirements.

In addition to the standards, the staff's proposal also mirrors other aspects of the adopted federal rule including requirements for not-to-exceed (NTE) limits, incentives to engine and equipment manufacturers for the early introduction of engines with advanced aftertreatment, new test procedures and test cycles, and extended compliance assistance for engine and equipment manufacturers. As a package, these requirements would help assure that the air quality benefits of the proposed standards are achieved and that engines remain cleaner in-use longer. The harmonization of compliance programs such as averaging, banking, and trading, and equipment manufacturer flexibility should help to ease administrative burdens and allow industry to maintain focus on the technical aspects of emission reductions.

The staff's proposal also supplements the federal rule in a few small but important ways that are intended to provide additional safeguards for a successful implementation of the off-road diesel program in California. For example, more descriptive labeling content on flexibility engines is needed to minimize the potential for abuse by providing ARB investigators a means to verify that the engines used in this program have been correctly placed in service according to the provisions of the regulation. The prohibition on removing the original engine label is meant to ensure the presence of a clear reference to original certification standards, which the engine must continue to meet even after rebuilding or repair.

In addition, coverage by an executive order is necessary for ARB to exercise its enforcement authority regarding flexibility engines. The executive order does not need to be current for the model year in which the flexibility engine is produced, but it must have at least been issued previously. Staff also proposes to continue ARB's in-use compliance/recall program to address noncompliance of the requirements from a California perspective as necessary.

While these are small but important supplements to the federal requirements, we anticipate that none of these changes will encumber compliance or incur additional implementation costs.

COMPARABLE FEDERAL REGULATIONS

On June 29, 2004, U.S. EPA promulgated the Tier 4 regulation (40 CFR 1039) and associated test procedures for new off-road diesel engines. The staff's proposal generally harmonizes ARB's regulation with the federal rule, while preserving specific features needed by California. Harmonized requirements include the alignment of standards, implementation schedules, compliance procedures, and test procedures.

The staff's proposal differs from the current U.S. EPA regulation in the following ways:

1. Expanded labeling requirement for engines used in the equipment manufacturer flexibility program to include the engine family name beginning in 2006.

2. Prohibition on removing or replacing labels after engine rebuilding beginning in 2006.

3. Clarification on the need for engines used in the equipment manufacturer flexibility program to have been covered by an executive order.

4. Preservation of ARB authority to enforce the regulation independently of the federal government.

The differences that remain between the two programs are justified by the benefit to human health, public welfare, and the environment. In addition, the differences from the federal program are authorized by Health and Safety Code sections 43013 and 43018.

BENEFITS OF THE PROPOSAL

Staff estimates that in 2020, the combined statewide benefits of staff's proposal and the federal rule would be approximately 6.9 tons per day PM, 72.8 tons per day NOx, and 3.0 tons per day NMHC, based on current off-road emissions inventory modeling. The estimated California cost-effectiveness associated with adoption of staff's proposal would be approximately $0.58 per pound of combined NMHC and NOx reduced, and $7.55 per pound of PM reduced. These estimates are based on the federal calculation of cost-effectiveness. In actuality, however, there are insignificant or no costs to the State associated with staff's proposal because the U.S. EPA's estimates already include California.

AVAILABILITY OF DOCUMENTS AND CONTACT PERSONS

The Board staff has prepared a Staff Report: Initial Statement of Reasons (Staff Report or ISOR) for the proposed regulatory action, which includes a summary of the economic and environmental impacts of the proposal. The ISOR is entitled: "Staff Report: Initial Statement of Reasons for the Proposed Rulemaking – Public Hearing to Consider Amendments to the California Off-Road Emissions Regulation for 2006 and Later Compression-Ignition Engines and Equipment."

Copies of the ISOR and the full text of the proposed regulatory language, in underline and strikeout format to allow for comparison with the existing regulations, may be accessed on the ARB's web site listed below or may be obtained from the Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental

Services Center, 1st Floor, Sacramento, California 95814, (916) 322-2990 at least 45 days prior to the scheduled hearing on December 9, 2004.

Upon its completion, the Final Statement of Reasons (FSOR) will be available and copies may be requested from the agency contact persons in this notice, or may be accessed on the ARB's web site listed below.

Inquiries concerning the substance of the proposed regulation may be directed to the designated agency contact persons, Ms. Jackie Lourenco, at (626) 575-6676 or jlourenc@arb.ca.gov, or Mr. Jeff Lowry, at (626) 575-6841 or jlowry@arb.ca.gov.

Further, the agency representative and designated back-up contact persons to whom nonsubstantive inquiries concerning the proposed administrative action may be directed are Artavia Edwards, Manager, Board Administration & Regulatory Coordination Unit, (916) 322-6070, or Amy Whiting, Regulations Coordinator, (916) 322-6533. The Board has compiled a record for this rulemaking action, which includes all the information upon which the proposal is based. This material is available for inspection upon request to the contact persons.

If you are a person with a disability, and you desire to obtain this document in an alternative format, please contact the Air Resources Board ADA Coordinator at (916) 323-4916, TDD (916) 324-9531, or (800) 700-8326 for TDD calls outside the Sacramento area.

This notice, the ISOR and all subsequent regulatory documents, including the FSOR, when completed, are available on the ARB Internet site for this rulemaking at http://www.arb.ca.gov/regact/offrdcie/offrdcie.htm

COSTS TO PUBLIC AGENCIES AND TO BUSINESSES AND PERSONS AFFECTED

The determinations of the Board's Executive Officer concerning the costs or savings necessarily incurred by public agencies and private persons and businesses in reasonable compliance with the proposed regulations are presented below.

Pursuant to Government Code sections 11346.5(a)(5) and 11346.5(a)(6), the Executive Officer has determined that the proposed regulatory action will not create costs or savings to any state agency or in federal funding to the state, costs or mandate to any local agency or school district whether or not reimbursable by the state pursuant to part 7 (commencing with section 17500), division 4, title 2 of the Government Code, or other nondiscretionary savings to state or local agencies. The ARB may incur additional implementation or enforcement costs at some future time.

In developing this regulatory proposal, the ARB staff evaluated the potential economic impacts on representative private persons or businesses. The ARB is not aware of any cost impacts that a representative private person or business would necessarily incur in reasonable compliance with the proposed action.

The Executive Officer has made an initial determination that the proposed regulatory action will not have a significant statewide adverse economic impact directly affecting businesses, including the ability of California businesses to compete with businesses in other states, or on representative private persons.

In accordance with Government Code section 11346.3, the Executive Officer has determined that the proposed regulatory action will not affect the creation or elimination of jobs within the State of California, the creation of new businesses or elimination of existing businesses within the State of California, or the expansion of businesses currently doing business within the State of California.

The Executive Officer has also determined, pursuant to title 1, CCR, section 4, that the proposed regulatory action will not affect small businesses because there will be no incremental cost, or an insignificant cost, associated with staff's proposal in addition to those already needed to comply with the federal regulation.

In accordance with Government Code sections 11346.3(c) and 11346.5(a)(11), the Executive Officer has found that the reporting requirements of the regulation that apply to businesses are necessary for the health, safety, and welfare of the people of the State of California.

In accordance with Health and Safety Code section 43013(c), the Executive Officer has determined that the standards and other requirements in the regulation are necessary, cost-effective, and technologically feasible for non-preempted new engines and equipment that are used in agricultural operations. In making this determination, the Executive Officer considered the technological effects of emission control standards on the cost, fuel consumption, and performance characteristics of mobile farm equipment subject to the regulation.

Before taking final action on the proposed regulatory action, the Board must determine that no reasonable alternative considered by the board or that has otherwise been identified and brought to the attention of the board would be more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons than the proposed action.

A detailed assessment of the economic impacts of the proposed regulatory action can be found in the Staff Report.

SUBMITTAL OF COMMENTS

The public may present comments relating to this matter orally or in writing at the hearing, and in writing or by e-mail before the hearing. To be considered by the Board, written submissions not physically submitted at the hearing must be received **no later than 12:00 noon, December 8, 2004**, and addressed to the following:

Postal mail is to be sent to:

Clerk of the Board
Air Resources Board
1001 I Street, 23rd Floor
Sacramento, California 95814

Electronic mail is to be sent to: offrdcie@listserv.arb.ca.gov, and received at the ARB **no later than 12:00 noon, December 8, 2004.**

Facsimile submissions are to be transmitted to the Clerk of the Board at (916) 322-3928 and received at the ARB **no later than 12:00 noon, December 8, 2004.**

The Board requests but does not require 30 copies of any written submission. Also, the ARB requests that written, facsimile and e-mail statements be filed at least 10 days prior to the hearing so that ARB staff and Board Members have time to fully consider each comment. The Board encourages members of the public to bring to the attention of staff in advance of the hearing any suggestions for modification of the proposed regulatory action.

STATUTORY AUTHORITY AND REFERENCES

This regulatory action is proposed under the authority granted in Health and Safety Code sections 39600, 39601, 43013, 43018, 43101, 43102, 43104, and 43105. This action is proposed to implement, interpret, and make specific Health and Safety Code sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5, and 43210-43212.

HEARING PROCEDURES

The public hearing will be conducted in accordance with the California Administrative Procedure Act, title 2, division 3, part 1, chapter 3.5 (commencing with section 11340) of the Government Code.

Following the public hearing, the Board may adopt the regulatory language as originally proposed, or with nonsubstantive or grammatical modifications. The Board may also adopt the proposed regulatory language with other modifications if the text as modified is sufficiently related to the originally proposed text that the public was adequately placed on notice that the regulatory language as modified could result from the proposed regulatory action. In the event that such modifications are made, the full regulatory text, with the modifications clearly indicated, will be made available to the public for written comment at least 15 days before it is adopted.

The public may request a copy of the modified regulatory text from the ARB's Public Information Office, Air Resources Board, 1001 I Street, Visitors and Environmental Services Center, 1st Floor, Sacramento, California 95814, (916) 322-2990.

CALIFORNIA AIR RESOURCES BOARD

Catherine Witherspoon
Executive Officer

Date: 10/12/04

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs see our Web –site at www.arb.ca.gov.

State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR RULEMAKING

PUBLIC HEARING TO CONSIDER AMENDMENTS TO THE CALIFORNIA OFF-ROAD EMISSIONS REGULATION FOR COMPRESSION-IGNITION ENGINES AND EQUIPMENT

Date of Release: **October 22, 2004**
Scheduled for Consideration: **December 9, 2004**

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EXECUTIVE SUMMARY

In January 2000, the Air Resources Board (ARB of Board) adopted amendments to the off-road emissions regulation for 2000 and later compression-ignition (diesel) engines and equipment. Those amendments established more stringent exhaust standards for particulate matter (PM), oxides of nitrogen (NOx), and non-methane hydrocarbon (NMHC) than were previously required. Furthermore, the amendments harmonized California's off-road diesel requirements with those of the United States Environmental Protection Agency (U.S. EPA). The 2000 standards, termed Tier 2 and Tier 3, are ongoing, and staff estimates that the statewide emissions inventory[1] will be reduced by 8 tons-per-day PM, 83 tons-per-day NOx, and 18 tons-per-day NMHC in 2010 because of them. The Board also adopted in-use durability requirements and an autonomous recall/warranty program in 2000 that invested California with full enforcement authority to ensure the regulatory compliance of off-road diesel engines throughout their entire useful lives.

Despite the significant improvements to air quality resulting from the Tier 2 and Tier 3 standards, many Californians are still plagued with unhealthful air. ARB estimates that over 50 percent of the State's air basins will be in violation of the federal eight hour ambient air quality standard beyond attainment due-dates if additional control measures are not undertaken to address the need for more reductions. Staff has recognized since the 2000 off-road diesel rulemaking that additional emission reductions were possible from the off-road sector with the incorporation of advanced emission control technologies.

Off-road diesel engines are similar to on-road diesel engines in design, but off-road emission control capability typically lags behind on-road capability. This is because of the added complexity in designing systems that will function reliably for the many different applications of off-road diesel engines. However, with cleaner standards now required for heavy-duty on-road diesel engines beginning in 2007 (ARB 2001), staff believes the time is appropriate to set similar standards for California's off-road diesel engines.

This report presents staff's proposal to amend existing regulations to harmonize with the requirements published by U.S. EPA in the Federal Register on June 29, 2004, to achieve a greater degree of emission reductions from non-preempt off-road diesel engines. The federal Clean Air Act preempts California from setting emission standards for new off-road engines rated less than 130 kilowatts (kW) used in farm or construction equipment ("preempt engines"). Because of this, staff worked diligently with U.S. EPA to develop a fourth tier (Tier 4) of emissions standards that would ensure the most stringent, technologically feasible standards for all of California's off-road diesel engines. The resulting federal Tier 4 standards are based on the use of advanced

[1] Estimated 2010 benefits are based on July, 2004, off-road emissions inventory data, and may differ from earlier calculations.

aftertreatment technologies, which will reduce PM and NOx emissions from new engines by up to 95 percent compared to previous emission requirements. This represents a significant reduction in emissions for California's preempt engines, which will constitute 71 percent of the entire off-road diesel population in 2020.

Staff's proposal to harmonize with the federal Tier 4 requirements would provide equally stringent standards for the remaining non-preempt engines in California. This would also preserve California's authority to ensure timely compliance and to enforce the regulation as necessary for these engines. Furthermore, harmonization serves the interest of the off-road industry in that resources would not have to be invested to comply with separate State and federal requirements.

In addition to the emissions standards, this proposal also mirrors other aspects of the adopted federal rule including requirements for not-to-exceed (NTE) limits, incentives to engine and equipment manufacturers for the early introduction of engines with advanced aftertreatment, new test procedures and test cycles, enhanced in-use compliance provisions, and transitional compliance assistance for engine and equipment manufacturers. As a package, these requirements would help assure that the air quality benefits of the proposed standards are achieved and that engines remain cleaner in-use longer. The harmonization of compliance programs such as averaging, banking, and trading, and equipment manufacturer flexibility should help to ease any administrative burdens and allow industry to maintain focus on the technical aspects of emission reductions.

Staff's proposal also supplements the federal rule in a few small, but important ways intended to provide additional safeguards for a more identifiable and enforceable deployment of flexibility allowances in California. To minimize the potential for abuse, staff proposes more descriptive labeling content requirements for flexibility engines to facilitate their identification by ARB inspectors and to provide a clear reference to original certification standards in the cases of rebuilding or repair. Staff also proposes to keep its autonomous in-use warranty/recall program to better address violations of the requirements from a California perspective. Neither of these changes is expected to encumber compliance nor incur additional implementation costs.

In 2020, the combined statewide benefits of staff's proposal and the federal rule would be approximately 6.9 tons per day PM, 72.8 tons per day NOx, and 3.0 tons per day NMHC, based on ARB's current off-road emissions inventory modeling. The estimated California cost-effectiveness associated with adoption of staff's proposal would be approximately $0.58 per pound of combined NMHC and NOx reduced, and $7.55 per pound of PM reduced. These estimates are based on the federal calculation of cost-effectiveness, appropriately adjusted to reflect what California's costs would be without harmonization. In actuality, however, there are no costs to the State associated with staff's proposal since U.S. EPA's estimates already include California's expenses. Based on these conclusions, staff recommends that the Board adopt this proposal.

1. INTRODUCTION

Compression-Ignition engines (hereafter "diesel engines") are used in a variety of off-road applications, and are often the preferred choice where durability and fuel economy are primary considerations. Some familiar examples include tractors, excavators, portable generators, transport refrigeration units (TRUs), irrigation pumps, welders, compressors, scrubber/sweepers, and a wide array of other agricultural, construction, and general industrial equipment. Although diesel engines are used extensively to propel other off-road equipment such as locomotives and commercial marine vessels, engines in those applications are not considered under this proposal.

The Air Resources Board (ARB or Board) and the United States Environmental Protection Agency (U.S. EPA) have made significant strides in controlling air pollution from off-road sources in recent years. Together, the two agencies have adopted three tiers of increasingly stringent emissions standards for off-road diesel engines (referred to as "nonroad diesel engines" in U.S. EPA publications). The first tier began in California in 1995 and the third tier will be phased-in across all applicable power categories by 2008. Despite these efforts, many regions of the State still suffer from unhealthy levels of air pollution.

To further improve California's air quality, and as agreed upon according to the settlement agreement amendments to the 1994 Ozone State Implementation Plan (SIP) (see subsection 3.3), staff is proposing that the Board adopt a fourth tier (Tier 4) of exhaust emission standards for off-road diesel engines in California. This is a crucial next step for improving air quality, where further reductions of particulate matter (PM) and ozone precursors are required to protect public health and to comply with federal and State air quality standards for ozone.

However, the federal Clean Air Act (CAA) Amendments of 1990 preempt California from regulating exhaust emissions from new farm and construction equipment under 130 kilowatts (kW), and ARB must rely on U.S. EPA to establish effective regulations for these preempt engines, which are a significant source of emissions in California. In 2020, approximately 71 percent of the roughly 560,000 land-based diesel engines in California will be under the exclusive regulatory authority of the federal government. This would be equivalent[2] to the ozone precursor emissions from 3.6 million passenger cars and the particulate emissions from 8.7 million passenger cars in 2020.

On May 11, 2004, the U.S. EPA Administrator, Michael Leavitt, signed the Clean Air Nonroad Diesel Rule into law, which promulgates Tier 4 standards for new nonroad diesel engines that can reduce emissions by up to 95 percent compared to previous standards (69 Fed. Reg. 38958 (2004)). These new standards are based on the same advanced exhaust aftertreatment technologies that are likely to be utilized by

[2] The comparisons utilize data from the off-road diesel emissions inventory database (May 2004) and the EMFAC2002 V2.2 04-03-2003 on-road model

heavy-duty on-road diesel engines beginning in 2007 (U.S. EPA 2001). U.S. EPA also adopted improved certification provisions including a transient test cycle, which will allow emission evaluations to be made under more appropriate engine operating conditions, and Not-To-Exceed (NTE) limits to verify emissions performance in-use. Staff's proposal harmonizes with the federal Tier 4 program, while maintaining ARB's enforcement authority to ensure timely compliance and emission reductions. Adoption of this proposal by the Board would provide equally stringent emission standards for California's non-preempt portion of engines.

This report has twelve sections. The Introduction and Background provide an overview and brief historical account of previous and existing emission control measures affecting the off-road diesel sector in California. Following those discussions is the Need for Control section, which explains why the proposed requirements are necessary. This is followed by a Summary of staff's proposal and a description of the Differences between the California and federal programs. Next is a discussion on Technology and Feasibility. The Environmental Impacts and Cost-Effectiveness of the proposal are discussed in the section after that, followed by the proposal's Economic Impacts and the Regulatory Alternatives considered. This is again followed by a discussion of Remaining Issues that arose during the development of the proposal. Staff's Conclusions and Recommendations are then summarized, followed by a list of the References used in this report.

2. BACKGROUND

This section provides a description of California's authority, existing off-road diesel regulations, emissions inventory, U.S. EPA programs, and the steps taken to inform the public about staff's proposal to amend the regulations.

2.1. Authority

California is the only State allowed to adopt emission requirements that are different from those of the federal government. This is appropriate since California has the worst air quality in the nation[3], and as such, has special emission control needs that may not be necessary for the rest of the country. The following subsection provides reference to the applicable legal citations that give California this authority.

Section 209(e)(2)(A) of the federal CAA authorizes California to adopt and enforce emission standards, and other requirements, for off-road engines and equipment, not subject to federal preemption, so long as the California standards "will be, in the aggregate, at least as protective of public health and welfare as applicable Federal

[3] The South Coast and San Joaquin Valley Air Basins, for example, are the only areas in the nation designated by U.S. EPA as "severe-17" and "extreme" zones for ozone non-attainment, respectively. This is based on 8-hour assessments in 40 CFR 81.305, http://www.epa.gov/ozonedesignations/part81r8c.pdf, dated June 15, 2004.

standards." California must apply for, and receive authorization from the U.S. EPA before federal requirements are waived and ARB may enforce its regulations.

In 1988, the State Legislature enacted the California Clean Air Act (CCAA), which declared that attainment of State ambient air quality standards is necessary to promote and protect public health, particularly the health of children, the elderly, and those with respiratory illness. The Legislature also directed that these standards be attained by the earliest practicable date.

Health and Safety Code (HSC) sections 43013 and 43018 authorize and direct ARB to achieve the maximum feasible and cost effective emission reductions from all mobile source categories, including off-road diesel engines and equipment.

2.2. Preemption

Along with authorizing California to set emissions standards for off-road engines and equipment, the federal CAA also prohibits the states, including California, from regulating certain types of engines and equipment. Section 209(e)(1)(A) of the federal CAA explicitly preempts California from regulating emissions from new farm and construction engines and equipment under 130 kW ("preempt engines").

Because only the U.S. EPA has authority to establish emission standards for preempt engines, ARB staff took an active role in working with U.S. EPA to develop a national emissions program that would cover those off-road diesel engines in California that ARB cannot regulate. Staff's proposal covers the remaining non-preempt engines, and harmonizes with the federal rule, to the extent feasible, to minimize any confusion and expenses that could result from significantly different State and federal requirements. A list of equipment types that are subject to federal preemption is included at the end of this report in Appendix A ("List of Preempted Off-Road Applications").

As required under CAA section 209(e)(2)(A), ARB will request U.S. EPA authorization for the adoption and enforcement of standards and other requirements relating to the control of emissions from non-preempt engines. Because ARB's proposed regulations closely mirror the federal requirements for these engines, staff believes they would be, in the aggregate, at least as protective of public health and welfare as the applicable federal Tier 4 standards. Further, because the emission reductions from these proposed regulations are necessary to meet the State's air quality commitments, staff's proposal would not be considered arbitrary or capricious.

2.3. Existing Regulations

Federal requirements notwithstanding, there are currently three tiers of increasingly stringent emission standards required for off-road diesel engines. Particulate matter (PM), oxides of nitrogen (NOx), non-methane hydrocarbons (NMHC), and carbon monoxide (CO) are the pollutants regulated by these requirements, though not always collectively. Off-road standards are unique in that they vary according to an engine's power rating, and have been implemented in stages rather than all at once in a single year. NMHC and NOx are usually combined into a single standard due to the inverse reciprocal relationship of those pollutants in untreated exhaust. However, separate NMHC and NOx standards will be necessary to support the advent of aftertreatment on off-road engines. The history and effects of the existing off-road diesel standards are briefly discussed in the following subsection.

2.3.1. Tier 1 Standards

The very first emission standards for new off-road diesel engines were adopted for engines less than 19 kW as part of the California requirements for 1995 and later small off-road engines (ARB 1994). Subsequently, in 1992, the Board approved standards for off-road diesel engines 130 kW and greater. These standards, which were implemented beginning in 1996, targeted NOx emission reductions without an increase in NMHC or PM emissions. The 130 kW boundary was chosen to avoid preemption issues in the implementation of the regulation rather than for technical or cost-effectiveness reasons.

The goal of initial off-road diesel control was to reduce emissions using the most feasible control technologies that would not require a need to change the packaging (shape) of the engine (ARB 1991). The majority of engine modifications that have been made to comply with the Tier 1 standards are fuel injector and fuel injection timing changes, combustion chamber enhancements, and the incorporation of engine after-coolers. Tier 1 has resulted in approximately a 50 percent drop in NOx emissions compared to previously uncontrolled off-road diesel engines of similar power. Following ARB's adoption of initial standards, U.S. EPA promulgated a substantially similar program for engines 37 kW and greater (see 40 CFR 89).

2.3.2. Tier 2 Standards

In 1992, the Board also adopted a second phase of more stringent emission standards for engines 130 ≤ kW ≤ 560 to begin in 2000. However, in 1998, U.S. EPA promulgated a slightly different version of California's 2000 standards plus a third, more stringent phase of emission standards to be implemented starting in 2006 (U.S. EPA 1998). To honor the Statement of Principles (SOP)[4] agreement, ARB went back to the Board in 2000 to fully align California's standards and implementation schedules with U.S. EPA's requirements (ARB 1999). Engines greater than 560 kW became applicable under the harmonized regulation in 2000, and the more stringent standards served to address ARB's 1994 State Implementation Plan (SIP) commitments.

[4] An agreement signed in 1995 by ARB, U.S. EPA, and engine manufacturers that called for the creation of multiple tiers of more stringent emissions standards in exchange for harmonized California and federal regulations, as feasible.

Current Tier 2 requirements, as they have come to be referred, are scheduled to be completely phased-in by 2006, and encompass the entire power spectrum of diesel off-road engine applications including those above 560 kW and those under 19 kW. Tier 2 standards were originally intended to be equivalent in stringency to the 1991 on-road heavy-duty diesel engine standards, and are based on the emission control technologies used by those engines. The harmonized Tier 1 and Tier 2 standards included durability provisions[5] to ensure that the standards would continue to be met throughout the useful life of the engine. Fuel injection timing and combustion refinements, turbo/super charging, and air-to-air after-cooling have been the primary engine changes needed by most manufacturers to comply with the Tier 2 standards. This has resulted in tailpipe reductions of 21 to 39 percent for NMHC+NOx with respect to the previous Tier 1 standards, and 41 to 61 percent for PM for power categories that were previously uncontrolled.

2.3.3. Tier 3 Standards

Tier 3 off-road diesel standards are scheduled to begin in 2006 and are applicable to engines $37 \leq kW \leq 560$. They will reduce NMHC+NOx emissions for most power categories by an additional 40 percent compared to existing Tier 2 standards. However, Tier 3 will not reduce PM emission levels beyond existing Tier 2 levels.

Some off-road diesel engines will comply with Tier 3 requirements in 2005, one year earlier than required by regulation. It was discovered that certain engine manufacturers were designing on-road diesel engines in the latter 1990s that intentionally circumvented emission requirements when operated outside the region of a certification test cycle, or off-cycle. Emissions were low when tested, but calibrations changed during off-cycle operation to favor better fuel economy at the expense of higher emissions. To avoid recalling engines with these "defeat devices", the engine manufacturers reached a settlement agreement with ARB and U.S. EPA in which they committed to a number of projects to advance the causes of improved air quality. One of the projects agreed upon in the consent decree/settlement agreement is for certain engine manufacturers to advance the introduction of Tier 3 compliant engines. To satisfy this commitment, those diesel engine manufacturers are obligated to implement the Tier 3 standards on engines rated between 225 and 560 kW, inclusive, in 2005 instead of 2006.

The control technologies that engine manufacturers are likely to use to comply with Tier 3 requirements will be enhanced combustion techniques including variable-timing overhead valve configurations, higher pressure fuel injection, exhaust gas recirculation (EGR), lean burn catalysts, and electronic engine management systems. More advanced aftertreatment technologies are not expected to be used to comply with the Tier 3 requirements because most of these technologies are sensitive to sulfur, and diesel fuel with less than 15 parts-per-million sulfur by weight (ppmw) for the off-road

[5] Durability provisions were not retroactively applied to Tier 1 engines, only to those rated less than 37 kW after the 2000 model year.

sector will not be available nationally until 2010 (USEPA 2004), although it will be available in California in 2006. Tables 2.1 - 2.3 below show the current California off-road diesel standards.

Table 2.1
Off-Road Diesel Exhaust Standards < 37kW
SORE, Tier 1, and Tier 2

POWER CATEGORY	DURABILITY PERIOD	STANDARD [1]	MODEL YEAR	NMHC+NOx	NMHC	NOx	CO	PM
				grams per kilowatt-hour [grams per brake horsepower-hour]				
$kW < 8$ [$hp < 11$]	NONE	SORE	1995	16/13.4 [2] [12/10]	—	—	402 [300]	1.2 [0.90]
			1996 - 1999		—	—	469 [350]	
	3000 HOURS OR 5 YEARS	Tier 1	2000 - 2004	10.5 [7.8]	—	—	8.0 [6.0]	1.0 [0.75]
		Tier 2	2005 - 2007	7.5 [5.6]	—	—		0.80 [0.60]
$8 \le kW < 19$ [$11 \le hp < 25$]	NONE	SORE	1995	16/13.4 [2] [12/10]	—	—	402 [300]	1.2 [0.90]
			1996 - 1999		—	—	469 [350]	
	3000 HOURS OR 5 YEARS	Tier 1	2000 - 2004	9.5 [7.1]	—	—	6.6 [4.9]	0.80 [0.60]
		Tier 2	2005 - 2007	7.5 [5.6]	—	—		
$19 \le kW < 37$ [$25 \le hp < 50$]	5000 HOURS OR 7 YEARS [3]	Tier 1	2000 [4] - 2003	9.5 [7.1]	—	—	5.5 [4.1]	0.80 [0.60]
		Tier 2	2004 - 2007	7.5 [5.6]	—	—		0.60 [0.45]

Notes:
1 Standards that first become applicable in 2000 or later do not apply to engines less than 50 cubic centimeters in displacement
2 Small off-road engine standards are subdivided by engine displacement - Class I ($65 \le cc < 225$) and Class II ($cc \ge 225$), respectively
3 The durability period for constant speed engines rated ≥ 3,000 rpm is 3,000 hours or 5 years, whichever occurs first
4 The federal Tier 1 standards for this power category began in 1999

Table 2.2
Off-Road Diesel Exhaust Standards 37 ≤ kW < 225
Tier 1, Tier 2, and Tier 3

POWER CATEGORY	DURABILITY PERIOD	STANDARD	MODEL YEAR	NMHC+NOx	NMHC	NOx	CO	PM
				grams per kilowatt-hour [grams per brake horsepower-hour]				
37 ≤ kW < 56 [50 ≤ hp < 75]	8000 HOURS OR 10 YEARS	Tier 1	2000 [5] - 2003	—	—	9.2 [6.9]	—	—
		Tier 2	2004 - 2007	7.5 [5.6]	—	—	5.0 [3.7]	0.40 [0.30]
		Tier 3 [6]	2008 - 2011	4.7 [3.5]	—	—		
56 ≤ kW < 75 [75 ≤ hp < 100]	8000 HOURS OR 10 YEARS	Tier 1	2000 [5] - 2003	—	—	9.2 [6.9]	—	—
		Tier 2	2004 - 2007	7.5 [5.6]	—	—	5.0 [3.7]	0.40 [0.30]
		Tier 3	2008 - 2011	4.7 [3.5]	—	—		
75 ≤ kW < 130 [100 ≤ hp < 175]	8000 HOURS OR 10 YEARS	Tier 1	2000 [7] - 2002	—	—	9.2 [6.9]	—	—
		Tier 2	2003 - 2006	6.6 [4.9]	—	—	5.0 [3.7]	0.30 [0.22]
		Tier 3	2007 - 2011	4.0 [3.0]	—	—		
130 ≤ kW < 225 [175 ≤ hp < 300]	8000 HOURS OR 10 YEARS	Tier 1	1996 - 2002	—	1.3 [1.0]	9.2 [6.9]	11.4 [8.5]	0.54 [0.40]
		Tier 2	2003 - 2005	6.6 [4.9]	—	—	3.5 [2.6]	0.20 [0.15]
		Tier 3	2006 - 2010	4.0 [3.0]	—	—		

Notes:
5 The federal Tier 1 standards for this power category began in 1998
6 Manufacturers may optionally certify engine families to the interim Tier 4 standards for this power category through 2012
7 The federal Tier 1 standards for this power category began in 1997

Table 2.3
Off-Road Diesel Exhaust Standards ≥ 225 kW
Tier 1, Tier 2, and Tier 3

POWER CATEGORY	DURABILITY PERIOD	STANDARD	MODEL YEAR	NMHC+NOx	NMHC	NOx	CO	PM
				grams per kilowatt-hour [grams per brake horsepower-hour]				
225 ≤ kW < 450 [300 ≤ hp < 600]	8000 HOURS OR 10 YEARS	Tier 1	1996 - 2000	—	1.3 [1.0]	9.2 [6.9]	11.4 [8.5]	0.54 [0.40]
		Tier 2	2001 - 2004	6.4 [4.8]	—	—	3.5 [2.6]	0.20 [0.15]
		Tier 3	2006 [8] - 2010	4.0 [3.0]	—	—		
450 ≤ kW ≤ 560 [600 ≤ hp ≤ 750]	8000 HOURS OR 10 YEARS	Tier 1	1996 - 2001	—	1.3 [1.0]	9.2 [6.9]	11.4 [8.5]	0.54 [0.40]
		Tier 2	2002 - 2004	6.4 [4.8]	—	—	3.5 [2.6]	0.20 [0.15]
		Tier 3	2006 [8] - 2010	4.0 [3.0]	—	—		
kW > 560 [hp > 750]	8000 HOURS OR 10 YEARS	Tier 1	2000 - 2005	—	1.3 [1.0]	9.2 [6.9]	11.4 [8.5]	0.54 [0.40]
		Tier 2	2006 - 2010	6.4 [4.8]	—	—	3.5 [2.6]	0.20 [0.15]

Notes:
8 Certain manufacturers are required to comply with these standards beginning in 2005 per the consent decree settlement agreement

2.4. Emissions Inventory

The emissions data referenced in this subsection were obtained from the publicly available 2004 California Almanac of Emissions and Air Quality[6] and the off-road emissions inventory database. Brake dust and tire wear, although significant sources of PM, are not included in the following analyses since the focus of this report is on exhaust emissions. The reactive organic gas (ROG[7]) component of hydrocarbon emissions from evaporative losses is also not included in the comparisons for the same reason. The analyses do not reflect the inclusion of federal or ARB proposed Tier 4 standards. Tier 4 emission benefits will be identified during the discussion on environmental impacts in subsection 7.1.1 of this report. All emission estimates are

[6] Almanac data can de downloaded at http://www.arb.ca.gov/aqd/almanac/almanac04/almanac04.htm.
[7] The terms "ROG" and "NMHC" are used synonymously in this report to represent the component of hydrocarbon most likely to form ozone. The pie chart comparisons are expressed in units of ROG to reflect inventory modeling parameters, and standards are expressed in units of NMHC.

statewide and annual averages. Figures 2.1, 2.2, and 2.3, below, show the relative contributions of the three categories of mobile emission sources.

Figure 2.1 Mobile ROG

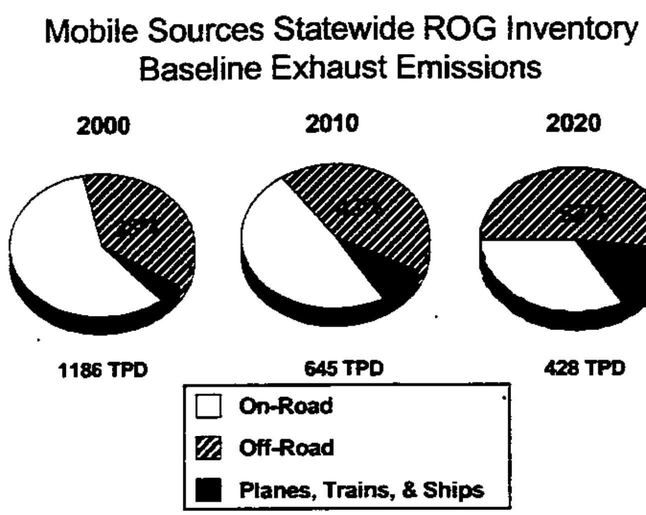


Figure 2.2 Mobile NOx

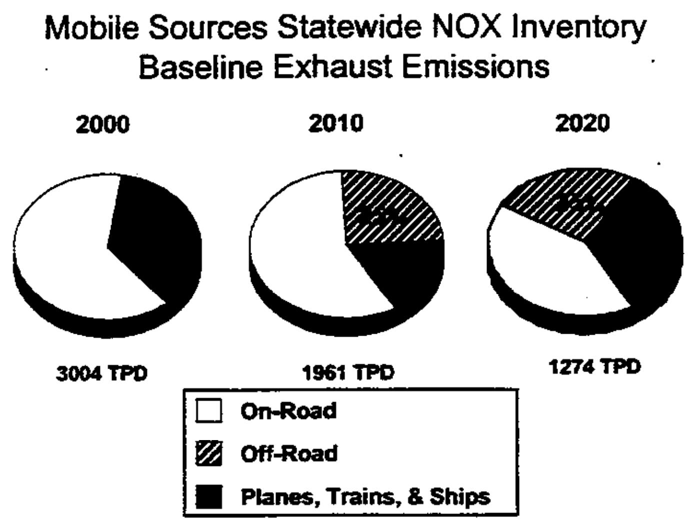
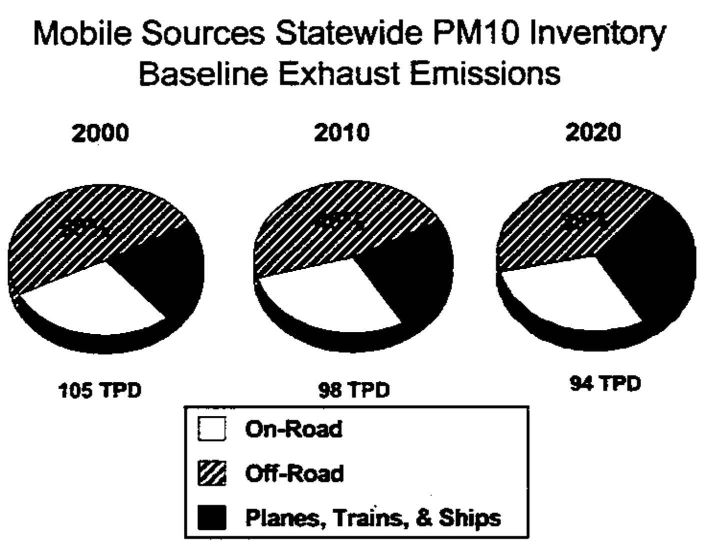


Figure 2.3 Mobile PM



Although the mobile source emissions inventory is decreasing overall as a result of State and federal regulations, the figures show that both ROG and NOx resulting from the use of land-based off-road engines (hereafter "off-road engines"[8]) generally become a greater portion of the remaining emissions through calendar year 2020. The PM[9]

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[8] The off-road estimates include recreational marine engines, but not trains, planes, or commercial ships.
[9] PM and PM10 are virtually the same component in diesel exhaust; therefore, the terms are used

percentage decreases, but off-road engines remain a significant source of PM from all mobile sources at 39 percent in 2020. Increased off-road activity and more stringent control of on-road heavy-duty trucks are largely responsible for the trends in ROG and NOx. Flat sales of agricultural equipment and the lack of comparably stringent standards for planes, trains, and ships explain the trend for PM.

Though not shown[10] in the figures above, off-road diesel engines are projected to account for 20 percent (249 TPD) of the total mobile source inventory for NOx and 18 percent (17.3 TPD) of the total mobile source inventory for PM in 2020. They are also projected to make up 36 percent of the total statewide inventory of PM that occurs exclusively from diesel exhaust, or diesel PM, in 2020.

Table 2.4 compares the statewide baseline off-road diesel emission inventories for PM, NOx, and ROG in 2000, 2010, and 2020. These baseline estimates include the effects of State and federal requirements through Tier 3; however, they do not include emissions from locomotives, airplanes, or marine engines. The baseline data also reflect PM benefits resulting solely from the use of 15 ppmw sulfur diesel fuel in California after 2006. ARB estimates that direct diesel particulate matter emissions, due to the low-sulfur fuel alone, would be reduced by about four percent due to the lower engine-out formation of sulfates (ARB 2003). This would include virtually all off-road diesel engines currently produced and those expected to be produced without advanced particulate emission control technologies.

Table 2.4 also shows the contribution of emissions from off-road diesel engines categorized into groups that can and cannot be regulated by California. The number of non-preempt engines – those that ARB can regulate – varies slightly from year to year due to fluctuations in consumer demand, but on the whole it is roughly 29 percent of the total number of off-road diesel engines in California. However, emissions do not necessarily follow the population fraction. For example, non-preempt NOx emissions exceed the population fraction and account for approximately 40 percent of the NOx inventory attributed to all off-road diesel engines in the State. Furthermore, non-preempt engines are projected to be responsible for the majority of NOx and NMHC emission reductions. This is discussed in greater detail in subsection 7.1.1.

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synonymously in this report.

[10] The NOx and PM percentages were obtained by comparing the 2020 off-road diesel data in Table 2.4 with the 2020 total mobile sources inventory data in Figures 2.2 and 2.3. The total statewide inventory percentage contribution of PM from off-road diesel engines in 2020 was calculated using the off-road diesel data in Table 2.4 and an assessment of 47.4 tons per day total statewide diesel exhaust PM from the 2004 California Almanac of Emissions and Air Quality.

Table 2.4
Off-Road Diesel Baseline Emission Inventories
Statewide Annual Averages

Government Jurisdiction	Pollutant	Emissions Inventory (tons per day)		
		2000	2010	2020
California Authority Non-Preempt Engines	PM [1]	11.6	7.1	5.1
	NOx	236.1	157.2	101.0
	ROG	23.5	13.4	9.6
Federal Authority Preempt Engines	PM [1]	27.6	21.9	12.2
	NOx	352.4	251.3	148.0
	ROG	51.3	33.6	15.3
Total	PM [1]	39.2	29.0	17.3
	NOx	588.5	408.5	249.0
	ROG	74.8	47.0	24.9

Notes:
1 PM estimates have been adjusted to reflect 15 ppmw sulfur fuel reductions after 2006

2.5. Federal Rules

In addition to the diesel Tier 1, Tier 2, and Tier 3 regulations already mentioned, U.S. EPA promulgated Tier 4 emissions standards on June 29, 2004 (see "Control of Emissions from New and In-Use Nonroad Diesel Engines," (40 CFR 1039, Subpart U)). The new emission standards are based on the same advanced exhaust aftertreatment technologies likely to be employed by heavy-duty diesel on-road engines beginning in 2007. ARB is proposing to adopt the federal Tier 4 standards for non-preempt off-road diesel engines in California. The federal rule also contains a two step requirement to reduce the level of sulfur in nonroad diesel fuel, first to 500 ppmw in 2007 and then to 15 ppmw in 2010. California has already adopted a 15 ppmw sulfur diesel fuel program for California that starts in 2006.

U.S. EPA has also adopted a rule that sets emissions standards similar to nonroad diesel Tier 2 standards for recreational marine engines rated equal to and above 37 kW (see "Control of Air Pollution from Marine Diesel Engines," 40 CFR 94). Recreational marine diesel engines less than 37 kW have previously been controlled to the same standards as land-based diesel engines, and are commonly included in the emissions estimates for off-road land-based diesel engines. Additional standards for these engines may be considered in a separate rulemaking.

2.6. Public Process

On November 29, 2001, ARB solicited input from off-road engine manufacturers and other stakeholders regarding the development of advanced aftertreatment technologies for off-road diesel engines in ARB Mailout MSC 01-17. The purpose of this request was to learn how far the technologies had progressed and to understand industry's concerns regarding implementation, timing, and durability.

ARB held public discussions regarding future off-road diesel standards at the Clean Air Plan workshop and SIP Summit in Sacramento, CA, between February, 2002, and January, 2004.

The Executive Officer of the ARB, Catherine Witherspoon, testified at two U.S. EPA hearings on June 10, and June 17, 2003, regarding U.S. EPA's then proposed Tier 4 rulemaking and ARB's intention to align with its provisions.

On August 23, 2004, staff posted a letter to the ARB website[11] stating ARB's intent to adopt standards for California's off-road diesel engines at the December 9, 2004, Board Hearing that would harmonize with U.S. EPA's Tier 4 standards. An electronic announcement was sent to all subscribers of the Mobile Source List Serve that same day to inform all interested parties that the letter had been posted.

3. NEED FOR CONTROL

This section provides the rationale behind ARB's proposal for more stringent exhaust standards and test procedures.

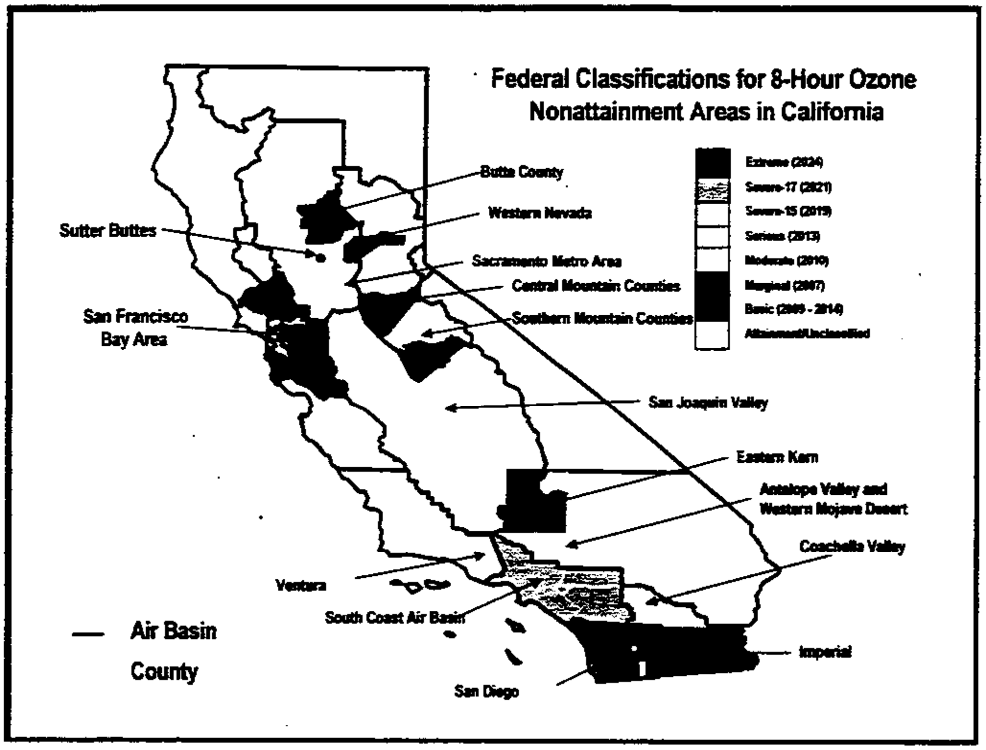
3.1. Overview

The emission standards being proposed would significantly reduce the human health and environmental impacts of PM and ground-level ozone. This section summarizes the air quality rationale for the proposed new standards.

Figure 3.1 below identifies air basins and counties that are in non-attainment with the recently adopted federal eight-hour standard for ozone.

[11] http://www.arb.ca.gov/msprog/offroad/orcomp/orcomp.htm/intentletter08232004.pdf

Figure 3.1
Eight Hour Ozone Non-Attainment Areas in California



Over 50 percent of California's air basins fall within this designation. Mobile sources presently[12] account for 68 percent of the total ozone precursors statewide (including evaporative emissions[13]), and the exhaust from off-road diesel engines is responsible for 20 percent of the NOx from all mobile sources, and 33 percent of the total NOx contribution from diesel mobile sources exclusively.

3.2. Diesel Exhaust

In order to start a diesel engine, finely misted fuel is injected, directly, or indirectly via a prechamber, into the engine's cylinder(s) with air that has been heated by piston compression. The power output of the engine is controlled by regulating the amount of fuel injected, unlike spark-ignition engines, which generally increase or decrease power by regulating the amount of air entering the engine. The heat of the compressed air in a diesel engine evaporates the fuel, which then ignites as it mixes with oxygen under high temperature and pressure inside the cylinder(s). Diesel fuel typically has a much higher sulfur content than gasoline, currently 140 ppmw on average in California (ARB 2003), and a lower evaporation rate making it suitable in diesel applications. Diesel engines operate best under lean air/fuel ratios (more air than fuel), which leaves behind excess oxygen.

[12] Estimates are for the 2003 calendar year.
[13] Evaporative emissions are included in this comparison because it includes all mobile and statewide sources, not just exhaust.

The pollutants of most concern in diesel exhaust are PM and NOx. NMHC and CO are also present, but are not emitted at comparably high levels due to their propensity to oxidize in the combustion chamber with abundant oxygen. The low evaporation rate of diesel fuel also helps in relegating evaporative emissions to insignificant levels.

3.2.1. Particulate Matter

Particulate matter from diesel exhaust is made primarily of four components:

- solid carbon soot,
- volatile and semi-volatile organic matter,
- inorganic solids (ash), and
- sulfate.

The formation of the solid carbon soot portion of PM is inherent in diesel engines due to the heterogeneous distribution of fuel and air in a diesel combustion system. Diesel combustion is designed to allow for lean combustion (excess oxygen) giving good efficiencies and low CO and NMHC emissions, with a small region of rich (excess fuel) combustion within the fuel injection plume. It is within this excess fuel region that PM is formed when high temperatures and a lack of oxygen cause the fuel to pyrolize[14], forming soot. Much of the soot formed in the engine is burned during the combustion process as the soot is mixed with oxygen in the cylinder at high temperatures. Any soot that is not fully burned before the exhaust valve is opened will be emitted from the engine as diesel PM.

The volatile and semi-volatile organic material in diesel PM is often referred to as the soluble organic fraction (SOF) in reference to a test method used to measure its level. SOF is primarily composed of engine oil that passes through the engine with no oxidation, or only partial oxidation, and condenses in the atmosphere to form PM. The SOF portion of diesel PM can be reduced through reductions in engine oil consumption and through oxidation of the SOF catalytically in the exhaust.

The inorganic solids (ash) in diesel PM come primarily from metals found in engine oil and, to a certain extent, from engine wear. Ash makes up a very small portion of total PM such that it is often not listed as a PM component and has no impact on compliance with PM emission standards. However, it does impact the maintenance of PM filter technologies because, in aggregate over a very long period of time, ash accumulation in the PM filter can reach a level such that it must be cleaned from the filter.

The sulfate portion of diesel PM is formed from sulfur present in diesel fuel and engine lubricating oil that oxidizes to form sulfuric acid, and then condenses in the atmosphere to form sulfate PM. Approximately two percent of the sulfur that enters a diesel engine

[14] Pyrolization is the process of using high temperature in an anaerobic environment to break down organic matter and release volatile organic products.

from the fuel is emitted directly from the engine as sulfate PM. The balance of the sulfur content is emitted from the engine as SO2 (RIA4 2004).

3.2.1.1. NOx Relationship

In addition to directly-emitted PM, secondary nitrate (a.k.a. indirect) PM accounts for a substantial fraction of the airborne particulate matter in some areas of California. This type of PM consists primarily of ammonium nitrate and represents about 25 percent of measured PM10 in the Los Angeles Basin (U.S. EPA 1997). Fine secondary nitrate particles are produced in the atmosphere from the NOx emitted by diesel engines and other sources. ARB believes that the control of secondary nitrate PM will be critical in meeting California's air quality attainment goals for the future.

3.2.1.2. Health Issues

The need for lower emission standards to protect public health, especially with respect to diesel PM, has prompted regulatory efforts throughout the world. Since virtually all particles in diesel particulate matter are 10 microns or less in diameter (PM10), with approximately 94 percent of them less than 2.5 microns in diameter (PM2.5), diesel particulate matter is readily respirable and can effectively reach the lowest airways of the lungs along with adsorbed compounds that are known as, or suspected of being, mutagens and carcinogens (SRP 1998). Accordingly, both ARB and U.S. EPA have identified diesel PM as a likely human carcinogen. Exposure to respirable diesel PM is associated with lung cancer, acute respiratory infection, exacerbation of asthma, increased hospital admissions, and an increase in mortality among the elderly and those with chronic heart and lung disease.

The estimated health risk from diesel PM is higher than the risk from all other toxic air contaminants combined. ARB estimates that 70 percent of the known statewide cancer risk from outdoor air toxics is attributable to diesel PM (Almanac 2004). Statewide, the estimated average lifetime potential cancer risk associated with diesel PM emissions is approximately 540 extra cases per million people[15], or 250 extra cases per year (Almanac 2004 and RRP 2000). In the South Coast Air Basin, the potential lifetime cancer risk associated with diesel PM emissions is estimated to be 720 extra cases per million people[16] (Almanac 2004), or approximately 150 extra cases per year (Almanac 2004 and Census 2000). Communities that adjoin busy roads and freeways, distribution centers, and other locations with large concentrations of diesel engines are particularly at risk.

Health impacts from exposure to the fine particulate matter component of diesel exhaust, PM2.5, have been calculated for California, using concentration-response equations from several epidemiological studies (Lloyd & Cackette 2001). Both mortality

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[15] These potential risk rates are based on 1.8 ug/m^3 average ambient PM concentration and are averaged over a 70 year lifespan.

[16] This estimate is for calendar year 2000 and distributes the risk over an average lifespan of 70 years.

and morbidity effects could be associated with exposure to either direct diesel PM2.5 or indirect diesel PM2.5, the latter of which arises from the conversion of diesel NOx emissions in the atmosphere to PM2.5 nitrates.

In California, the average population weighted exposure to directly emitted diesel PM2.5 is 1.8 micrograms per cubic meter (µg/m3). Long-term exposure to ambient concentrations of diesel PM2.5 at this level is estimated to have led to a range of about 2,000 to 2,500 premature deaths, statewide, for the year 2000. Indirect diesel PM2.5 (at 0.81 µg/m3 concentration level) is also estimated to contribute to an additional 900 premature deaths, although the mortality estimates may include some premature deaths due to cancer, because the epidemiological studies did not identify the cause of death.

Exposure to fine particulate matter, including diesel PM2.5, can also be linked to a number of heart and lung diseases. For example, it was estimated that statewide, on average, 2500 hospital admissions for chronic obstructive pulmonary disease, pneumonia, cardiovascular disease, and asthma were associated with exposure to direct diesel PM2.5. An additional 1,100 admissions were linked to exposure to indirect diesel PM2.5.

Staff's proposal, discussed in detail in subsection 4.2.1, will require PM reductions up to 95 percent more than currently required for new off-road diesel engines.

3.2.2. Ozone

Ground-level ozone is created by the photochemical reaction between NOx and ROG. Breathing ozone can trigger a variety of health problems,including chest pain, coughing, throat irritation, shortness of breath, and congestion. It can worsen bronchitis, emphysema, and asthma. Ozone can also reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

The elderly, children, and people with compromised respiratory systems are among those persons who may be most affected by exposure to ozone. However, healthy people can also experience difficulty breathing when exposed to ozone pollution. Because ozone forms in hot weather, anyone who spends time outdoors in the summer may be affected, particularly children, outdoor workers and people exercising. Many Californians live in areas where the federal ozone health standards are exceeded.

Ground-level ozone also damages vegetation and ecosystems. It leads to reduced agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased susceptibility to diseases, pests, and other stresses such as harsh weather. Ground-level ozone also damages the foliage of trees and other plants, affecting the landscape of cities, parks and forests, and recreational areas. NOx also contributes to acid deposition and the overgrowth of algae in coastal estuaries.

3.3. State Implementation Plan (SIP)

Off-road diesel engine standards will be a part of California's post-2010 control strategy for attaining the eight-hour ozone and PM2.5 air quality standards. The emission benefits from these standards will be incorporated into future SIPs. A commitment for ARB to consider adoption of more stringent emission standards for off-road diesel engines is included in an agreement to settle a lawsuit filed over the 1994 SIP as discussed below.

In 1997, three environmental groups, namely Communities for a Better Environment, the Coalition for Clean Air, and the Natural Resources Defense Council, filed a complaint in the United States District Court for the Central District of California. The lawsuit was filed against ARB, the South Coast Air Quality Management District, and U.S. EPA related to California's progress in achieving the 1994 SIP commitments. ARB reached a settlement agreement with these groups in January 1999, which was amended most recently in July 2003, to include additional elements (SSA 2003). Although the 2003 SIP revision is intended to replace the State's original commitments under the 1994 SIP for the South Coast, the settlement agreement will remain in place until ARB fulfills its obligations as outlined.

The agreement contains a schedule under which ARB committed to achieving the remaining near-term emission reductions from the 1994 SIP. ARB also committed to submit to the Board, and propose for adoption, a number of specific measures including the adoption of more stringent emission standards for off-road diesel engines no later than December 31, 2004. The amendments to the off-road diesel regulation proposed in this report are intended to fulfill ARB's commitment with respect to the settlement agreement.

4. SUMMARY OF PROPOSED REGULATIONS

The staff recommends that the Board amend sections 2420, 2421, 2423, 2424, 2425, and 2327, Title 13, California Code of Regulations, as set forth in Attachment 1: "Proposed Amendments to the California Regulations for 2006 and Later Off-Road Compression-Ignition Engines and Equipment" and Attachment 2: "Proposed Amendments to the California Exhaust Emission Standards and Test Procedures for New 2008 and Later Tier 4 Off-Road Compression-Ignition Engines and Equipment, Part I-C" of this report. The proposed regulatory language is intended to harmonize California's exhaust emission requirements for new off-road diesel engines with those published by U.S. EPA on June 29, 2004 (69 FR 38958-39273), with minor differences as discussed in section 5 of this report. Although the California and federal programs for diesel engines will be similar upon adoption of this proposal, ARB will retain its authority to further regulate off-road mobile sources in the future and its ability to enforce the regulations in California.

In sum, the proposed amendments require new off-road diesel engines to meet more stringent exhaust emission standards for PM, NOx, NMHC, and CO than are currently required. Enhancements to test procedures and the certification process are proposed to ensure meaningful compliance with the new standards and to provide compliance flexibility without sacrificing air quality benefits. The following subsections discuss the major provisions of the staff proposal in further detail.

The amendments, which are discussed below, can be categorized as follows:

- Applicability
- Tier 4 Emission Standards and Implementation Schedules
- Enhanced Certification Requirements
- Enhanced Test Procedures, and
- Expanded Compliance Flexibility Provisions
- Miscellaneous

4.1. Applicability

The provisions in this proposal continue to apply to off-road diesel engines produced for sale in California with the exception of engines with a per cylinder displacement of less than 50 cubic centimeters, engines used to propel locomotives, underground mining equipment, marine vessels, aircraft, preempt engines and equipment, and off-road military tactical vehicles or equipment that have been exempted from regulations under the federal national security exemption.

Recreational marine engines less than 37 kW are the significant omission with respect to the applicability of the Tier 4 proposal compared to previous off-road diesel regulations. U.S. EPA has chosen instead to regulate these engines under a future rulemaking that would consolidate all diesel marine engines less than 30 liters per cylinder. Comments on the need for, and the feasibility of, more stringent recreational marine diesel standards regarding this rulemaking are currently being solicited. In response, ARB intends to recommend that U.S. EPA promulgate a PM standard based on the reduction capacity of oxidation catalysts in the near-term, to be followed with advanced aftertreatment equivalent levels in the 2013 time frame. The precedent for aftertreatment-based standards on watercraft has already been established in California with ARB's adoption of catalyst-forcing standards for 2009 gasoline fueled inboard and sterndrive boats (ARB 2001b). Staff believes that the technology needed to adapt diesel exhaust aftertreatment to a marine environment would be nearly identical to the technology needed for gasoline marine engines. Until new standards are adopted, recreational marine engines will continue to meet the previous tiers of off-road standards, as appropriate.

4.2. Standards and Implementation Schedules

This section explains proposed exhaust standards, crankcase standards, not-to-exceed limits, and smoke test standards. Table 4.1 below identifies the model year when the new Tier 4 requirements are first applicable for each engine power category.

Table 4.1
Applicability by Model Year

Power Category	Model Year
kW < 19	2008 [1]
19 ≤ kW < 56	2008 [2]
56 ≤ kW < 130	2012
130 ≤ kW ≤ 560	2011
kW > 560	2011

Notes:
1 Hand-start, air cooled, direct injection engines below 8 kW are not be subject to the PM standard until the 2010 model year.
2 Engines 37 ≤ kW < 56 may opt out of meeting interim standards by complying with final standards early in the 2012 model year.

4.2.1. Exhaust Emission Standards

Staff proposes that the Board adopt more stringent PM, NOx, and NMHC emission standards for new off-road diesel engines as outlined and scheduled in Table 4.2 below. The standards would be the same as those adopted federally in the U.S. EPA Tier 4 rulemaking. Staff is not proposing more stringent CO standards. Current emission standards for all pollutants would continue to apply until the more stringent proposed emission standards become effective.

Interim Tier 4 standards, targeting 50 percent tailpipe reductions in PM, would be introduced beginning with the 2008 model year for engines less than 56 kW, and ultra stringent PM and/or NOx standards based on advanced aftertreatment technologies would begin phasing-in on engines greater than and equal to 19 kW in 2011. The final Tier 4 standards would reduce tailpipe emissions upwards of 90 percent compared to previous off-road diesel standards. The proposed off-road aftertreatment based standards are modeled after the 2007 on-road heavy-duty diesel standards.

By 2020, the proposed Tier 4 off-road diesel standards would reduce the statewide PM emissions inventory by 40 percent, the NOx inventory by 29 percent, and the NMHC inventory by 12 percent. Reductions in NOx will also reduce secondary nitrate PM emissions. The resulting emission reductions will translate into needed improvements in air quality in California and assist in attaining applicable ambient air quality standards. The benefits of this proposal are discussed in detail in subsection 7.1 of this report.

Table 4.2
Proposed Tier 4 Off-Road Diesel Emission Standards

MAXIMUM ENGINE POWER	MODEL YEAR	TYPE	PM	NMHC+NOX	NMHC	NOX	CO
			grams per kilowatt-hour				
kW < 19	2008 and later	FINAL	0.40 [1]	7.5	-	-	8.0/6.6 [2]
19 ≤ kW < 37	2008 - 2012	INTERIM	0.30	7.5	-	-	5.5
	2013 and later	FINAL	0.03	4.7			
37 ≤ kW < 56 [3]	2008 - 2012	INTERIM	0.30	4.7	-	-	5.0
	2013 and later	FINAL	0.03				
56 ≤ kW < 75	2012 - 2014 [4]	PHASE-IN	0.02	-	0.19	0.40	5.0
		PHASE-OUT		4.7	-	-	
		ALT NOx		-	0.19	3.4 [5]	
	2015 and later	FINAL				0.40	
75 ≤ kW < 130	2012 - 2014 [4]	PHASE-IN	0.02	-	0.19	0.40	5.0
		PHASE-OUT		4.0	-	-	
		ALT NOx		-	0.19	3.4 [5]	
	2015 and later	FINAL				0.40	
130 ≤ kW ≤ 560	2011 - 2013	PHASE-IN	0.02	-	0.19	0.40	3.5
		PHASE-OUT		4.0	-	-	
		ALT NOx		-	0.19	2.0	
	2014 and later	FINAL				0.40	
560 kW < GEN [6] ≤ 900 kW	2011 - 2014	INTERIM	0.10	-	0.40	3.5	3.5
	2015 and later	FINAL	0.03		0.19	0.67	
GEN > 900 kW	2011 - 2014	INTERIM	0.10	-	0.40	0.67	3.5
	2015 and later	FINAL	0.03		0.19		
ELSE [7] > 560 kW	2011 - 2014	INTERIM	0.10	-	0.40	3.5	3.5
	2015 and later	FINAL	0.04		0.19		

Notes:
1 The Tier 4 PM standard for hand-start, air cooled, direct injection engines below 8 kW is 0.60 g/kW-hr, but is not required until 2010.
2 The CO standard is 8 g/kW-hr for engines below 8 kW and 6.6 g/kW-hr for engines 8 ≤ kW < 19.
3 Engine families in this power category may alternately meet Tier 3 PM standards from 2008-2011 in exchange for introducing final PM standards in 2012.
4 Manufacturers have the option of complying with the Tier 4 standards over a two year period at 50% per year using banked Tier 2 credits or over a three year period at 25% per year without the use of credits. The three year phase-in period is shown as the more likely option. The 2014 model year cannot extend beyond December 30, 2014, when the 3 year phase-in option is used.
5 This Manufacturers may comply with the standards during the transitional implementation years using either a phase-in / phase-out approach or by using the Alternate NOx approach. The three year 25% alternate NOx standard is shown as it corresponds to the three year phase-in period shown in the table. The two year 50% phase-in NOx standard would be 2.3 g/kW-hr.
6 "GEN" refers to generator engines only.
7 "ELSE" refers to all mobile machinery excluding generator engines.

4.2.1.1. Power Category Reclassification

The new Tier 4 standards would be phased-in according to power category. Tier 4 power categories differ from previous power categories in that there are now only five distinct groupings, whereas nine existed before. The five Tier 4 power categories are shown in Table 4.2 above with alternating gray and white shading. Fewer categories reduce the burden on engine manufacturers at certification and allow more compliance options for equipment manufacturers without sacrificing long-term post 2014 air quality benefits. For example, more equipment flexibility allowances would be available within a power category that could potentially be used to address problematic applications over a longer period of time; however, the total number of flexibility allowances for all power categories would remain the same. Additionally, the previous power category defined by engines 37 ≤ kW < 75 has been split into two separate categories defined by engines 37 ≤ kW < 56 and engines 56 ≤ kW < 75. This regrouping would more closely match the degree of challenge involved in transferring advanced emission control technology from highway engines to off-road engines by limiting advanced NOx aftertreatment requirements to engines greater than and equal to 56 kW. This would ease the burden of certifying engines between 37 ≤ kW < 56 due to the less rigorous NOx standards.

4.2.1.2. Phase-in Allowances

A new feature for diesel off-road standards in staff's Tier 4 proposal is the gradual phasing-in of aftertreatment NOx standards for some power categories. Manufacturers would be allowed to continue producing engines that meet previously certified levels of NMHC+NOx emissions for a portion of new sales (hereafter phase-out engines) during years for which the phase-in provisions are permitted. Generally speaking, up to 75 percent of the engines produced in the 56 ≤ kW < 130 power category from 2012 through 2014 could be phase-out engines, and 50 percent would be permitted in the 130 ≤ kW ≤ 560 category from 2011 through 2013. Other compliance options exist for these categories as explained in the attached regulations and test procedures including the use of alternate NOx standards for all engines in lieu of phase-in/phase-out implementation. These are the same allowances adopted by U.S. EPA in the federal nonroad Tier 4 rule.

4.2.2. Not-To-Exceed (NTE) Limits

The NTE limits have been developed as a means to confirm the emissions performance of engines under all normal in-use operating conditions, not just those encountered during certification testing. In the past, some diesel manufacturers were designing their engines to perform differently depending on whether they were operated on a certification test cycle or off-cycle (see subsection 2.3.3). This had a negative impact on emissions despite the fact that the engines were meeting the certification limits. To ensure against a similar occurrence in the future, staff proposes that the Board adopt NTE limits and test procedures for new off-road diesel engines to align with federal Tier 4 NTE requirements beginning in 2011. These limits and test procedures are similar to those that U.S. EPA and ARB have adopted for 2007 and later heavy-duty on-road diesel engines. Table 4.3 below shows the NTE starting date that would correspond to each power category.

Table 4.3
NTE Implementation Schedule

Power Category	NTE Implementation Model Year [1,2]
kW < 19	2013
19 ≤ kW < 56	2013 [3,4]
56 ≤ kW < 130	2012 [4]
130 ≤ kW ≤ 560	2011 [4]
kW > 560	2011

Notes:
1 All engines in a given power category are required to meet the NTE limits.
2 NTE limits are not applicable for NOx and NMHC on phase-out engines that are certified to the same numeric limits or FELs as engines which were previously certified under the Tier 3 requirements.
3 NTE limits would apply in 2012 for engines in the 37 ≤ kW < 56 power category that do not comply with 2008 interim Tier 4 standards.
4 NTE limits do not apply for engines certified to transient alternate FELs (ALT 20%) unless those engines are also certified to optional transient standards.

For off-road diesel engines subject to NTE limits, the engine manufacturer would be required to state in the application for certification that the engine is able to meet the NTE limits under all conditions that may reasonably be expected to occur in normal equipment operation and use. Manufacturers would be required to maintain a detailed description of all testing as specified in the test procedures, engineering analysis, and other information that forms the basis for this statement.

For a limited time, engine manufacturers would be permitted to certify an engine family with NTE deficiencies. The NTE deficiency provision would allow the Executive Officer to certify a nonroad diesel engine as compliant although some specific NTE limits may not be fully met. This provision provides a means of relief to address the occurrence of unanticipated technical problems, which are limited in nature but, cannot be resolved in time to meet production schedules. The number of NTE deficiencies that a manufacturer can apply for during the first three model years of the NTE requirement is unlimited. However, manufacturers would not be allowed to apply for more than three deficiencies per engine family for the fourth through seventh model years, and no deficiencies would be granted after the seventh model year.

Table 4.4 below shows the methodology that would be used to determine NTE thresholds for each applicable pollutant. The detailed NTE requirements, including how to perform an emissions test, can be found in the attached test procedures.

Table 4.4
Criteria for Determining NTE Limits [1]

Pollutant	Apply NTE Multiplier of 1.25 when ...	Apply NTE Multiplier of 1.50 when ...
NOx	NOx Standard or FEL ≥ 2.5 g/kW-hr	NOx Standard [2] or FEL< 2.5 g/kW-hr
NMHC	NOx Standard or FEL ≥ 2.5 g/kW-hr	NOx Standard [2] or FEL< 2.5 g/kW-hr
NMHC+NOx	NMHC+NOx Standard or FEL ≥ 2.7 g/kW-hr	NMHC+NOx Standard [2] or FEL< 2.7 g/kW-hr
PM	PM Standard or FEL ≥ 0.07 g/kW-hr	PM [2] Standard or FEL [3] < 0.07 g/kW-hr
CO	Always	Never

1 Other provisions as specified in the test procedures may affect the calculation of NTE limits.
2 Engines must be certified to these limits without the use of ABT credits.
3 For engines certified to a PM FEL less than or equal to 0.01 g/kW-hr, the PM NTE limit shall be 0.02 g/kW-hr.

4.2.3. Universal Closed Crankcase Requirement

Staff proposes to amend the regulations to require closed crankcase requirements for all off-road diesel engine engines including those previously exempted due to turbochargers, pumps, blowers, or superchargers used for air induction. These changes would become effective beginning in 2008 and phased-in by power category (see Table 4.1 above). Optionally, crankcase emissions may be vented to the atmosphere if these emissions are added to the total of exhaust emissions and so long as the deterioration of crankcase emissions is taken into account for the purposes of certification and in-use testing (see subsection 4.4.5). This provision would align crankcase requirements with 2007 federal heavy-duty highway and California heavy-duty on-road requirements.

4.2.4. Smoke Test Standards

Staff proposes to amend the smoke requirements for new off-road diesel engines to align with federal Tier 4 smoke standards. These changes would become effective beginning in 2008 and phased-in by power category (see Table 4.1 above). With this change, engines employing a particulate filter and certified to a Family Emission Limit (FEL) of 0.07 g/kW-hr or lower would be exempted from this requirement. Smoke levels would need to take into account the effects of deterioration for certification and in-use testing. The particulate filter should effectively eliminate all visible smoke from an engine so equipped. Single-cylinder engines, propulsion marine engines, and constant-speed engines would continue to be exempted from this requirement.

4.3. Early Introduction Incentives for Engine Manufacturers

To encourage the early introduction of Tier 4 off-road diesel engines in California, staff proposes to align with the provisions in U.S. EPA's final rule allowing engine manufacturers to benefit from producing engines certified to the Tier 4 standards prior to the 2011 model year. In exchange for the early introduction of these engines, engine manufacturers would be allowed to make fewer Tier 4 engines after 2011, a concept that U.S. EPA terms "engine offsets" to avoid confusion with Averaging, Banking, and Trading (AB&T) program credits. The number of offsets that could be generated would depend on the degree to which the engines are able to meet, or perform better than, the final Tier 4 standards.

Table 4.5 summarizes the requirements and available offsets for engine manufacturers in this program. As the purpose of the incentive is to encourage the introduction of clean technology engines earlier than required, actual emission standard levels would need to be met, and met early, by qualifying engines to earn the early introduction offsets. In other words, the standards must be met without the use of AB&T credits, and actual production of the engines must begin by September 1 of the year prior to the first model year when the standards would otherwise be applicable. Also, to avoid double-counting, the early incentive engines can earn either engine offsets or AB&T emissions credit, but not both. Note that this is different from the approach taken in the early Tier 4 incentive program for equipment manufacturers (see subsection 4.7.2.6) where incentives for both the engine manufacturer (AB&T credits) and the equipment manufacturer (flexibilities) are needed to ensure a successful early introduction of clean engines. Since 15 ppmw sulfur diesel fuel will be readily available in California by 2007, staff proposes to allow engine manufacturers to begin certifying engines to the very low emission levels required for eligibility in this incentive program, beginning with the 2007 model year.

An important aspect of the early incentive provision is that it must be done on an engine count basis. That is, a diesel engine meeting new standards early would count as one and one half diesel engines later. This contrasts with a provision done on an engine percentage basis which would count one percent of diesel engines early as one and one half percent of diesel engines later. Basing the incentive on an engine count basis removes the uncertainty regarding fluctuations in engine sales for different model years.

Another important aspect of this program is that it is limited to engines sold prior to the 2013 model year for engines $19 \le kW < 56$, prior to the 2012 model year for engines $56 \le kW < 130$, and prior to the 2011 model year for engines $130 \le kW \le 560$. In other words, as in the heavy-duty on-road diesel program, nonroad diesel engines sold during the transitional "phase-in" model years would not be considered "early" introduction engines and would therefore not be eligible for generating early introduction offsets. However, such engines and vehicles would still be able to generate AB&T credits. Because engines over 560 kW have no phase-in provisions, staff proposes to allow offsets for early incentive engines in this power category for any model year prior to 2015. For the same reason, there is no PM-only offset for these engines. As with the phase-in itself, and for the same reasons, an early introduction engine could only be used to offset engines in the same engine power category as the offset-generating engine.

Table 4.5
Incentives for Engine Manufacturers

EARLY INTRODUCTION	POWER CATEGORY	QUALIFYING STANDARDS [1] g/kW-hr	PER-ENGINE INCENTIVE
Final Tier 4 PM-Only [2]	19 ≤ kW < 56	0.03 PM	3 for 2 PM-Only
	56 ≤ kW < 560	0.02 PM	
Final Tier 4 ALL	19 ≤ kW < 56	0.03 PM / 4.7 NMHC+NOx	3 for 2
	56 ≤ kW ≤ 560	0.02 PM / 0.40 NOx / 0.19 NMHC	
	GEN > 560	0.03 PM / 0.67 NOx / 0.19 NMHC	
	ELSE > 560	0.04 PM / 3.5 NOx / 0.19 NMHC	
Ultra Low NOx	kW ≥ 19	Final Tier 4 PM & NMHC / 0.20 NOx	2 for 1

Notes:
1 Engines must also meet the Tier 4 crankcase emissions requirements and must be certified for all other Tier 4 requirements such as transient testing and Not-To-Exceed testing as appropriate.
2 Offsets must be earned prior to the start of phase-in requirements in applicable engine groups (prior to 2013 for 19≤kW<56 engines, prior to 2012 for 56≤kW<130 engines, prior to 2011 for 130≤kW≤560 engines, prior to 2015 for >560 kW engines)

4.4. Certification

The amendments in this section are related to labeling, executive orders, test fuel, test procedures, deterioration factors, and definitions.

4.4.1. Labeling

This section proposes federal alignment with most aspects of the labeling requirements for off-road diesel engines and equipment as well as some California specific changes.

4.4.1.1. Flexibility Label Content

Staff generally proposes to align with federal labeling requirements for new off-road diesel engines, except that the label must state that the engine complies with California or both California and U.S. EPA regulations.

However, staff also proposes a modified version of the label content for engines that qualify under the transitional flexibility provisions for equipment manufacturers (flexibility engines). This proposal, including revised labeling content, is discussed in detail in subsection 5.1.1.

4.4.1.2. Rebuilt Labeling Prohibition

Staff also proposes to adopt language prohibiting the removal of the original label from off-road diesel engines that have been rebuilt or remanufactured. This proposal is discussed in detail in subsection 5.2.

4.4.2. Executive Orders

Staff proposes to amend the current regulations to clarify that engines certified under the transitional flexibility provisions for equipment manufacturers, discussed in subsection 4.7 of this report, must be covered by an Executive Order. The Executive Order need not be current for the year in which the engine is used as a flexibility allowance, but may have been issued previously so long as the engine was certified to the appropriate standards required by the flexibility provision. This requirement is discussed in detail in subsection 5.1.2.

4.4.3. Test Fuel

Staff proposes to align with the federal nonroad rule regarding the use of ultra low-sulfur diesel fuel (15 ppmw) as the certification test fuel for all engines in 2011 and as likewise permitted for new engines in previous years. Since ultra low-sulfur diesel fuel will be the only fuel available to the California off-road market by 2007, previously uncertified new engine families for that year may also use ultra low-sulfur fuel as their certification test fuel. Carry-over engine families that have previously been certified using higher sulfur content certification fuel must continue to certify using that fuel.

4.4.4. Test Procedures

The current off-road diesel test procedures "California Exhaust Emission Standards and Test Procedures for New 2000 and Later Off-Road Compression-Ignition Engines and Equipment, Part I-B" will continue to apply through 2007 and beyond as applicable to engines and equipment designed to comply with the Tier 1, Tier 2, or Tier 3 standards. New test procedures applicable beginning in 2008 for engines designed to meet the Tier 4 standards are proposed for adoption by the Board and are equivalent to the federal requirements in 40 CFR, Part 1039 and the documents incorporated by reference. A copy of the new test procedures is included at the end of this report in Attachment 2. Staff's proposed amendments to the current test procedures to restrict applicability to pre-Tier 4 engines and equipment are included in Attachment 3: "Proposed Amendments to the California Exhaust Emission Standards and Test Procedures for New 2000 and Later Tier 1, Tier 2, and Tier 3 Off-Road Compression-Ignition Engines and Equipment, Part I-B."

The Tier 4 emission standards proposed in subsection 4.2.1 are based on using the existing steady-state (modal) test cycle or alternative Ramped-Modal Cycle and a new transient test cycle specific to off-road engines. A new steady-state test cycle would also be specified as an alternative for transport refrigeration units (TRU)s. PM measurement techniques have also been modified. The following subsection briefly describes the most significant proposed amendments to the test procedure provisions.

4.4.4.1. Ramped-Modal Cycle (RMC) Alternative

The optional RMC steady-state test cycle is a modified version of the existing steady-state test cycle which allows continuous PM sampling through a single filter. The RMC permits more consistent and reliable emissions testing of diesel engines with add-on emission control components and eliminates the downtime between modes. It also permits the sampling of emissions to be done on a composite basis for the whole test as opposed to sampling emissions mode-by-mode. This continuous emission sampling approach allows regeneration events from devices such as particulate traps to be captured more reliably and with greater repeatability. Engine manufacturers would benefit from using this optional cycle by virtue of the reduced cost in going to a single filter. Further, their test runs will be subject to less test cell "tuning" and fewer test runs will be needed to "fit" the emission test cycle to the dynamometer in order to operate a particular engine (U.S. EPA 2004).

4.4.4.2. Off-Road Transient Test Cycle

The Nonroad Transient Composite (NRTC) test cycle, as the name implies, is the compilation of a number of cycles developed by U.S. EPA to reproduce realistic operating conditions for equipment such as backhoes, dozers, and other off-road equipment. It supplements the existing off-road steady-state test cycle such that the majority of off-road diesel engines subject to the proposed Tier 4 requirements would be required to certify using both test cycles. The NRTC captures transient emissions over much of the typical off-road engine operating range, and helps to ensure effective control of the regulated pollutants. This new transient requirement is expected to significantly reduce in-use exhaust emissions from off-road diesel engines by providing a more thorough and realistic evaluation of emission control system performance. Proper transient testing captures engine emissions from the broad range of engine speed and load combinations that the engine may encounter in-use, while steady-state testing captures emissions at the eight operating points that are typical for off-road diesel engines. Transient testing will also identify emissions that result from speed and load fluctuations due to turbocharger engagement, throttle lag, etc (U.S. EPA 2004).

Transient testing would be required according to the implementation schedule shown in Table 4.6 below. In general, the requirement is applicable to all engines at the time those engines are first equipped with advanced aftertreatment technologies for reducing emissions of PM or NOx. Testing would not be required for diesel engines rated above 560 kW or constant speed engines; nor would it be required for measuring NMHC, NOx, and CO on phase-out[17] or flexibility engines.

[17] This exemption applies only to phase-out engines that are certified to the same gaseous standards or FELs as previously certified Tier 3 engines.

Table 4.6
Transient Test Cycle Implementation Schedule

Power Category [1]	Model Year Implementation [2]
kW < 19	2013
19 ≤ kW < 56	2013
56 ≤ kW < 130	2012
130 ≤ kW ≤ 560	2011

Notes:
1 Transient testing is not required for engines > 560 kW
2 Transient testing is not required for gaseous pollutants on phase-out engines or flex engines

4.4.4.3. Cold Start Transient Testing

To better approximate actual in-use emissions, the transient test procedure includes the effects of engine operation after an extended period of inactivity (cold soak). Since most advanced exhaust aftertreatment technologies work less efficiently when cold, it is critical to address cold-start emissions in the measurement test procedures. U.S. EPA has determined, based on test data provided by industry, that a five percent weighting factor is appropriate for categorizing the effects of cold-start emissions. This is based on the scenario of an off-road engine with an overnight soak and a total of seven hours of operation over the course of a workday. At this weighting, engine manufacturers would likely need to take cold-start emissions into consideration when designing emission control strategies.

4.4.4.4. Transport Refrigeration Unit (TRU) Test Cycle

Staff's proposal includes a provision for a four-mode steady-state test cycle designed specifically for engines used in TRU applications. This test cycle is more representative of TRU operation than the other steady-state cycles currently available and it may be used by engine manufacturers in lieu of normal steady-state testing to certify their TRU engines. Engine manufacturers opting to use the TRU test cycle will be able to test their engines under a broad range of intermediate test speeds at specified test cycle engine load points.

4.4.4.5. PM Measurement Techniques

Staff's proposal includes changes to the test procedures to improve the precision of emission measurements. In general, the requirements would be nearly identical to the test procedures adopted for implementation on 2007 and later heavy-duty on-road diesel engines. Most noteworthy of the changes are those directed at improving the accuracy and precision of PM measurements. These include changes to the type of PM filters that are used and improvements in how PM filters are weighed before and after emission measurements, including requirements for more precise microbalances. A single filter methodology would replace the existing multiple filter methodology for engines with particulate filters. The single filter proposal would represent a cost savings to engine manufacturers.

4.4.5. Deterioration Factors

The purpose of this amendment is to ensure that technologies with undemonstrated durability in off-road applications, such as particulate filters and NOx adsorbers, demonstrate compliance with the proposed emission requirements throughout their useful lives. Further, manufacturers that choose to vent crankcase emissions to the exhaust or atmosphere in lieu of meeting a closed system requirement must consider deterioration of these emissions when certifying their engines.

Listed below are proposed amendments applicable to the use of deterioration factors:

(1) Additive deterioration factor for exhaust emissions. Except as specified in paragraph (2) below, an additive deterioration factor must be used for exhaust emissions. An additive deterioration factor for a pollutant is the difference between exhaust emissions at the end of the useful life and exhaust emissions at the low-hour test point. In these cases, the manufacturer would adjust the official emission results for each tested engine at the selected test point by adding the factor to the measured emissions. If the factor is less than zero, zero would be used. Additive deterioration factors would need to be specified to one more decimal place than the applicable standard.

(2) Multiplicative deterioration factor for exhaust emissions. The use of a multiplicative deterioration factor would be allowed if good engineering judgment calls for the deterioration factor for a pollutant to be the ratio of exhaust emissions at the end of the useful life to exhaust emissions at the low-hour test point. For example, if aftertreatment technology is used, it may be appropriate to use a multiplicative deterioration factor. The manufacturer could then adjust the official emission results for each tested engine at the selected test point by multiplying the measured emissions by the deterioration factor. If the factor is less than one, one would be used. A multiplicative deterioration factor may not be appropriate in cases where testing variability is significantly greater than engine-to-engine variability. Multiplicative deterioration factors would need to be specified to one more significant figure than the applicable standard.

(3) Deterioration factor for smoke. Deterioration factors for smoke would always be additive, as described in paragraph (1) above.

(4) Deterioration factor for crankcase emissions. If an engine vents crankcase emissions to the exhaust or to the atmosphere, the manufacturer must account for crankcase emission deterioration, using good engineering judgment. Separate deterioration factors may be used for crankcase emissions of each

pollutant (either multiplicative or additive). Alternatively, combined deterioration factors may be used that include exhaust and crankcase emissions together for each pollutant.

4.4.6. Definitions

This section provides background on two key terms that are defined in the U.S. EPA nonroad rule. Staff proposes alignment with the definitions of these terms.

4.4.6.1. Maximum Engine Power

In order to assign standards more objectively, staff proposes to align with the federal nonroad definition for "Maximum Engine Power." The proposed definition provides more standardized guidance than the previously utilized terms "rated power" and "power rating" for determining which power category an engine belongs to and the applicable standards it must meet. An engine's maximum power is the maximum brake power point on the nominal power curve for the engine configuration. The nominal power curve of an engine configuration is the relationship between maximum available engine brake power and engine speed for an engine, using the mapping procedures of 40 CFR, Part 1065, based on the manufacturer's design and production specifications for the engine. This information may also be expressed by a torque curve that relates maximum available engine torque with engine speed. The nominal power curve must be within the range of the actual power curves of production engines considering normal production variability.

4.4.6.2. Maximum Test Speed

Staff proposes alignment with the federal definition of "Maximum Test Speed" as found in 40 CFR, Part 1065.515. This definition of maximum test speed is the single point on an engine's normalized maximum power versus speed curve that lies farthest away from the zero-power, zero-speed point. This is intended to ensure that the maximum speed of the test is representative of actual engine operating characteristics and is not improperly used to influence the parameters under which their engines are certified. In such cases where the definition of maximum test speed results in an engine speed that is unrepresentative of in-use operation, the Executive Officer would have authority to specify a different maximum speed if the manufacturer can show that the alternative is more representative (see 40 CFR, Part 1065.10(c)).

4.5. Durability and Warranty Provisions

The U.S. EPA nonroad rule did not make significant changes to the useful life, warranty, recall testing periods, selective enforcement audit, or emissions related maintenance requirements. Staff therefore proposes to retain its already harmonized provisions for these requirements, with the addition of an updated list of emission related components to more thoroughly reflect the emergence of advanced aftertreatment technologies. However, other provisions have been modified or appended such as in-use testing, defect reporting, replacement engine provisions, separate aftertreatment shipments, and in-use compliance margins. These changes are addressed below. Except as noted, staff proposes to adopt these amended or appended provisions to align with the federal requirements.

4.5.1. In-Use Testing

U.S. EPA does not specify an in-use testing program for Tier 4 engines in its final rulemaking, although it does obligate manufacturers (at least on paper) to certify engines that will meet NTE limits during in-use operation. Both U.S. EPA and ARB are currently developing in-use NTE test programs for off-road diesel engines patterned after a program that is being developed for on-road heavy-duty diesel vehicles. These in-use NTE requirements are expected to provide superior verification of emission performance in the field and to eventually become the in-use testing program for those engines. Staff proposes to harmonize with U.S. EPA regarding NTE certification requirements now and with in-use NTE requirements in the future. However, for the time being at least, California proposes to retain its own in-use compliance and recall program for off-road diesel engines as previously adopted under Articles 2.1 - 2.3, Chapter 2, Title 13, California Code of Regulations. No changes to that program are proposed.

4.5.2. Defect Reporting Requirements

U.S. EPA has amended its defect reporting requirements for Tier 4 engines such that investigations and reports would be triggered by a number of incidences that are proportional to engine power and the number of engines in an engine family, rather than to a fixed percentage as was previously practiced. The new approach should result in fewer overall defect reports being submitted by manufacturers than would otherwise be required under the old defect-reporting requirements because the number of defects triggering the submission requirement rises with the engine family size.

As shown in Table 4.7, an investigation threshold of 10 percent of total production, or 50 engines, whichever is greater, for any single engine family in one model year shall apply to engines less than or equal to 560 kW. In addition, a defect-reporting threshold of two percent of total production or 20 engines will apply, whichever is greater. For engines greater than 560 kW, the same percentage thresholds apply, but the percentage values will be extended down to smaller engine families to reflect their disproportionate contribution to total emissions. For these engines, the absolute thresholds are 25 engines for investigations and 10 or 15 engines for defects.

Further, manufacturers are now obligated to track and report available warranty claims and any other available information from dealers, hotlines, diagnostic reports, or field-service personnel to identify possible defects. Staff proposes to align with U.S. EPA regarding defect reporting requirements, which are presented in more detail in Attachment 1 and Attachment 2.

Table 4.7
Investigation and Defect-Reporting Thresholds for Varying Sizes of Engine Families

Engine Size	Investigation Threshold	Defect-reporting Threshold
≤ 560 kW	Less than 500: 50 500-50,000: 10% 50,000+: 5,000	Less than 1,000: 20 1,000-50,000: 2% 50,000+: 1,000
> 560 kW	Less than 250: 25 250+: 10%	Less than 150: 10 150-750: 15 750+: 2%

4.5.3. Replacement Engines

In California, manufacturers are currently required to submit a report on the number and types of replacement engines they sell at the end of a model year. U.S. EPA added regulatory language to its Tier 4 rule to address concerns that manufacturers could potentially use the replacement-engine provisions to produce large numbers of previous-tier engines. Specifically, U.S. EPA included a statement that manufacturers may not use the replacement-engine exemption to circumvent the regulations. In addition, U.S. EPA plans to use the data-collection provision to ask manufacturers to report the number of engines they sell under the replacement-engine exemption. Staff proposes to incorporate similar language for its replacement engine regulatory requirements. Staff also proposes to extend the reporting requirements to include 2006 and later model year replacement engines. Subsection 5.3 provides additional information regarding this proposal.

4.5.4. Separate Aftertreatment Shipment

U.S. EPA promulgated provisions that allow engine manufacturers to ship engines to equipment manufacturers without aftertreatment devices installed or otherwise included as part of the engine shipment. This allowance would temporarily exempt engines from final assembly in cases where it would be impractical to install aftertreatment devices on the engine before shipment or where shipping the engine with aftertreatment already installed would require it to be disassembled and reinstalled when the engine was placed in the equipment. To ensure that the aftertreatment device is properly installed and used with the engine that it was certified with, the federal rule requires the following:

- Engine manufacturers are required to include the aftertreatment devices in the price of the engine and provide detailed and clear instructions so that the equipment manufacturer can readily install the engine and its components in a configuration covered under the executive order held by the engine manufacturer.

- Engine manufacturers must have a contractual agreement obligating the equipment manufacturer to complete the final assembly into a certified configuration.

- Engine manufacturers must ship any aftertreatment devices directly to the equipment manufacturer or arrange for their shipment from an aftertreatment device supplier.

- Engine manufacturers must tag the engines and keep records.

- Engine manufacturers must obtain annual affidavits from each equipment manufacturer as to the parts and part numbers that the equipment manufacturer installed on each engine.

- Engine manufacturers must conduct a limited number of audits of equipment manufacturers' facilities, procedures, and production records to monitor adherence to the instructions it provided.

Ultimately, the engine manufacturer is responsible for the in-use compliance of the engine as installed. Staff proposes to adopt the federal language for the separate catalyst shipment allowance and associated requirements.

4.5.5. Other Issues

U.S. EPA also made some minor changes to the compliance program. These changes are summarized in Table 4.8 and referenced by section. Staff believes that these changes are straightforward and non-controversial. A detailed explanation can be found in staff's proposed regulations and test procedures for Tier 4 off-road diesel engines in Attachment 1 and Attachment 2 of this report, respectively.

Table 4.8
Regulatory Changes

Issue	Federal Regulatory Provision
Applicability to alcohol-fueled engines	§§1039.101, 1039.107
Prohibited controls	§1039.115
Emission-related maintenance instructions	§1039.125
Engine installation instructions	§1039.130
Engine labels	§§1039.20, 1039.135, 1068.320
Engine family definition	§1039.230
Test engine selection	§1039.235
Deterioration factors	§1039.240
Engines that use noncommercial fuels	§1039.615
Use of good engineering judgment	§1068.5
Separate shipment of aftertreatment	§1068.260
Exemptions	40 CFR 1068 Subpart C
Importing engines	40 CFR 1068 Subpart D
Hearings	40 CFR 1068 Subpart G

4.5.6. Temporary In-Use Compliance Margins

To reduce the risk of non-compliance in the early years of the Tier 4 regulation, staff proposes that in-use standards be "cushioned" by the addition of an error margin to the certification standards. This would align with federal requirements and would provide assurance to off-road engine manufacturers that they will not face recall if they exceed certification standards by a small amount during this transition to cleaner diesel technologies. Although off-road manufacturers are expected to benefit greatly from the experiences gained in the on-road sector, which must meet similar standards several years earlier, designing an engine to meet the diversity of applications in the off-road sector will still be challenging. The allowance would provide relief for a limited number of model years after the Tier 4 off-road standards take effect and would be similar to the provisions for 2007 and later on-road heavy-duty diesel engines.

Table 4.9 below shows the compliance margins being proposed and their applicability.

Table 4.9
Add-On Levels Used in Determining In-Use Standards

Engine Power	Model Years	NOx		PM
		Add-On Level [1] (g/kW-hr)	For Operating Hours	Add-On Level [2] (g/kW-hr)
19 ≤ kW < 56	2013 - 2014	none		0.01
56 ≤ kW < 130	2012 - 2016	0.16	≤ 2000	0.01
		0.25	2001 - 3400	
		0.34	> 3400	
130 ≤ kW ≤ 560	2011 - 2015	0.16	≤ 2000	0.01
		0.25	2001 - 3400	
		0.34	> 3400	
kW > 560	2011 - 2016	0.16	≤ 2000	0.01
		0.25	2001 - 3400	
		0.34	> 3400	

1 Applicable only to those engines certifying to standards or with FELs at or below 2.1 g/kW-hr NOx
2 Applicable only to those engines certifying to standards or with FELs at or below the Tier 4 PM standards (0.02 g/kW-hr for 56 ≤ kW ≤ 560 engines, 0.03 g/kW-hr for 19 ≤ kW < 56 engines and for > 560 kW engines in generator sets, and 0.04 g/kW-hr for all other > 560 hp engines).

4.6. Averaging, Banking, and Trading Program

California's existing regulations for off-road diesel engines include an averaging, banking, and trading (AB&T) program that mirrors the administrative provisions of the federal program. Manufacturers are required to fulfill the same reporting and authorization requirements to ARB regarding engines certified in California as they are to U.S. EPA regarding engines certified nationally. However, the California program does not restrict the generation and use of AB&T credits within State borders, nor does it use a separate calculation for determining credits, but rather allows California credits to be accounted for under the federal program and used accordingly. The current AB&T program is applicable to NMHC, NOx, and PM emissions and the Tier 4 AB&T program would continue to be applicable to these same pollutants. In U.S. EPA's final rule, the basic structure of the existing AB&T program was retained, but a number of changes were made to accommodate the implementation of the new Tier 4 emission standards. These changes to the AB&T program are intended to enhance the ability of engine manufacturers to meet the more stringent Tier 4 standards while limiting the production of very high-emitting engines. The new AB&T program also aims to avoid any unnecessary delays in the transition to new exhaust emission control technologies.

Staff is proposing that the Board adopt the amended federal AB&T program provisions. Since the proposed AB&T program for use in California would be identical in nature to the federal AB&T program, staff is not providing an exhaustive explanation of the specific requirements. Only the major provisions of the program are discussed below. The complete proposed AB&T program provisions can be found in Attachment 2 of this report.

4.6.1. Family Emission Limit (FEL) Caps

The existing AB&T program for off-road diesel engines includes FEL caps, or limits, on the maximum emission levels from credit-using engine families. No engine family may be certified above these FEL caps. These limits provide manufacturers with compliance flexibility while protecting against the introduction of unnecessarily high-emitting engines.

Table 4.10 contains the proposed FEL caps and the effective model year for the FEL caps (along with the associated proposed Tier 4 standards). As proposed, a new transient test will be required for most engines, as well as the current steady-state test. The FEL established by the engine manufacturer will be used as the enforceable limit for the purpose of compliance testing under both test cycles. In addition, under the NTE limits, the FEL times the appropriate multiplier will be used as the enforceable limit for the purpose of such compliance testing.

Table 4.10
FEL Caps for the Tier 4 Standards in the AB&T Program

Power Category	Model Year	NOx or (NMHC+NOx) Standard	NOx or (NMHC+NOx) FEL Cap	PM Standard	PM FEL Cap
		g/kW-hr			
kW < 19	2008 +	(7.5) [1]	(10.5) [1] for < 8 kW (9.5) [1] for ≥ 8 kW	0.40 [2]	0.80
19 ≤ kW < 37	2008 - 2012	(7.5) [1]	(9.5) [1]	0.30	0.60
	2013 +	(4.7) [3]	(7.5) [3]	0.03	0.05 [4]
37 ≤ kW < 56	2008 - 2012 [5]	(4.7) [1]	(7.5) [1]	0.30	0.40
	2013 + [6]			0.03	0.05 [4]
56 ≤ kW < 130	2012 +	0.40	0.80 [7,8,9]	0.02	0.04 [4]
130 ≤ kW ≤ 560	2011 +	0.40	0.80 [7,8,9]	0.02	0.04 [4]
kW > 560	2011 - 2014	3.5	6.2	0.10	0.20
		0.67 [9]			
Generator Sets kW > 560	2015 +	0.67	1.07 [7]	0.03	0.05 [4]
Else kW > 560	2015 +	3.5	6.2	0.04	0.07 [4]

Notes:
1 This is the previous tier combined (NMHC+NOx) standard or FEL cap. These levels are not being revised and are listed here solely for reference.
2 A manufacturer may delay implementation until 2010 and then comply with a PM standard of 0.60 g/kW-hr for air-cooled, hand-startable, direct-injection engines under 8 kW.
3 This is a combined (NMHC+NOx) standard or FEL cap.
4 As described in the following section, a small number of engines are allowed to exceed this FEL cap.
5 The FEL caps do not apply if the manufacturer opts out of the 2008 standards. In such cases, the existing Tier 3 standards and FEL caps continue to apply.
6 The FEL caps apply in model year 2012 if the manufacturer opts out of the 2008 standards.
7 For engines certified as phase-out engines, the NMHC+NOx FEL caps for the Tier 3 standards apply.
8 For engines certified to the alternative NOx standards during the phase-in, the NOx FEL caps shown in Tables 4.12 and 4.13 apply.
9 The 0.67 g/kW-hr NOx standard applies only to engines above 900 kW used in generator sets.

4.6.2. Limited Use of Higher FEL Caps

U.S. EPA is allowing a limited number of engines to have a higher FEL than the caps noted in Table 4.10 under certain circumstances. The FEL cap for such engines would be set based on the level of the standards that applied in the year prior to the new standards and will allow manufacturers to produce a limited number of engines certified to these earlier standards in the Tier 4 timeframe. The allowance to certify up to these higher FEL caps will apply to Tier 4 engines 19 ≤ kW ≤ 560 beginning as early as the 2011 model year, and will apply to engines above 560 kW starting with the 2015 model year. The provisions are intended to provide some limited flexibility for engine manufacturers as they make the transition to the aftertreatment-based Tier 4 standards while ensuring that the vast majority of the engines are converted to the low-emission technologies expected under the Tier 4 program.

Staff is proposing to adopt the same limited use provision for higher FEL caps. Under these provisions, a manufacturer would be allowed to certify up to 40 percent of its engines above the FEL caps shown in Table 4.10 over the first four years the aftertreatment-based Tier 4 standards take effect. This percentage would be calculated as a cumulative total of the percent of engines exceeding these FEL caps in each year over the four years. A maximum of 20 percent would be allowed in any give year. After the fourth year the Tier 4 standards apply, the allowance to certify engines using the higher FEL caps will still be available but for no more than five percent of the engines a manufacturer produces in each power category in a given year.

Table 4.11 presents the model years, percent of engines, and higher FEL caps that will apply under these allowances. Engines certified under these higher FEL caps during the first four years would not be required to perform transient testing or NTE testing, and air-charged engines 56 ≤ kW ≤ 560 would not be required to have closed crankcase controls. However, beginning in the fifth year, when the five percent allowance takes effect, these engines will be considered Tier 4 engines and all other requirements for Tier 4 engines will also apply, including the Tier 4 NMHC standard, transient testing, NTE testing, and closed crankcase controls.

Table 4.11
Allowance for Limited Use of FEL Caps Higher than Tier 4 FEL Caps

Power Category	Model Years	Engines Allowed to have Higher FELs	NOx FEL Cap (g/kW-hr)	PM FEL Cap (g/kW-hr)
19 ≤ kW < 56	2013-2016 [1]	40% [2]	Not applicable	0.30
	2017 + [1]	5%		
56 ≤ kW < 130	2012 - 2015	40% [2]	4.4 [3] for hp < 75	0.40 [4] for hp ≤ 75
	2016 +	5%	3.8 [3] for hp ≥ 75	0.30 [4] for hp ≥ 75
130 ≤ kW ≤ 560	2011 - 2014	40% [2]	3.8 [3]	0.20 [4]
	2015 +	5%		
> 560 kW	2015 - 2018	40% [2,5]	3.5	0.10
	2019 +	5%		

Notes:
1 For manufacturers choosing to opt out of the 2008 model year Tier 4 standards for engines 37 ≤ kW < 56 and instead comply with the Tier 4 standards beginning in 2012, the 40% allowance would apply to model years 2012 through 2015, and the 5% allowance would apply to model year 2016 and thereafter.
2 Compliance with 40% limit is determined by adding the percent of engines that have FELs above the FEL caps shown in Table 4.10 in each of the four years. A manufacturer may not have more than 20% of its engines exceed the FEL caps shown in Table 4.10 in any model year in any power category.
3 The allowance to certify to the higher NOx FEL cap is not applicable during the phase-in period.
4 The higher PM FEL cap is applicable to phase-out engines only during the phase-in period.
5 The limits of 40% or 5% allowed to exceed the NOx FEL cap would apply to engines used in generator sets only. (Engines > 560 kW used in other machines are allowed to have a NOx FEL as high as 6.2 g/kW-hr.) The limits of 40% or 5% allowed to exceed the PM FEL cap would apply to all engines above 560 kW.

4.6.3. Restrictions

Under the Tier 4 program, manufacturers could simultaneously produce two different groups of 56 ≤ kW ≤ 560 engines during the NOx phase-in period. In one group ("phase-out engines"), engines would certify to the applicable Tier 3 NMHC+NOx standard and be subject to the NMHC+NOx AB&T restrictions and allowances previously established for Tier 3. In the other group ("phase-in engines"), engines would certify to the 0.40 g/kW-hr NOx standard, and be subject to the restrictions and allowances under Tier 4. Although engines in the two groups would be certified to different standards, manufacturers would be allowed to transfer credits across these two groups of engines with the following adjustment to the amount of credits generated.

Manufacturers will be able to use credits generated during the phase-out of engines certified to the Tier 3 NMHC+NOx standard to average with engines certified to the 0.40 g/kW-hr NOx standard, but these credits would be subject to a 20 percent devaluation to compensate for the contribution of NMHC in the Tier 3 standard. Thus, each gram of NMHC+NOx credits from the phase-out engines will be worth 0.8 grams of NOx credits in the new AB&T program. The ability to average credits between the two groups of engines will give manufacturers a greater opportunity to gain experience with the low-NOx technologies before they are required to meet the final Tier 4 standards across their full production. The 20 percent discount will also apply, for the same reason, to all NMHC+NOx credits used for averaging purposes with the NOx standards for engines equal to and greater than 56 kW.

Another restriction will be that manufacturers may only use credits generated from other Tier 4 engines or from engines certified to the previously applicable tier of standards, except for engines in the power category 37 ≤ kW < 56. Manufacturers would be allowed to use previously generated Tier 2 credits to demonstrate compliance with the interim Tier 4 standards in 2008 for this power category. Manufacturers that choose instead to comply with the Tier 3 standards in 2008 and only the final Tier 4 standards in 2012 would not be allowed to use Tier 2 credits on Tier 4 engines. Only Tier 3 credits could be used under the standard provisions.

An additional restriction concerns the use of AB&T credits above the 560 kW threshold. Because the standards for Tier 4 engines greater than 560 kW will not be based on the use of PM aftertreatment technology in 2011, or NOx aftertreatment for all engines except generators in 2015, manufacturers will not be allowed to use credits from these engines to demonstrate compliance with engines equal to and below 560 kW.

4.6.4. NOx FEL Caps for Engines Certified to the Alternative NOx Standards

As proposed, a set of alternative NOx standards will be allowed for those manufacturers that need to certify "split" engine families during the phase-in years. These engines will be allowed to participate in the AB&T program. Table 4.12 presents the FEL caps that will apply to engines certified to the alternative NOx standards during the phase-in years.

Table 4.12
NOx FEL Caps for Engines Certified to the Alternative NOx Standards

Power Category	Alternative NOx Standard (g/kW-hr)	NOx FEL Cap (g/kW-hr)
56 ≤ kW < 130 50/50/100 phase-in option	2.3	3.0
56 ≤ kW < 130 25/25/25/100 phase-in option	3.4	4.4 (for 56 ≤ kW < 75) 3.8 (for 75 ≤ kW < 130)
130 ≤ kW ≤ 560	2.0	2.7

Since manufacturers will be allowed to use AB&T for demonstrating compliance with the alternative standards for engines 56 ≤ kW ≤ 560, manufacturers will also be allowed to exceed the FEL caps noted in Table 4.12. These would be included in the 40 percent of engines allowed to exceed the FEL caps over the first four years in which the Tier 4 standards are in effect. Table 4.13 presents the NOx FEL caps that would apply to engines certified under the alternative standards limited by the 40 percent cap over the first four years. For manufacturers certifying under the reduced phase-in option (25/25/25/100 percent), engines may not exceed the FEL cap during the years the alternative standard applies.

Table 4.13
Limited Use NOx FEL Caps Under the Alternative NOx Standards

Power Category	Model Years	NOx FEL Cap (g/kW-hr)
56 ≤ kW < 130 50/50/100 phase-in option	2012-1013	4.4 for kW < 75 3.8 for kW ≥ 75
130 ≤ kW ≤ 560	2011-2013	3.8

All AB&T program provisions are described in greater detail in the proposed regulatory amendments, standards and test procedures in Attachment 1 and Attachment 2 of this report, respectively.

4.7. Equipment Manufacturer Transitional Flexibility Provisions

The sections that follow describe the main components of the U.S. EPA Tier 4 flexibility program, which is similar to the proposed California provisions with the exception of labeling requirements for flexibility engines. California's proposed modifications to the label content are discussed in subsection 4.7.2.9.

4.7.1. Original Flexibility Program

California incorporated U.S. EPA's transitional flexibility program for equipment manufacturers as part of the Tier 2 and Tier 3 amendments to the off-road diesel regulation. This original program is still in the early stages of implementation, but to date the program appears to be working as intended with most equipment manufacturers having used up only a portion of their allowances according to U.S. EPA data.

Engines that do not meet current model year emissions standards, but which have been previously certified, and can be used by equipment manufacturers in their existing product offerings without significant modification, are eligible to be sold new under the provisions of the transitional flexibility program for equipment manufacturers. The flexibility program is intended to provide relief in the event that an engine supplier does not provide enough lead time for an equipment manufacturer to modify the chassis of a particular piece of equipment to accommodate a new engine that may be packaged significantly differently than the previous model. Each equipment manufacturer is permitted to install previously certified engines in equipment adding up to 80 percent of one year's national production spread out over a period of seven years. There are additional allowances for small volume manufacturers and for hardship situations that can extend the percent of production allowances. The provisions of this original program were not intended to be used beyond the 2014 model year.

Equipment manufacturers do not need to apply for permission to use these provisions; however, engine manufacturers must annually submit a list of equipment manufacturers requesting flexibility engines, including engine models and quantities, as part of their certification applications. The program is administered on a national level by U.S. EPA, and California is a special participant entitled to the same reporting, notification, and approval authority as U.S. EPA for engines sold within the State. There are no limits on the number of flexibility engines that can be sold in a particular state so long as the total from all states does not exceed 80 percent of the national sales for one year.

Under this original program, flexibility engines were not specifically required to posses emission labels indicating their participation in the program. Some manufacturers have voluntarily attached labels to their flex engines, but in most cases the information they provide serves little purpose in helping to identify the specifications of the engine.

4.7.2. Tier 4 Flexibility Program

In its Tier 4 rulemaking, U.S. EPA adopted a new round of flexibility provisions for equipment manufacturers to help ease the transition to Tier 4 requirements. Although modeled after the original program, this new provision includes several new and enhanced features to protect against possible abuses and to provide better understanding of the extent to which the flexibility provisions are being used and distributed. No longer allowed is the provision for using uncertified engines in applications below 37 kW. The Tier 4 program also identifies new opportunities for flexibility not provided for in the original proposal. The following subsections summarize the main components of the program, including a supplement to the federal program proposed by staff to ensure a more identifiable and enforceable deployment of flexibility provisions in California through more descriptive engine labels.

4.7.2.1. Percent-of-Production Allowances

The percent of production allowances under the Tier 4 flexibility program remain the same as under the original program. Each equipment manufacturer is allowed to produce flexibility engines over a seven year period in cumulative quantities that sum up to 80 percent of a single year's national production at the end of the seven year period. The allowances would apply separately to each of the five Tier 4 power categories, as defined in subsection 4.2.1.1, with eligibility beginning the year Tier 4 standards first apply to that category. With fewer Tier 4 power categories than under the previous program, more engine families will populate each category resulting in proportionately more flexibility allowances that could potentially be used to extend the lead time for bringing an especially challenging engine family into compliance with the Tier 4 standards. Table 4.14 shows the applicable usage periods for each power category.

Table 4.14
Flexibility Usage Periods

Power Category	Flexibility Program	Flexibility Period Options (Model Years)	Flexibility Standards
< 19 kW	Tier 2/3	2000 - 2006	Pre-controlled
	Tier 4	2008 - 2014	Tier 2 Standards
19 ≤ kW < 37	Tier 2/3	1999 - 2005	Pre-controlled
	Tier 4	2008 - 2014	Tier 2 Standards
	Tier 4 Delayed	2012 -2018	Model Year 2008 Tier 4 Standards
37 ≤ kW < 56	Tier 2/3	2004 - 2010	Tier 1 Standards
	Tier 4	2008 - 2014 [1]	Tier 3 Standards
	Tier 4 Delayed	2012 - 2018	Model Year 2008 Tier 4 Standards
56 ≤ kW < 75	Tier 2/3	2004 - 2010	Tier 1 Standards
	Tier 4	2012 - 2018	Tier 3 Standards
	Tier 4 Delayed	2014 - 2020	Model Year 2012 Tier 4 Standards
75 ≤ kW < 130	Tier 2/3	2003 - 2009	Tier 1 Standards
	Tier 4	2011 - 2017	Tier 3 Standards
	Tier 4 Delayed	2014 - 2020	Model Year 2011 Tier 4 Standards
130 ≤ kW ≤ 560	Tier 2/3	2003 - 2009 [2]	Tier 1 Standards
		2001 - 2007 [3]	
		2002 - 2008 [4]	
	Tier 4	2011 - 2017	Tier 3 Standards
	Tier 4 Delayed	2014 - 2020	Model Year 2011 Tier 4 Standards
> 560 kW	Tier 2/3	2006 - 2012	Tier 1 Standards
	Tier 4	2011 - 2017	Tier 2 Standards
	Tier 4 Delayed	2015 - 2021	Model Year 2011 Tier 4 Standards

Notes:
1 This usage period is only available if interim Tier 4 standards have been met starting in 2008.
2 Applies to the power range 130 ≤ kW < 225.
3 Applies to the power range 225 ≤ kW < 450.
4 Applies to the power range 450 ≤ kW ≤ 560.

Staff estimates that the entire 80 percent flexibility allowance, if used to its maximum extent by all equipment manufacturers, would result in a one percent increase in NOx emissions (2.1 TPD) and about a six percent increase in PM emissions (0.6 TPD), statewide, in 2020. However, the equipment manufacturer flexibility program is a key factor in assuring sufficient lead time to implement the Tier 4 standards as scheduled.

Regarding flexibility allowances, the following engines would not have to be included in the equipment manufacturer's percent of production calculations: 1) diesel off-road equipment using engines built before the effective date of the Tier 4 standards, 2) equipment using engines certified to the previous Tier of standards under any small business provision, 3) all engines certified to the Tier 4 standards, including those engines that produce emissions at higher levels than the standards, but for which an engine manufacturer uses AB&T credits to demonstrate compliance (they would count as Tier 4 complying engines), and 4) engines that meet the Tier 4 PM standards, but are allowed to meet the Tier 3 NMHC+NOx standards during the phase-in period (they would also count as Tier 4 complying engines).

4.7.2.2. Delayed Implementation Option

A provision of the Tier 4 flexibility program allows equipment manufacturers to choose when to begin using flexibility allowances. As shown in Table 4.14 above, the start of the seven year period may generally be delayed to coincide with the commencement of final Tier 4 standards rather than the start of interim standards. Allocations for engines less than 19 kW must be used starting in 2008 since no interim standards are specified for this range of engines.

Although this provision has the potential to delay the promulgation of final Tier 4 standards from a fleet-wide perspective, there would be no loss in long-term emission benefits according to U.S. EPA since the flexibility engines under the delay schedule will have to meet more stringent standards than under the non-delay schedule. Furthermore, more engines with particulate filters will be introduced during the interim standards period to make up for the unused flexibility engines resulting in greater short-term PM benefits than under the non-delay schedule.

4.7.2.3. Small Volume Allowances

The Tier 4 flexibility program provides a choice between the same relief for small volume manufacturers as under the original flexibility program, or an optional provision that would allow fewer allowances per power category, but which could be spread out over multiple engine families.

Under the original proposal, a manufacturer would be allowed to exceed the 80 percent of production total for its flexibility allowances and produce a total of 700 flexibility engines per power category to be used over seven years in no more than 200 engine increments per year per power category. Further, this allowance applies to only one engine family per power category for the duration of the seven years. Since some small volume manufacturers produce several engine families in a year, this relief may not go far enough.

The alternate small volume allowance addresses this situation by permitting a total of 525 flex engines to be produced per power category over a seven year period for use in applications less than 130 kW with no more than 150 flex engines to be used per year per power category. For applications requiring engines greater than or equal to 130 kW, a manufacturer may produce a total of 350 flex engines per power category to be used over seven years in 100 engine increments per year per power category. There is no limit on the number of engine families for which these alternate allowances apply.

4.7.2.4. Technical Hardship Allowances

Staff recommends adoption of a new provision for the Tier 4 flexibility program that would allow equipment manufacturers to petition additional relief on the basis of technical or engineering hardships. Allowances of up to 70 percent in addition to the 80 percent of production allowance (150 percent total) could be granted should the manufacturer be able to justify the need. This new provision would be available to all equipment manufacturers, but would only be applicable when the equipment manufacturer is different from the engine manufacturer. In other words, a vertically integrated manufacturer, i.e., a manufacturer who produces both engines and equipment, could petition additional flexibility allowances, but only if that manufacturer was installing an engine from another manufacturer into one of its own chassis, or vice versa. This provision is most likely to benefit non-integrated equipment manufacturers who may be at a technical disadvantage with respect to manufacturers who produce both engines and equipment, and who can rely on other programs such as AB&T to ease the burden of compliance, if necessary.

This additional flexibility allowance would only be available for the Tier 4 power categories $19 \leq kW \leq 560$ since engines less than 19 kW will not require advanced aftertreatment, and nearly all of the equipment above 560 kW is produced by manufacturers qualifying for small volume allowances described in subsection 4.7.2.3.

Appeals for relief under this provision would need to be made in writing to the Chief of the Mobile Source Operations Division and would be decided on a case-by-case basis. The equipment manufacturer would have the burden of demonstrating the existence of extreme technical or engineering hardship conditions that are beyond its control. It must also demonstrate that it has exercised reasonable precautions to avoid the situation. The exemption could only be granted upon written application setting forth essentially why the previously successful relationship between engine and equipment manufacturer has not provided adequate lead time to address a particular equipment model.

An application for technical hardship exemption would not be granted unless the equipment manufacturer demonstrates that the full 80 percent allowed under the percent of production allowance is reasonably expected to be used up in the first two years of the seven-year flexibility period. Furthermore, any technical hardship allowance would have to be used up within two years after the Tier 4 percent of production allowances start for any power category.

4.7.2.5. Retroactive Use of Flexibilities

The Tier 4 flexibility program allows equipment manufacturers to start using a limited number of their Tier 4 flexibility allowances, including small volume allowances, once the seven-year period of the original flexibility program expires. In this way, a manufacturer could continue exempting a troublesome Tier 3 application, if necessary, beyond the allotted time of the original flexibility program. Equipment manufacturers may use no more than 10 percent of their Tier 4 percent of production allowances, or up to 100 of their Tier 4 small volume allowances, prior to the commencement of the Tier 4 standards for each power category. Flexibility allowances provided under the technical hardship provision cannot be used retroactively.

Using Tier 4 allowances early will reduce the number of allowances available for transitioning to the Tier 4 standards. The amount of equipment utilized early will be subtracted from the total Tier 4 allowances, leaving the remainder to be applied in the normal timeframes. The short-term emissions impact associated with the early use of flexibility allowances in California would likely be negligible.

4.7.2.6. Early Introduction Incentives for Equipment Manufacturers

In addition to the flexibility provisions already mentioned, equipment manufacturers may earn unlimited additional allowances for the early introduction of Tier 4 compliant engines. This incentive provision is generally applicable to engines 19 ≤ kW ≤ 560, and conditionally applicable to engines above 560 kW.

The purpose of this provision is to allow equipment manufacturers an opportunity to share in the benefits for the early introduction of cleaner engines. Previously, only the engine manufacturer was the beneficiary of early introduction credits, but this provision transfers the incentive to the equipment manufacturer so long as that manufacturer meets certain criteria. If the equipment manufacturer fails to meet the requisite conditions, or declines the flexibility allowance, the early introduction benefits fall back to the engine manufacturer (see subsection 4.3 for details).

Equipment manufacturers installing engines complying with the final Tier 4 standards would earn one flexibility allowance for each early Tier 4 compliant engine used in its equipment. Equipment manufacturers installing engines 56 ≤ kW ≤ 560 that comply with the final Tier 4 PM standard and the alternative NOx standard would earn one-half of a flexibility allowance for each early Tier 4 engine used in its equipment. Table 4.15 below illustrates some of the criteria for determining an early Tier 4 engine and the earned flexibility benefits.

Table 4.15
Offset Generating Incentives for Equipment Manufacturers

POWER CATEGORY	QUALIFYING STANDARDS (g/kW-hr)	INSTALLATION DEADLINE	FLEXIBILITY ALLOWANCE
19 ≤ kW < 56	0.03 PM / 4.7 NMHC+NOx	December 31, 2012 [1]	1 for 1
56 ≤ kW ≤ 130	0.02 PM / 0.40 NOx / 0.19 NMHC	December 31, 2011	1 for 1
	0.02 PM / 3.4 NOx / 0.19 NMHC [2]		1 for 2
130 ≤ kW ≤ 560	0.02 PM / 0.40 NOx / 0.19 NMHC	December 31, 2010	1 for 1
	0.02 PM / 2.0 NOx / 0.19 NMHC [2]		1 for 2
GEN > 560	0.03 PM / 0.67 NOx / 0.19 NMHC	December 31, 2014	1 for 1
ELSE > 560	0.04 PM / 3.5 NOx / 0.19 NMHC		

Notes:
1 The installation date for 37 ≤ kW < 56 engines purchased from manufacturers choosing to opt out of the 2008 model year Tier 4 standards and instead comply with the Tier 4 standards beginning in 2012 would be December 31, 2011
2 To be eligible, engines must meet the 0.02 g/kW-hr PM standard and the alternative NOx standards

Benefits would be generated and used on an engine power basis across any of the power categories within the 56 ≤ kW ≤ 560 power range. For example, an early introduction of seventy-five 500 kW engines could be used to offset three-hundred and seventy-five 100 kW engines (75*500 kW = 375*100 kW = 37,500 kW). Other restrictions apply regarding the generation and use of early introduction allowances pertaining to engines greater than 560 kW.

To provide assurance that early Tier 4 compliant engines will be placed into equipment within a reasonable time frame, engine manufacturers are required to certify candidate engines before September 1 of the year before the Tier 4 standards take effect in order for them to be eligible to earn offset generating credits. Similarly, equipment manufacturers must install offset generating engines in equipment before January 1 of the year before the Tier 4 standards take effect to claim credits. Compliance with transient testing requirements, as applicable, NTE limits, and closed crankcase requirements are also required for the early introduction allowances.

4.7.2.7. Economic Hardship Allowance

The Tier 4 flexibility program also contain a safety-valve provision whereby an equipment manufacturer that does not make its own engines could obtain limited additional relief by providing evidence that, despite its best efforts, it cannot meet the implementation dates, even with all the flexibility provisions outlined above. Such a situation might occur if an engine supplier, without a major business interest in the equipment manufacturer, were to change or drop an engine model very late in the implementation process.

Appeals for hardship relief must be made in writing to the Chief of the Mobile Source Operations Division, must be submitted before the earliest date of noncompliance, must include evidence that failure to comply was not the fault of the equipment manufacturer (such as a broken contract), and must include evidence that serious economic hardship to the company would result if relief is not granted. Staff intends to work with the applicant to ensure that all other remedies available under the flexibility provisions are exhausted before granting additional relief, and would limit the period of relief to no more than one year. Manufacturers should be able to complete their strategy on how they will meet a new emission standard within the first year of implementation. Therefore, applications for hardship relief would only be accepted during the first year after the effective date of an applicable new emission standard.

Staff would like to make clear that it expects this provision to be rarely used. Each granting of relief would be treated as a separate agreement with no prior guarantee of success, and with the inclusion of measures, agreed to in writing by the equipment manufacturer, for recovering the lost environmental benefit.

4.7.2.8. Existing Inventory Allowance and Replacement Engines

Staff proposes to extend provisions for equipment manufacturers to continue using engines built prior to the effective date of the Tier 4 standards to further ease the transition to the Tier 4 standards. Federal anti-stockpiling language will be appended to the provision to harmonize with U.S. EPA.

4.7.2.9. Flexibility Engine Labeling Requirements

Staff proposes to adopt more descriptive labeling requirements for engines produced under the equipment manufacturer flexibility provisions described above than those adopted by U.S. EPA in its final Tier 4 rule. This proposal, including the revised label content, is discussed at length in subsection 5.1.1.

4.7.2.10. Import Restrictions

The original flexibility program treats foreign importers as individual equipment manufacturers with respect to the allocation of flexibilities. As a group, these importers could potentially combine for more flexibility allowances than 80 percent of the foreign equipment manufacturer's production for the United States market by each claiming to qualify under the small volume flexibility provision.

To address this potential for abuse, staff proposes to align with federal requirements specifying that only those off-road equipment manufacturers that install engines and have primary responsibility for designing and manufacturing equipment will qualify for the allowances, or other relief, provided under the Tier 4 flexibility provisions. Foreign equipment manufacturers who comply with the provisions discussed in the proposed regulations and test procedures, found in Attachment 1 and Attachment 2 of this report, respectively, will receive the same allowances and other transitional provisions as domestic manufacturers. Importers with little involvement in the manufacturing and assembling of equipment will not receive any allowances or other transitional relief directly, but may import flexibility equipment if it is covered by an allowance or transitional provision associated with a foreign equipment manufacturer. These provisions allow transitional allowances and other provisions to be used by foreign equipment manufacturers in the same way as domestic equipment manufacturers, while limiting the potential for abuse.

Additionally, foreign equipment manufacturers that participate in the flexibility program will be required to post a monetary bond for engines imported into the United States. The bond requirement is necessary for ensuring that foreign equipment manufacturers are subject to the same level of enforcement as domestic equipment manufacturers, and for collecting any judgments assessed against a foreign equipment manufacturer for violations of flexibility provisions.

4.7.2.11. Enforcement and Recordkeeping Requirements

Staff proposes to extend the enforcement and recordkeeping requirements from the original flexibility program such that engine manufacturers would be allowed to continue to build and sell engines to meet the market demand created by the flexibility program, provided they receive written assurance from the equipment manufacturers that such engines are being procured for this purpose. Engine manufacturers who participate in this program would be required to annually provide copies of letters from equipment manufacturers requesting such engines to the Chief of the Mobile Source Operations Division.

Equipment manufacturers choosing to take advantage of the allowances must:

(1) keep records of the production of all pieces of equipment produced for sale (on a national basis) exempted under the allowance provisions for at least two full years after the final year in which allowances are available for each power category;

(2) record the serial and model numbers and dates of production of equipment and installed engines, rated power of each engine, and the calculations used to verify that the allowances have not been exceeded in each power category; and

(3) make these records available to the Executive Officer upon request.

Secondary manufacturers who purchase new equipment, modify or re-label it (i.e., privately branded equipment), and resell it as new equipment would be subject to the regulations in the same way as independent dealers and distributors. The equipment manufacturer flexibility provisions would only apply to the manufacturer who originally installs the engine into the equipment.

All companies/manufacturers that are under the control of a common entity, and that meet the definition of an off-road equipment manufacturer, must be considered together for the purposes of applying exemption allowances. This would provide certain benefits for the purpose of pooling exemptions but would also preclude the abuse of the small volume allowances that would exist if companies could treat each operating unit as a separate equipment manufacturer.

Staff recognizes that the Tier 4 flexibility program may involve a certain amount of complexity and administrative burden; however, this program is entirely voluntary and manufacturers not wishing to participate do not have to do so.

4.7.2.12. Notification and Reporting Requirements

As in the federal rule, staff proposes that equipment manufacturers wishing to participate in the Tier 4 flexibility program be required to notify the Chief of the Mobile Source Operations Division prior to using Tier 4 allowances. No such requirement exists in the original flexibility program. Equipment manufacturers would be required to submit their written notification before the first calendar year in which they intend to use the transitional provisions. Adoption of this notification requirement would help to ensure that flexibility allowances are used appropriately in California.

The specific information to be provided to the Chief of the Mobile Source Operations Division would be:

(1) the equipment manufacturer's name, address, and contact person's name, phone number;

(2) the allowance program that the equipment manufacturer intends to use by power category;

(3) the calendar years in which the equipment manufacturer intends to use the exception;

(4) an estimation of the number of engines to be exempted under the flexibility provisions by power category;

(5) the name and address of the engine manufacturer from whom the equipment manufacturer intends to obtain exempted engines; and

(6) identification of the equipment manufacturer's prior use of Tier 2 and Tier 3 flexibility provisions.

Staff also proposes to adopt new reporting requirements such that equipment manufacturers participating in the flexibility program would be required to submit an annual accounting to the Chief of the Mobile Source Operations Division showing their calculated number of maximum flexibility allowances by power category based on sales from the previous year. Equipment manufacturers would also have to report the number of flexibilities used and the percent of production these allowances represent for the current year. Each report would include a cumulative calculation (both total number and, if appropriate, the percent of production) for all years the equipment manufacturer is using the flexibility provisions for each of the Tier 4 power categories. This proposal is consistent with the reporting requirements of the federal Tier 4 flexibility program.

4.8. Miscellaneous

Staff proposes to amend the preemption reference in Title 13 CCR, 2420(a)(1) to clarify that new locomotive engines are not subject to California's off-road diesel regulation. Title 13 CCR, 2420(a)(1) currently references Section 209(e)(1)(A) of the Federal Clean Air Act (42 U.S.C. 7543(e)(1)(A)) when identifying preempt engines and equipment that are outside the scope of applicability of the regulation. However, the preemption for new locomotive engines is found in Section 209(e)(1)(B) of the Federal Clean Air Act; therefore, the current preemption reference could be interpreted not to include new locomotive engines, which is not the intent. Staff proposes to change the reference to "Section 209(e)(1) of the Federal Clean Air Act (42 U.S.C. 7543(e)(1))," which would then encompass all preemption engines as being outside the scope of the regulation.

Staff also proposes to extend the voluntary provisions for designating Blue Sky Series engines for Tier 1, Tier 2, and Tier 3 engines. Current requirements do not extend beyond the 2004 model year. This change would harmonize with current U.S. EPA requirements.

5. DIFFERENCES BETWEEN CALIFORNIA AND FEDERAL REGULATIONS

Staff has endeavored to harmonize California's off-road diesel proposal with the provisions of U.S. EPA's Clean Air Nonroad Diesel Final Rule (40 CFR, Part 1039 and incorporated Parts). To this end, ARB staff recommends that the Board adopt the majority of provisions outlined in the federal rule, including all emission standards and implementation schedules for California's non-preempt diesel engines. However, staff's proposal differs from the federal program in some relatively minor, but important ways that are necessary to protect the air quality benefits of the Mobile Source program. These differences are primarily documentary in nature and do not present any technical obstacles for the off-road industry to overcome. Staff is also proposing to retain its autonomous In-Use Compliance and Recall Program previously adopted by the Board in 2000 as part of the regulatory amendments for 2000 and later compression-ignition engines.

5.1. Flexibility Program for Equipment Manufacturers

Although staff is in conceptual agreement with the provisions of the federal Tier 4 flexibility program for equipment manufacturers, additional safeguards are needed to ensure a more identifiable and enforceable deployment of flexibility provisions in California.

5.1.1. Flexibility Engine Labeling

U.S. EPA recognized the need for labeling flexibility engines in its Tier 4 rule, and now requires both the engine and equipment manufacturer to affix labels indicating that these engines are to be used only according to flexibility provisions under penalty of law. Labeling was not specifically required under the original flexibility program adopted as part of the Tier 2/3 regulation. Although U.S. EPA's new labeling requirement is a step in the right direction, it does not go far enough in describing emissions performance to provide verification of whether or not the flexibility engine has been correctly placed in service. The table below is provided to show an example of why the U.S. EPA labeling requirement, without an engine family designation, is inadequate. The table lists the certification level that flexibility engines must meet depending on when the manufacturer first begins using flexibility allowances. According to the table, Tier 3 engines could be used as flexibility allowances in the 19 ≤ kW < 56 power category from 2008-2014, but interim Tier 4 engines must be used if the allowances are delayed until 2012-2018. Consequently, there is a three year overlap from 2012-2014 during which the certification level of the flexibility engine could not be directly ascertained from the U.S. EPA emissions label. The other power categories are subject to the same or similar type of confusion.

Table 5.1
Tier 4 Flexibility Usage Periods

Power Category	Flexibility Period Options (Model Years)	Flexibility Standards
< 19 kW	2008 – 2014	Tier 2 Standards
19 ≤ kW < 56	2008 - 2014 [1]	Tier 3 Standards [2]
	2012 – 2018	Model Year 2008 Tier 4 Standards
56 ≤ kW < 130	2012 – 2018	Tier 3 Standards
	2014 – 2020	Model Year 2012 Tier 4 Standards
130 ≤ kW ≤ 560	2011 – 2017	Tier 3 Standards
	2014 – 2020	Model Year 2011 Tier 4 Standards
> 560 kW	2011 – 2017	Tier 2 Standards
	2015 – 2021	Model Year 2011 Tier 4 Standards

Notes:
1 This usage period is available for allowances greater than or equal to 37kW only if interim Tier 4 standards have been met starting in 2008.
2 Flexibility allowances under 37kW may contain engines certified to the Tier 2 standards.

In practical terms, this means that ARB field investigators would not be able to determine the appropriateness of these flexibility engines upon inspection. Although it may be possible to verify the emissions performance of the engines post inspection by contacting the engine manufacturer directly, this diverts resources and hinders the field inspector's ability to identify violations and enforce the regulation in a timely manner. Furthermore, should the flexibility engine ever need to be rebuilt or repaired, U.S. EPA's label would not be able to provide an adequate reference for determining that the engine had been rebuilt to at-least the original emissions specifications as required, or that correct replacement parts had been used to repair an emissions related malfunction.

Staff is aware that some manufacturers are voluntarily labeling their flexibility engines, and other manufacturers have been requested by staff to begin labeling or to provide more descriptive labeling content. However, a strictly voluntary program does not provide the assurance of compliance and may not result in a standardized application of the remedy. Therefore, staff proposes to amend existing regulations such that the label to be attached by the engine manufacturer must include the engine family name to which the flexibility engine was originally certified. In this way, ARB field investigators would be able to immediately identify a flexibility engine and know the standards to which it was certified. This knowledge would aid the investigator in determining that all required emission control equipment was present on the engine, and that it had not been tampered with. The label would also be used to identify whether or not the engine is a candidate for a future retrofit or re-power control measure in California. Although this amendment applies to the engine manufacturer only, both engine and equipment manufacturers would be held responsible for ensuring that the flexibility engine possesses the correct label at the time of sale.

Staff also proposes that this amendment take effect earlier than required under the federal rule, and apply to Tier 2/3 engines used as flexibility allowances beginning in 2006. Under this proposal, one of two labels with modified statements of compliance would be affixed to the engine to differentiate between participation in the original Tier 2/3 flexibility program or the new Tier 4 flexibility program. The proposed statement of compliance for these labels would read as follows:

Engines Allowed Under the New Tier 4 Flexibility Program
"THIS ENGINE BELONGS TO FAMILY _____._____ AND MEETS ARB EMISSION STANDARDS UNDER 13 CCR 2423(d). SELLING OR INSTALLING THIS ENGINE FOR ANY PURPOSE OTHER THAN FOR THE EQUIPMENT FLEXIBILITY PROVISIONS CITED MAY BE A VIOLATION OF STATE LAWS SUBJECT TO CIVIL PENALTY."

Uncertified Engines Less Than 37 kW Allowed Under the Tier 2/3 Flexibility Program
"THIS ENGINE QUALIFIES FOR USE IN EQUIPMENT RATED BELOW 37 KW AND IS EXEMPT FROM CURRENT MODEL YEAR EMISSION STANDARDS UNDER THE ARB EQUIPMENT FLEXIBILITY PROVISIONS IN 13 CCR 2423(d). SELLING OR INSTALLING THIS ENGINE FOR ANY PURPOSE OTHER THAN FOR THE EQUIPMENT FLEXIBILITY PROVISIONS CITED MAY BE A VIOLATION OF STATE LAW SUBJECT TO CIVIL PENALTY."

The revised statement of compliance does not preclude the referencing of similar federal requirements that would be satisfied simultaneously by meeting the provisions of Section 2423(d). Furthermore, the Executive Officer may, upon request, approve alternate labeling specifications provided that they meet the intent of this requirement.

5.1.2. Executive Order Clarification

Staff proposes to amend the existing regulations to more clearly indicate that non-preempt engines certified under the flexibility provisions for equipment manufacturers must be covered by an Executive Order. The Executive Order need not be current for the year in which the engine is used as a flexibility allowance, but may have been issued previously so long as the engine was certified to the appropriate standards required by the flexibility provision.

Title 13 CCR, 2420(a)(3) defines the scope of applicability for needing an Executive Order as "Every new off-road compression-ignition engine that is manufactured for sale, sold, offered for sale, ... into California ... subject to any of the standards prescribed in this article [Article 4] ..."

ARB interprets this language to include engines sold under the transitional flexibility provisions for equipment manufacturers. In its amendment, staff intends to clarify that

Executive Orders are required for all engines, including flexibility engines. Title 13, CCR 2423(d)(1)(A) currently reads as follows:

> "Equipment rated at or above 37kW. For off-road equipment and vehicles with engines rated at or above 37kW, a manufacturer may take any of the actions identified in the 2000 and Later Test Procedures (Section 89.1003(a)(1)) for a portion of its California-directed production volume of such equipment and vehicles during the seven years immediately following the date on which Tier 2 engine standards first apply to engines used in such equipment and vehicles, provided that the seven-year sum of the U.S.-directed portions in each year, as expressed as a percentage for each year, does not exceed 80, and provided that all such equipment and vehicles or equipment contain only Tier 1 engines;"

The reference to 40 CFR, Part 89.1003(a)(1) provides a list of otherwise prohibited actions that may be applied to flexibility engines. It reads:

> "The following acts and the causing thereof are prohibited:

(i) In the case of a manufacturer of new nonroad engines, vehicles, or equipment for distribution in commerce, the sale, or the offering for sale, or the introduction, or delivery for introduction, into commerce, of any new nonroad engine manufactured after the applicable effective date under this part, or any nonroad vehicle or equipment containing such engine, unless such engine is covered by a certificate of conformity issued (and in effect) under regulations found in this part.

(ii) In the case of any person, except as provided in subpart G of this part, the importation into the United States of any new nonroad engine manufactured after the applicable effective date under this part, or any nonroad vehicle or equipment containing such engine, unless such engine is covered by a certificate of conformity issued (and in effect) under regulations found in this part."

At first glance, this may appear to exempt flexibility engines from requiring an Executive Order[18]; however, this would be inconsistent with language in the same section that requires "... all [flexibility] equipment and vehicles or equipment [to] contain only Tier 1 engines;" In order to qualify as a Tier 1 engine, the engine must have been previously certified to the Tier 1 standard and thereby covered by an Executive Order. The purpose, therefore, of 40 CFR, Part 89.1003(a)(1) is not to exempt flexibility engines from needing an Executive Order, but to exempt them from needing an Executive Order current to the year in which the flexibility engines are used.

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[18] A "certificate of conformity" is synonymous to an Executive Order for the purpose of this reference (Section 89.2, California Exhaust Emission Standards and Test Procedures for New 2000 and Later Off-Road Compression-Ignition Engines, December 28, 2000).

U.S. EPA has attempted to clarify this provision in its final rule by referencing a new section, 40 CFR, Part 1068.101(a)(1), which essentially rewords the prohibited actions language in 40 CFR, Part 89.1003(a)(1) by adding the qualifying statement that "... engines must have a valid certificate of conformity for its model year ..." It therefore follows that flexibility engines would be exempt from this otherwise prohibited action, which means that flexibility engines do not have to be covered by a certificate of conformity/executive order for "... its model year ..." or in other words, for the model year in which it is sold. The full text of 40 CFR, Part 1068.101(a)(1) is copied below:

> "You may not sell, offer for sale, or introduce or deliver into commerce in the United States or import into the United States any new engine or equipment after emission standards take effect for that engine or equipment, unless it has a valid certificate of conformity for its model year and the required label or tag. You also may not take any of the actions listed in the previous sentence with respect to any equipment containing an engine subject to this part's provisions, unless the engine has a valid certificate of conformity for its model year and the required engine label or tag. This requirement also covers new engines you produce to replace an older engine in a piece of equipment, unless the engine qualifies for the replacement-engine exemption in Sec. 1068.240. We may assess a civil penalty up to $31,500 for each engine in violation."

Staff believes this is an awkward means of clarifying the requirement that flexibility engines must have been previously certified and covered by a Certificate of Conformity, or an Executive Order, and might still be subject to misinterpretation. Therefore, staff instead proposes to remove all references to 40 CFR, Part 89.1003(a)(1) in the California regulations pertaining to flexibility allowances and to create a subsection stating plainly that:

> "Engines used in accordance with the transitional flexibility provisions for equipment manufacturers described in section 2423(d) must be covered by an Executive Order. The Executive Order need not be current for the year in which the engine is claimed as a flexibility allowance, but may have been issued previously so long as the engine was certified to the appropriate standards required by the flexibility provision."

An Executive Order is needed in addition to, or in lieu of, a federal Certificate of Conformity so that ARB has the authority to enforce non-preempt engines found to be in violation of the off-road diesel regulations. Engines used as flexibility allowances prior to the adoption of this amendment would not be subject to enforcement actions retroactively.

5.2. Rebuild Labeling Prohibition and Supplemental Label Requirement

Staff proposes to adopt language prohibiting the removal or defacing of the original emissions label from non-preempt off-road diesel engines that have been rebuilt or remanufactured. The rebuilder or remanufacturer must take care to protect the original label from the effects of sandblasting, acid dipping, or any other restorative process. A supplemental label must be affixed to the rebuilt or remanufactured engine indicating the date of renovation and other pertinent information, but must not obscure in any way the visibility of the original label or imply that the rebuilt or remanufactured engine is "new" or that it belongs to an engine family other than the one to which it was originally certified. Retaining the original label offers proof, and a means to verify, that the engine was "rebuilt to a certified configuration of the same or later model year as the original engine" as required by 40 CFR, Part 89.130(c) and 40 CFR, Part 1068.120(f). Furthermore, the original label will be used to identify whether or not the rebuilt or remanufactured engine can be used in a future retrofit or re-power control measure. ARB investigators have discovered that the replacement of engine labels is a common practice among some engine re-builders.

Notwithstanding, the original label on any engine that is remanufactured to "like-new" condition and which is recertified to current-year emission requirements including all durability and warranty provisions, must be removed by the remanufacturer and replaced with one identifying the engine as belonging to a family meeting current-year emission requirements. A supplemental label may be affixed by the remanufacturer, if desired, but must adhere to the requirements for supplemental labels described in the paragraph above.

5.3. Extension of Replacement Engine Reporting Requirements

When replacing a California certified off-road diesel engine, equipment manufacturers are required to use the cleanest engines whenever feasible. However, if newer, cleaner engines do not "fit" into older equipment, the engine manufacturer may continue to produce replacement engines that are identical in configuration in all material respects to the original engine being replaced provided that 1) the engine manufacturer has ascertained that no certified lower-emitting engine is available, 2) the replacement engine is properly labeled as a replacement engine, and 3) the actual number of replacement engines produced for California is reported annually.

Currently, manufacturers are only required to satisfy the replacement engine reporting requirements, including an inventory of engines sold and proof that every effort was made to find a cleaner replacement, through the 2004 model year. Staff proposes to extend the reporting requirements for replacement engines to 2005 and subsequent model years.

5.4. In-Use Compliance/Recall Program

U.S. EPA has recall procedures in place to ensure that certified engines meet the emission standards over the useful life of the engine. California incorporated off-road language into its own in-use compliance and recall program under Articles 2.1 - 2.3, Chapter 2, Title 13, California Code of Regulations in 2000. Staff is proposing no changes to its In-Use Compliance/Recall Program. The program will continue to be applicable to all non-preempt off-road diesel engines in California, including those meeting the Tier 4 standards and those used as flexibility allowances. California reserves the right to investigate and recall engines found to be in violation of the regulations apart from U.S. EPA, if necessary.

The California program for in-use compliance/recall should not cause manufacturers any significant burden. The program procedures would only be performed when needed (i.e., when information might indicate a problem with meeting the emission standards). This proposal will allow the ARB to continue to ensure that engines are meeting the emission standards, regardless of any subsequent changes to the federal programs.

6. TECHNOLOGY AND FEASIBILITY

This section discusses the most likely technologies to be employed in meeting the Tier 4 standards, and the feasibility of implementing them in the timeframes proposed.

6.1. Federal Feasibility Review

The technological feasibility of the proposed standards has already been thoroughly evaluated by U.S. EPA as part of their Regulatory Impact Analysis. Staff concurs with U.S. EPA's conclusion that given the timing of the emissions standards proposed in the federal final rule, and this report, and the availability and continuing development of emission control technologies, off-road diesel engines can be designed to meet the proposed Tier 4 standards in the lead time provided.

The thoroughness of the U.S. EPA analysis, and staff's concurrence with that analysis, render redundant any exhaustive discussion of technological feasibility in this report. This Section will, therefore, briefly discuss some of the likely control strategies. Much of the information contained herein is derived from Chapter 4 of U.S. EPA's Regulatory Impact Analysis: Technologies and Test Procedures for Low-Emission Engines.

6.2. Summary of Technologies

In general, manufacturers of off-road diesel engines are expected to use emission controls similar to those already in use by the manufacturers of on-road diesel engines, although effectiveness could vary due to the different operating conditions experienced by off-road engines and the wide variety of applications.

Arguably the most challenging consideration in transferring advanced emission control technologies to the off-road will be exhaust temperature. Exhaust temperature is critical for the regeneration of catalyzed exhaust emission control devices. The following abridgment will focus primarily on PM and NOx aftertreatment, which staff believes to be the most likely means of achieving final Tier 4 standards. However, some of the technologies for meeting interim standards will also be discussed. For the most part, staff is summarizing the feasibility studies already performed by U.S. EPA and documented in its Regulatory Impact Analysis pertaining to the final nonroad diesel regulation. To complement this, staff also provides the results of an ARB / U.S. EPA funded test program by Southwest Research Institute that evaluated the performance of particulate filters and ultra low-sulfur diesel fuel on three diesel engines.

6.2.1. Exhaust Temperature Management

The primary concern for catalyst-based emission control technologies is exhaust temperature. In general, exhaust temperature increases with engine power and can vary dramatically as engine power demands vary. For catalyzed diesel particulate filters (CDPFs), exhaust temperature determines the rate of filter regeneration, and if too low, causes a need for supplemental means to ensure proper filter regeneration. A CDPF controls PM emissions under all conditions and can function properly even when exhaust temperatures are low for an extended time and the regeneration rate is lower than the soot accumulation rate, provided that occasionally exhaust temperatures, and the soot regeneration rate, are increased enough to regenerate the CDPF. Similarly, there is a minimum temperature (e.g., 200° Celsius) for NOx adsorbers below which regeneration is not readily feasible and a maximum temperature (e.g., 500° Celsius) above which NOx adsorbers are unable to effectively store NOx. Therefore, there is a need to match diesel exhaust temperatures to conditions for effective catalyst operation under the various operating conditions of off-road engines.

U.S. EPA has conducted an analysis of various operating cycles and various engine power density levels to better understand the matching of off-road engine exhaust temperatures, catalyst installation locations, and catalyst technologies. This study, documented in U.S. EPA's Regulatory Impact Analysis, shows that for many engine power density levels and equipment operating cycles, exhaust temperatures are quite well matched to catalyst temperature window characteristics. In particular, the nonroad transient composite test cycle was shown to be well matched to the NOx adsorber characteristics with estimated performance in excess of 90 percent for a turbocharged diesel engine tested under a range of power density levels. The analysis also indicated that the exhaust temperatures experienced over the nonroad transient test cycle are better matched to the NOx adsorber catalyst temperature window than the temperatures that would be expected over the highway Federal Test Procedure (FTP) test cycle.

Still, some off-road engines may experience in-use conditions requiring the use of temperature management strategies (e.g., active regeneration) to effectively use the NOx adsorber and CDPF systems. Accordingly, the cost analysis estimates for meeting Tier 4 standards assumes that all off-road engines complying with a PM standard of 0.04 g/kW-hr or lower will have an active means to control temperature, although some applications likely may not need one. Based on U.S. EPA's analyses, staff does not believe that there are any off-road engine applications above 19 kW for which active temperature management will not work.

6.2.2. PM Control Technologies

The following is a summary of technologies expected to be used to meet the Tier 4 PM standards.

6.2.2.1. In-Cylinder Control

The soot portion of PM emissions can be reduced by increasing the availability of oxygen within the cylinder for soot oxidation during combustion. Oxygen can be made more available by either increasing the oxygen content in-cylinder or by improving the mixing of the fuel and oxygen in-cylinder. Several current technologies can influence oxygen content and in-cylinder mixing, including improved fuel-injection systems, air management systems, and combustion system designs. In addition to enabling compliance with required emission standards, the application of better combustion system technologies across the broad range of off-road applications offers an opportunity for significant reductions in engine-out PM emissions and possibly for reductions in fuel consumption.

6.2.2.2. Diesel Oxidation Catalysts

Diesel oxidation catalysts (DOCs) are the most common form of diesel aftertreatment technology today and have been used for compliance with the PM standards for some on-road diesel engines since the early 1990s. DOCs reduce diesel PM by oxidizing a small fraction of the soot emissions and a significant portion of the SOF emissions. In general, the DOC's effectiveness to reduce PM emissions is normally limited to approximately 30 percent because the SOF portion of diesel PM for modern diesel engines is typically less than 30 percent, and because the DOC typically increases sulfate emissions, reducing the overall effectiveness of the catalyst. Limiting fuel sulfur levels to 15 ppmw allows DOCs to be designed for maximum effectiveness (nearly 100% control of SOF with highly active catalyst technologies) since their control effectiveness is not reduced by sulfate formation. The sulfate formation rate is still high, but because the sulfur level in the fuel is low, the resulting PM emissions are well controlled.

DOC effectiveness to control NMHC and CO emissions are directly related to the "activity" of the catalyst material used in the DOC washcoat. Highly active DOCs can reduce NMHC emissions by 97 percent while low activity catalysts realize approximately 50 percent NMHC control. Today, highly active DOC formulations cannot be used for NMHC and CO control because the sulfur in current diesel fuel leads to unacceptable sulfate PM emissions. However, with the low-sulfur diesel fuel that will be available under this program, DOCs will be able to provide substantial control of these pollutants. The use of DOCs is likely to factor in heavily as part of an overall compliance strategy for engines meeting the interim PM standards in 2008. For those engines, DOCs would also provide significant reductions in CO and NMHC. Oxidation catalyst technologies (i.e., DOCs and CDPFs) generally will also be an effective tool for ensuring compliance with the NTE provisions of the Tier 4 program. In addition, test data show that toxics such as polycyclic aromatic hydrocarbons (PAHs) can be reduced by more than 80 percent with a DOC (RIA4 2004).

6.2.2.3. Diesel Particulate Filters

CDPFs have been shown to be very effective at reducing PM mass by dramatically reducing the soot and SOF portions of diesel PM. In addition, recent data show that they are also very effective at reducing the overall *number* of emitted particles when operated on ultra low-sulfur fuel (RIA4 2004). CDPFs have been shown to reduced particle count by over 95 percent, including some of the smallest measurable particles (< 50 nanometers). The combination of CDPFs with ultra low-sulfur fuel is expected to result in very large reductions in both PM mass (> 90 percent) and the number of ultra-fine particles. CDPFs are also capable of decreasing NMHC in excess of 90 percent.

Engine operating conditions have little impact on the particulate trapping efficiency of CDPFs, so 90 percent and greater efficiencies for elemental carbon particulate matter will apply to engine operation within the NTE zone and over the regulated transient cycles. These efficiencies will also be realized over steady-state test conditions such as the International Standards Organization C1 schedule. However, CDPF performance is dependent on the filter's ability to regenerate accumulated particulates and on sulfate formation. Sulfate formation will reduce the measured removal rate of particulates at some NTE operating conditions and some steady-state modes, even when using 15 ppmw sulfur diesel fuel. Additionally, a minimum operating temperature must be achieved for CDPF regeneration to occur. Exhaust temperature can vary significantly depending on operation and duty-cycle, and may not be sufficient to initiate regeneration for some off-road applications using a passive system. For these applications, an active diesel particulate filter system (i.e., one that requires external heat) may be necessary to ensure that temperature remains high enough, long enough to allow regeneration to occur. Although not typically an issue with new engines, excessive oil consumption can also reduce the efficiency of passive CDPFs due to the high content of sulfur in the lubricating oil. Active particulate filters may be needed to ensure regeneration for these engines.

Recent testing by the Southwest Research Institute (SwRI), in San Antonio, Texas, under joint contract with ARB and U.S. EPA, clearly demonstrated that the proposed Tier 4 PM standards are achievable on off-road diesel engines using passive particulate filters and ultra low-sulfur diesel fuel. The engines evaluated were a 1999 Caterpillar 3408 rated at 358 kW, a 1999 Cummins QSL9 rated at 242 kW, and a prototype development engine based on a 1995 Deere 4045T rated at 81 kW. All three engines were tested on a number of transient and steady-state test cycles, including the nonroad transient composite test cycle, with and without particulate filters. Emissions performance with passive filters was typically well below the 0.02 g/kW-hr proposed PM standard. Table 6.1, below, shows the PM results for each engine as evaluated on the nonroad transient composite and the C1 steady-state test cycles. Particulate filters were supplied by DCL, Inc., and Engine Control Systems, Inc., with substrates from Corning and Delphi (SwRI 2004). Based on the results of this study, staff believes that engine manufacturers should have great success in employing CDPF technology as proposed.

Table 6.1
Catalyzed Diesel Particulate Filter Testing at SwRI
Transient and Steady-State PM Results
Caterpillar, Deere Development Engine, and Cummins

Engine	Test Cycle [1]	PM (g/kW-hr)		Reduction [2]
		Engine Out	w/ Filter	
CAT 3408	Transient	0.343	0.012	96 %
	Steady-State	0.170	0.015	91 %
DDE 4045P	Transient	0.192	0.017	91 %
	Steady-State	0.173	0.013	92 %
CUM QSL9	Transient	0.208	0.007	97 %
	Steady-State	0.159	0.011	93 %

Note:
1 Transient testing was performed on the U.S. EPA nonroad transient composite test cycle and steady-state testing was performed on the 8-mode C1 test cycle.
2 The sulfur content of the fuel used in these evaluations was measured by SwRI to be 12 parts per million by weight

6.2.3. NOx Control Technologies

The rate of NOx formation in the combustion chamber is exponentially related to peak cylinder temperatures and is also strongly related to nitrogen and oxygen content. NOx control technologies for diesel engines have traditionally focused on reducing emissions by lowering the peak cylinder temperatures and by decreasing the oxygen content of the intake air.

6.2.3.1. In-Cylinder NOx Control

Fuel injection timing retard, fuel-injection rate control, charge air cooling, exhaust gas recirculation (EGR) and cooled EGR are some forms of in-cylinder NOx control. The use of these technologies can result in significant reductions in NOx emissions, but are limited due to practical and physical constraints of heterogeneous diesel combustion.

U.S. EPA's Highway Diesel Progress Review Report investigated the extent to which in-cylinder NOx control technologies had advanced. The report noted that a number of diesel engine manufacturers introduced cooled EGR systems on their heavy-duty diesel engines in 2002 that met the 2004 emission standards for NMHC+NOx (3.4 g/kW-hr). Engine manufacturers have demonstrated that these systems can be further refined to allow NOx emissions compliant with the 2007 NOx averaging level of approximately 1.6 g/kW-hr. To reduce NOx emissions below 1.6 g/kW-hr, engine manufacturers will likely need to increase EGR flow rates. Although there are challenges to applying similar technologies to off-road diesel engines (most notably the lack of ram-air for cooling), fundamental NOx control technologies are applicable to all diesel engines. The continuing development of heavy-duty on-road diesel technologies for in-cylinder NOx control, such as cooled EGR and Caterpillar's Advanced Combustion and Emission Reduction Technology (ACERT), is a good indication that off-road diesel engines 19 ≤ kW ≤ 560, and non-generator off-road engines greater than 560 kW, will be able to comply with their respective Tier 4 standards.

A new form of diesel engine combustion, commonly referred to as homogenous diesel combustion, or premixed diesel combustion, can give very low NOx emissions over a limited range of diesel engine operation. In the regions of diesel engine operation over which this combustion technology is feasible (light-load conditions), NOx emissions can be reduced enough to comply with the 0.4 g/kW-hr NOx emission standard. Some engine manufacturers are already producing engines that utilize this technology over a narrow range of engine operation. Unfortunately, it is not currently feasible to apply this technology over the full range of diesel engine operation.

6.2.3.2. Lean-NOx Catalyst

Passive and active lean-NOx catalyst systems have been under development for some time. However, neither system typically yields more than a 30 percent reduction in NOx. The active lean-NOx catalyst injects a reductant[19] that serves to reduce NOx to nitrogen and oxygen (diesel fuel is typically used as the reductant). The reductant is introduced upstream of the catalyst and reduces oxygen locally allowing NOx emissions to be reduced by the catalyst.

The lean-NOx catalyst washcoat incorporates a zeolite[20] technology that acts to adsorb hydrocarbons from the exhaust stream. Once adsorbed on the zeolite, the hydrocarbons will oxidize and create an oxygen-poor region that is more conducive to reducing NOx. To promote hydrocarbon oxidation at lower temperatures, the washcoat can incorporate platinum or other precious metals. The platinum also helps to eliminate the emission of unburned hydrocarbons that can occur if too much reductant is injected, referred to as "hydrocarbon slip." With platinum, the NOx conversion can take place at the low exhaust temperatures that are typical of diesel engines. However, the presence of the precious metals can lead to production of sulfate PM.

Although active lean-NOx catalysts have been shown to provide up to 30 percent NOx reduction under limited steady-state conditions, this NOx control is achieved with a fuel

[19] A substance capable of bringing about the chemical reduction of another substance as it itself is oxidized.

[20] Zeolites are three-dimensional, micro-porous, crystalline solids with well-defined structures used to adsorb a variety of materials including volatile organic chemicals, isomers, and gases.

economy penalty upwards of seven percent due to the need to inject fuel into the exhaust stream. NOx reductions over the transient on-road FTP cycle are on the order of twelve percent due to excursions outside the optimum NOx reduction efficiency temperature range for these devices. Consequently, the active lean-NOx catalyst does not appear to be capable of enabling the significantly lower NOx emissions required by the Tier 4 NOx standards.

Passive lean-NOx catalysts use no reductant injection. The passive lean-NOx catalyst is therefore even more limited in its ability to reduce NOx because the exhaust gases normally contain very few hydrocarbons. For that reason, current passive lean-NOx catalysts are only capable of ten percent steady-state NOx reductions. Neither of the lean-NOx catalyst technologies described can provide the significant NOx reductions necessary to meet the Tier 4 standards.

6.2.3.3. NOx Adsorber

The NOx adsorber is an extension of the three-way catalyst technology developed for gasoline powered vehicles more than twenty years ago. It enhances the three-way catalyst function through the addition of storage materials on the catalyst surface that can adsorb NOx under oxygen-rich conditions. NOx adsorbers work to control NOx emissions by storing NOx on the surface of the catalyst during the lean engine operation typical of diesel engines. The adsorber then undergoes subsequent brief rich regeneration events through the injection of a reductant (typically fuel) where the NOx is released and reduced across precious-metal catalysts. The NOx storage period can be as short as 15 seconds, or as along as 10 minutes, depending on engine-out NOx emission rates and exhaust temperature. This method for NOx control has been shown to be highly effective when applied to diesel engines, but has some technical challenges associated with it. Primary among these is sulfur poisoning of the catalyst.

NOx adsorber performance can be enhanced by incorporating a CDPF into the system. Partial oxidation of the secondary fuel reductant injected into the exhaust during regeneration could lead to soot formation. Using a CDPF upstream of the NOx adsorber, but downstream of the secondary fuel injection, allows partial oxidation of the fuel hydrocarbons to occur on the surface of the CDPF. The CDPF efficiently captures any soot formed during partial oxidation of the injected fuel, preventing an increase in soot emissions. The partial oxidation reaction over the CDPF is exothermic and can be used to increase the rate of temperature rise for the NOx adsorber, similar to the use of light-off catalysts with cascade three-way catalyst systems in gasoline vehicles. The fuel economy penalty from injecting the reductant varies depending on NOx adsorber control strategy, but a typical value is about three percent.

The ability of a diesel engine equipped with a NOx adsorber to control NOx emissions consistently in excess of 90 percent is dependent on the management of temperature. When the engine and NOx adsorber-based emission control system are well matched and integrated, NOx reductions can be far in excess of 90 percent. Conversely, if exhaust temperatures are well in excess of 500° Celsius, or well below 200° Celsius, for significant periods of engine operation, NOx control efficiency may be reduced. Researchers are developing and testing new formulations designed to increase the high temperature stability of the NOx adsorber and to widen the window of operation.

A NOx/Oxygen (O_2) sensor is needed for NOx adsorber regeneration control and is a component originally designed and developed for gasoline powered vehicles. Oxygen sensors have proven to be extremely reliable and long lived in passenger car applications, which see significantly higher temperature ranges than are normally encountered on a diesel engine. There is no reason why the application of a NOx/O_2 sensor on a diesel engine should prove more difficult. While diesel exhaust can cause fouling of the NOx/O_2 sensor damaging its performance, this situation can be addressed through the application of a CDPF in front of the sensor. The CDPF then protects the sensor from PM, but does not hinder its operation.

As previously mentioned, one of the technical challenges associated with NOx adsorbers relates to sulfate poisoning. While NOx adsorbers are known to be extremely efficient at storing NOx on the surface of the catalyzing surface during lean operation, they are, unfortunately, also efficient at storing oxides of sulfur (SOx). In fact, SOx has significantly more affinity for the adsorber than NOx does and is typically not released during regeneration. Thus, sulfate compounds quickly occupy the NOx storage sites on the catalyst rendering the catalyst ineffective (poisoned) for further NOx reduction.

The stored sulfur compounds are removed by exposing the catalyst to hot and rich air-fuel ratio conditions for a brief period. Under these conditions, the stored sulfate is released and reduced in the catalyst. This sulfur removal process, called desulfation, can restore the performance of the NOx adsorber to near new operation. NOx adsorber desulfation appears to be closely related to the temperature of the exhaust gases, air-fuel ratio, and the NOx adsorber catalyst formulation. Lower air-fuel ratios work to promote the release of sulfur from the surface, promoting faster and more effective desulfation. Both U.S. EPA and ARB staff believe that the NOx adsorber will be the dominant method of meeting the final Tier 4 NOx standards.

6.2.3.4. Selective Catalytic Reduction

Selective Catalytic Reduction (SCR) is another catalyst based method for reducing NOx. It requires an ammonia reductant to be injected in the exhaust to initiate catalysis. Most SCR systems, however, are based on an ammonia variant called urea, which tends to be less toxic and easier to handle and store than other forms of ammonia. With the appropriate control system to meter urea in proportion to engine-out NOx emissions, urea SCR catalysts can reduce NOx exhaust emissions by more than 90 percent making the technology a viable candidate for meeting the Tier 4 NOx standards. SCR systems are also much less sensitive to sulfur poisoning than the other catalyst based methods of NOx control already discussed. They have been used effectively in stationary generator sets for over five years, and more recently in mobile source applications such as trucks, locomotives, and marine engines (MECA 2003).

There are some potential drawbacks with SCR technology, however, as it requires periodic user intervention to replenish urea storages in order to continue functioning properly. Since the urea consumption rate can be on the order of five percent of the engine fuel consumption rate, urea would likely need to be replenished at almost the same intervals that the engine is refueled, unless the urea storage tank is quite large (U.S. EPA 2004). Further, the infrastructure for dispensing automotive-grade urea to diesel fueling stations does not yet exist in sufficient quantity to satisfy the demand that would be created to meet the Tier 4 NOx standards should this technology be employed exclusively by engine manufacturers. Still, these issues could be overcome with the proper incentives and through innovative thinking. An on-board diagnostics requirement to monitor urea levels, for example, could be one way to verify that urea tanks were being replenished as needed to maintain emission system performance. Other methods may be possible as well.

Although SCR is not precluded as a means to meeting the Tier 4 NOx standards, it must be stipulated that a manufacturer intending to certify using this technology would need to satisfactorily demonstrate that its engine will use urea at all times in-use before an Executive Order would be issued.

7. ENVIRONMENTAL IMPACTS AND COST-EFFECTIVENESS

This Section presents the air quality benefits and the cost-effectiveness of the proposed standards. Staff's analyses of air quality benefits are based on ARB's off-road emissions inventory database, and cost-effectiveness is based on U.S. EPA's national analysis, adjusted to reflect California expenses and emission reductions.

7.1. Air Quality Benefits

The following summarizes the air quality impacts and benefits of staff's proposal.

7.1.1. Emissions Inventory Reductions

The intent of the proposed regulation is to reduce emissions from off-road diesel engines and equipment in the most technologically feasible and cost-effective manner possible. As shown in Table 7.1, it is estimated that by 2020 California's proposed emissions standards, and those already adopted by the U.S. EPA, would result in statewide emission reductions of 6.9 tons per day PM, 72.8 tons per day NOx, and 3.0 tons per day NMHC. These PM and NOx reductions would be equivalent[21] to taking

[21] The comparison was made for ozone precursor emissions only using data from the off-road diesel emissions inventory database (May 2004) and the EMFAC2002 V2.2 04-03-2003 on-road model. An equivalent particulate emissions comparison would correlate to the removal of 13.6 million passenger cars in 2020.

7.7 million passenger cars off California's highways in 2020. The baseline inventory includes all ARB and U.S. EPA's regulations currently in effect, except for the federal Tier 4 program. The federal Tier 4 program is excluded to facilitate the comparison between preempt and non-preempt emission benefits. Both the baseline and the control estimates assume the use of manufacturer flexibility provisions amounting to 80 percent over a four year period (a seven year period is allowed, but staff believes a four year period is more likely to be used) in increments of 40 percent the first year, 20 percent the next year, and 10 percent for years three and four. The data in these tables reflect the latest emissions information contained in California's off-road diesel emissions inventory database.

Table 7.1
2020 Projected Emission Benefits of the Tier 4 Proposal
Statewide Annual Averages

Government Jurisdiction	Pollutant	Emissions Inventory [1,2]		Reduction (tons per day)
		Baseline (tons per day)	Controlled (tons per day)	
California Proposal Non-Preempt Engines	PM	5.1	2.6	2.5
	NOx	101.0	62.2	38.8
	NMHC	9.6	7.8	1.8
Federal Authority Preempt Engines	PM	12.2	7.8	4.4
	NOx	148.0	114.0	34.0
	NMHC	15.3	14.1	1.2
Total	PM	17.3	10.4	6.9
	NOx	249.0	176.2	72.8
	NMHC	24.9	21.9	3.0

Notes:
1 PM estimates have been adjusted to reflect 15 ppmw sulfur fuel reductions after 2006
2 Emissions from recreational marine engines are not included in these estimates

Table 7.2 shows the estimated total population of engines by power category in 2020 as well as a projection of those engines expected to meet the Tier 4 standards at that time. These projections are based on meeting the interim Tier 4 standards, at a minimum, and take into account the same flexibility usage rates described earlier in subsection 7.1.1. As expected, the majority of engines less than 19 kW would be Tier 4 compliant in 2020 since the standards for that category, as proposed, begin in 2008. The $19 \leq kW < 56$ category is also heavily dominated by Tier 4 engines, but engines in this power range do not turn-over as quickly as engines rated less than 19 kW; therefore, the percent of the fleet meeting Tier 4 standards is less than that for the previous power category despite the same implementation starting date. The $56 \leq kW < 130$ category begins meeting Tier 4 standards later than the rest of the power categories, in 2012, and this is evidenced by a relatively low percentage of engines meeting the Tier 4 standards. The standards for the $130 \leq kW \leq 560$ and the over 560 kW categories begin one year earlier, in 2011, and have a higher rate of Tier 4 compliant engines.

Table 7.2
2020 Engine Populations by Power Category

Power Category	Total Engines [1]	Tier 4 Engines [1,2]	
kW < 19	117,978	112,216	95 %
19 ≤ kW < 56	190,941	149,117	78 %
56 ≤ kW < 130	191,687	106,778	56 %
130 ≤ kW ≤ 560	59,634	38,261	64 %
kW > 560	1,185	826	70 %
TOTAL	561,425	407,198	73 %

Notes:
1 All representations are for combined preempt and non-preempt engines
2 Estimates are based on 40/20/10/10 flexibility usage rates

Table 7.3 shows the benefits of the combined staff proposal and federal Tier 4 rule for two of the largest air basins in California, namely the South Coast Air Basin and the San Joaquin Valley Air Basin. Together these two air basins are home to almost half of all the off-road diesel engines in California and their associated emissions.

Table 7.3
2020 Benefits of the Tier 4 Proposal for Select Air Basins

Air Basin	Pollutant	Emissions Inventory [1,2,3] Baseline (tons per day)	Emissions Inventory [1,2,3] Controlled (tons per day)	Reduction (tons per day)
South Coast (157,059 Engines)	PM	5.2	3.1	2.1
	NOx	69.7	49.3	20.4
	NMHC	7.1	6.3	0.8
San Joaquin Valley (111,401 Engines)	PM	2.9	1.7	1.2
	NOx	43.8	31.0	12.8
	NMHC	4.4	3.8	0.6

Notes:
1 All calculations are annual average estimates expressed as statewide preempt plus non-preempt ratios
2 PM estimates have been adjusted on pre-Tier 4 equipment to reflect 15 ppmw sulfur fuel reductions
3 Emissions from recreational marine engines are not included in these estimates

7.1.2. Toxic Air Contaminants

Diesel exhaust is a mixture of many gases and fine particulate coated with organic substances. Over 40 chemicals in diesel exhaust have been identified by the State of California as toxic air contaminants (see Table 7.4 below). Many of the components in diesel exhaust, such as PM2.5, benzene, arsenic, dioxins, and formaldehyde, are also known carcinogens in California. Other components, such as toluene and dioxins, are known reproductive toxicants. Since the proposal will reduce PM and NMHC emissions, an added benefit will be a reduction in public exposure to the toxic compounds related to those pollutants.

Table 7.4
Toxic Air Contaminants in Diesel Exhaust

acetaldehyde	inorganic lead
acrolem	manganese compounds
aniline	mercury compounds
antimony compounds	methanol
arsenic	methyl ethyl ketone
benzene	naphthalene
beryllium compounds	nickel
biphenyl	4-nitrobiphenyl
bis{2-ethylhexyl]phthalate	phenol
1,3-butakiene	phosphorus
cadmium	polycyclic organic matter, including
chlorine	polycyclic aromatic hydrocarbons (PAHs)
chlorobenzene	propionaldehyde
chromium compounds	selenium compounds
cobalt compounds	styrene
creosol isomers	toluene
cyanide compounds	xylene isomers and mixtures
dibutylphthalate	o-xylenes
dioxins and dibenzofurans	m-xylenes
ethyl benzene	p-xylenes
formaldehyde	

Note:
California Health and Safety Code, section 39655, defines, in part, a "toxic air contaminant" as "an air pollutant which may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health."

7.1.3. Environmental Justice

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (Senate Bill 115, Solis; Stats 1999, Ch. 690; Government Code § 65040.12(c)). The Board has established a framework for incorporating environmental justice into ARB's programs consistent with the directives of State law. The policies subsequently developed apply to all communities in California, but they recognize that environmental justice issues have been raised more in the context of low income and minority communities, which sometimes experience higher exposures to some pollutants as a result of the cumulative impacts of air pollution from multiple mobile, commercial, industrial, areawide, and other sources.

Over the past twenty years, ARB, local air districts, and federal air pollution control programs have made substantial progress towards improving the air quality in

California. However, some communities continue to experience higher exposures than others as a result of the cumulative impacts of air pollution from multiple mobile and stationary sources and thus may suffer a disproportionate level of adverse health effects. Because the same ambient air quality standards apply to all regions of the State, all communities, including environmental justice communities, will benefit from the air quality benefits associated with the proposal. Alternatives to the proposed recommendations, such as maintaining the current exhaust emission standards without further reducing air pollution, would adversely affect all communities. As additional relevant scientific evidence becomes available, the off-road diesel engine standards will be reviewed again to make certain that the health of the public is protected with an adequate margin of safety.

To ensure that everyone has had an opportunity to stay informed and participate fully in the development of off-road diesel engine standards, staff has distributed information as described in subsection 2.6 of this report.

7.1.4. Health Impacts

Full implementation of staff's proposal and the federal rule would prevent approximately 900 premature deaths per year in California and account for a savings of $6.3 billion in health-related costs per year by calendar year 2030 based on the U.S. EPA scaling process for PM-related health benefits (RIA9 2004).

Additionally, 400 cases of chronic bronchitis would be prevented annually in 2030, as well as 20,000 cases of asthma exacerbations for children and 400,000 cases of restricted activity days for adults (RIA9 2004).

7.2. Cost-Effectiveness

The cost of complying with the proposed emission standards and regulations in California is not expected to be different than the cost of complying with the federal regulations. Therefore, no additional cost is anticipated from the adoption of staff's proposal. The estimated cost of complying with the standards will vary depending on the power category and model year under consideration.

The cost-effectiveness for aligning with the federal requirements in California is expected to be similar to the national cost-effectiveness (RIA9 2004) with the exception of the PM benefits attributed solely to the use of ultra low-sulfur diesel fuel. The highest federal fleet-wide cost-effectiveness of the NMHC+NOx standards is about $0.51 to $0.58 per pound of ozone precursors reduced. This compares favorably with other adopted emission control measures in California. The range of cost-effectiveness for the PM standards is expected to be $6.70 to $7.55 per pound of PM reduced after adjusting for the federal inclusion of benefits solely from the ultra low-sulfur diesel fuel, for which California has taken credit in a previous rule. The federal cost-effectiveness for PM including the benefits of ultra low-sulfur diesel fuel is $5.60 to $5.90 per pound.

A more detailed summary of these estimates is provided in Appendix B: "Federal Cost-Effectiveness of the Off-Road Compression-Ignition Emission Standards."

8. ECONOMIC IMPACTS

The proposed regulatory amendments harmonize with the federal regulations finalized on May 11, 2004. The California adoption of the standards would not impose additional costs above the costs to comply with the federal standards. The adoption is actually expected to benefit engine manufacturers, who may face production inefficiencies when they have to comply with different standards. The harmonization of the standards would reduce production inefficiencies, thereby lowering compliance costs. Therefore, staff believes that the proposed amendments would have no noticeable impact on business competitiveness, California employment, or on business creation, elimination, and expansion. This section discusses, in greater detail, the potential cost and economic impacts of the proposed amendments based on U.S. EPA findings.

8.1. Legal Requirement

Sections 11346.3 and 11346.5 of the Government Code require State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

State agencies are required to estimate the cost or savings to any state or local agency, and school districts. The estimate is to include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

8.2. Affected Businesses

Any business that is involved in manufacturing and/or rebuilding off-road diesel engines, and equipment manufacturers that utilize these engines in their equipment, may potentially be affected by the federal standards and the proposed State standards. U.S. EPA has identified approximately 600 off-road equipment manufacturers using diesel engines in several thousand different equipment models. There are also more than 50 engine manufacturers producing diesel engines for these applications nationwide. Also affected are businesses that operate or service diesel engines. An estimated 553,800 off-road diesel engines will be utilized in equipment and vehicles operating in California in 2010 with that number increasing to over 560,000 by 2020.

8.2.1. Estimated Costs to Engine and Equipment Manufacturers

The costs of the proposed new requirements to engine manufacturers have been estimated and are based on U.S. EPA's Regulatory Impact Analysis for the national emission standards. Engine manufacturers will likely evaluate multiple technologies to meet the new emission standards. However, to estimate the incremental impact of the federal standards on engine costs, U.S. EPA assumed a single combination of technologies. Note that the costs presented here do not include potential savings associated with an engine averaging, trading, and banking program or the transition program (flexibilities) for equipment manufacturers. In addition, U.S. EPA assumed that engine companies who are eligible for the small business engine manufacturer specific provisions do not take advantage of the unique flexibilities the regulation provides for them, which includes the opportunity to delay compliance with the Tier 4 emission standards for a full three model years. While it is expected that manufacturers will use these flexibilities to reduce compliance costs, they are not factored into the cost analysis because they are voluntary programs. Given these assumptions, it is likely that the costs provided here are overestimated since they only relate to regulatory requirements and do not consider the voluntary flexibilities that offer the opportunity for significant cost reductions. Unless noted otherwise, all costs are in 2002 dollars.

The total costs include variable costs (for incremental hardware costs, assembly costs, and associated markups) and fixed costs (for tooling, research and development, and certification). For diesel engines, the projected compliance costs are largely due to using new technologies such as advanced emissions control technologies to meet the proposed Tier 4 emissions standards. Compliance costs for engines are broken out by horsepower category and impact year. The costs per unit change from year to year because engine standards are implemented differently in each power category. As shown in Table 8.1, the fixed cost per engine typically decreases after five years as these annualized costs are depreciated. The regulation's market impacts are primarily driven by the per-engine variable costs that remain relatively constant over time.

For off-road equipment, the majority of the projected compliance costs are due to the need to redesign the equipment. The variable cost consists of the cost of new or modified equipment hardware and of labor to install the new emission control devices. The fixed cost consists of the redesign cost to accommodate new emission control devices. The per unit compliance costs are weighted average costs within the appropriate horsepower range. The equipment compliance costs are broken out by horsepower category and impact year. As shown in Table 8.2, the majority of costs per piece of equipment are the fixed costs. The overall compliance costs per piece of equipment are less than half the overall costs associated with the same horsepower category engine (RIA10 2004).

Table 8.1
Compliance Costs per Engine

Power Range	Cost Types	2008	2009	2010	2011	2012	2013	2014	2015	2020	2030
0 ≤ kW < 19	Variable	$129	$129	$123	$123	$123	$123	$123	$123	$123	$123
	Fixed	$33	$32	$31	$30	$30	$0	$0	$0	$0	$0
	Total	$162	$161	$154	$153	$153	$123	$123	$123	$123	$123
19 ≤ kW < 37	Variable	$147	$147	$139	$139	$139	$849	$849	$645	$645	$645
	Fixed	$49	$48	$47	$46	$45	$74	$73	$71	$0	$0
	Total	$196	$195	$186	$185	$184	$923	$922	$716	$645	$645
37 ≤ kW < 56	Variable	$167	$167	$158	$158	$158	$837	$837	$636	$636	$636
	Fixed	$50	$49	$49	$48	$47	$76	$75	$73	$0	$0
	Total	$217	$216	$207	$206	$205	$913	$912	$709	$636	$636
56 ≤ kW < 75	Variable	$0	$0	$0	$0	$1,133	$1,133	$1,122	$1,122	$1,122	$1,122
	Fixed	$0	$0	$0	$0	$80	$78	$108	$106	$0	$0
	Total	$0	$0	$0	$0	$1,213	$1,211	$1,230	$1,228	$1,122	$1,122
75 ≤ kW < 130	Variable	$0	$0	$0	$0	$1,375	$1,375	$1,351	$1,351	$1,351	$1,351
	Fixed	$0	$0	$0	$0	$78	$77	$106	$105	$0	$0
	Total	$0	$0	$0	$0	$1,453	$1,452	$1,457	$1,456	$1,351	$1,351
130 ≤ kW < 450	Variable	$0	$0	$0	$2,191	$2,190	$1,697	$2,137	$2,136	$2,132	$2,126
	Fixed	$0	$0	$0	$326	$321	$316	$437	$430	$0	$0
	Total	$0	$0	$0	$2,517	$2,511	$2,013	$2,574	$2,566	$2,132	$2,126
kW ≥ 450	Variable	$0	$0	$0	$2,911	$2,910	$2,246	$2,733	$6,153	$5,347	$5,347
	Fixed	$0	$0	$0	$861	$848	$835	$1,083	$1,526	$0	$0
	Total	$0	$0	$0	$3,772	$3,758	$3,081	$3,816	$7,679	$5,347	$5,347

Source: U.S. EPA's Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines, May 2004.

Costs are in 2002 dollars.

Table 8.2
Costs per Piece of Equipment

Power Range	Cost Types	2008	2009	2010	2011	2012	2013	2014	2015	2020	2030
0 ≤ kW < 19	Variable	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Fixed	$15	$15	$14	$14	$14	$13	$13	$13	$0	$0
	Total	$15	$15	$14	$14	$14	$13	$13	$13	$0	$0
19 ≤ kW < 37	Variable	$0	$0	$0	$0	$0	$20	$20	$16	$16	$16
	Fixed	$8	$8	$8	$7	$7	$42	$41	$40	$31	$0
	Total	$8	$8	$8	$7	$7	$62	$61	$56	$47	$16
37 ≤ kW < 56	Variable	$0	$0	$0	$0	$0	$21	$21	$17	$17	$17
	Fixed	$8	$8	$8	$8	$8	$44	$43	$42	$32	$0
	Total	$8	$8	$8	$8	$8	$65	$64	$59	$49	$17
56 ≤ kW < 75	Variable	$0	$0	$0	$0	$45	$45	$48	$48	$48	$48
	Fixed	$0	$0	$0	$0	$109	$107	$132	$130	$120	$0
	Total	$0	$0	$0	$0	$154	$152	$180	$178	$168	$48
75 ≤ kW < 130	Variable	$0	$0	$0	$0	$46	$46	$49	$49	$49	$49
	Fixed	$0	$0	$0	$0	$170	$168	$207	$204	$189	$0
	Total	$0	$0	$0	$0	$216	$214	$256	$253	$238	$49
130 ≤ kW < 450	Variable	$0	$0	$0	$75	$75	$60	$80	$80	$79	$79
	Fixed	$0	$0	$0	$378	$372	$366	$453	$446	$415	$0
	Total	$0	$0	$0	$453	$447	$426	$533	$526	$494	$79
kW ≥ 450	Variable	$0	$0	$0	$57	$57	$46	$61	$123	$111	$111
	Fixed	$0	$0	$0	$690	$680	$670	$806	$1,404	$1,310	$0
	Total	$0	$0	$0	$747	$737	$716	$867	$1,527	$1,421	$111

Source: U.S. EPA's Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines, May 2004.

Costs are in 2002 dollars.

8.2.2. Potential Impacts on Business

The new federal standards are expected to impose additional costs on engine manufacturers, rebuilders, and equipment manufacturers that utilize these engines in their equipment. A more thorough analysis of these costs is provided in chapter 6 of U.S. EPA's Regulatory Impact Analysis. As shown in Table 8.3, U.S. EPA estimated the prices for seven engine categories using price data compiled from a variety of sources. These prices were sales weighted where appropriate.

Table 8.3
Baseline Engine Prices

Power Range	Estimated Price
kW < 19	$1,500
19 ≤ kW < 37	$2,900
37 ≤ kW < 56	$3,000
56 ≤ kW < 75	$4,000
75 ≤ kW < 130	$5,500
130 ≤ kW < 450	$20,000
kW ≥ 450	$80,500

Source: U.S. EPA Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines, May 2004.

The incremental costs of the new standards can be viewed in the context of their fraction of the total purchase price of equipment. As illustrated in Table 8.4, the ratio of variable engine compliance costs to market price ranges from about 29 percent for engines 19 ≤ kW < 37 to roughly three percent for engines equal to and above 450 kW. These different ratios lead to different relative shifts in the supply curves, and different impacts on the change in market price and quantity for each market. As stated earlier, the regulation's market impacts are driven primarily by the per-engine variable costs that remain relatively constant over time, which is why Table 8.4 does not compare total or fixed engine costs. Fixed costs are the unavoidable price of doing business and might give a false sense of the influence that the proposal would have on engine prices if included.

Table 8.4
Ratio of Variable Engine Compliance Costs to Engine Price

Power Range	Variable Engine Compliance Cost / Engine Price
kW < 19	8.2%
19 ≤ kW < 37	29.3%
37 ≤ kW < 56	27.9%
56 ≤ kW < 75	28.3%
75 ≤ kW < 130	25.0%
130 ≤ kW < 450	8.5%
kW ≥ 450	2.8%

Source: U.S. EPA Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines, May 2004.

The California adoption of the new federal standards is not going to alter the above costs because these costs already include the cost to California. The harmonization of the standards would actually benefit most engine manufacturers, because they have would not have to comply with different standards for California.

8.2.3. Potential Impact on Business Competitiveness

The proposed amendments would have no significant impact on the ability of California businesses to compete with businesses in other states. The amendments would harmonize the California standards with the federal standards for off-road diesel engines. Thus, California operators of off-road diesel equipment and vehicles would not be disadvantaged relative to operators from other states. The harmonization of the standards should actually benefit engine manufacturers and equipment manufacturers. This is because these manufacturers would not have to deal with different requirements that can result in production inefficiencies.

8.2.4. Potential Impact on Employment

The proposed amendments are not expected to cause a noticeable change in California employment. The adoption of the federal standards in California is expected to benefit manufacturers, who might be faced with production inefficiencies if they had to comply with different California and federal standards. As mentioned above, the harmonization of the standards would reduce production inefficiencies, thereby lowering compliance costs. Since these costs are generally passed on to vehicle operators, they could benefit from lower compliance costs. This would, in turn, moderate any adverse impact the federal standards might have on employment.

8.2.5. Potential Impact on Business Creation, Elimination or Expansion

The proposed amendments would have no noticeable impact on the status of California businesses including small businesses. The proposed emission standards would be the same as the federal standards. Therefore, no additional costs for off-road diesel equipment or vehicle operators in California are expected. The implementation flexibilities proposed would help alleviate the potential impact on businesses including small businesses.

8.2.6. Potential Impact on Small Businesses

Small business entities comprise 68 percent of the off-road diesel private sector nationally based on estimates from the U.S. EPA. However, the sales from these small business entities are only about 11 percent of the total sales from the category. The ten largest engine manufacturers are responsible for 80 percent of the engines sold. The cost to small businesses should be considerable lower than for the rest of the off-road industry as a result of the many compliance facilitating provisions afforded to small business and small volume entities in the regulation.

8.3. Potential Costs to Local and State Agencies

As discussed in section 9 of this report, ARB must either adopt the requirements in this proposal, or other requirements that would result in equivalent or greater air quality benefits in order to comply with the federal Clean Air Act. Staff believes the proposed requirements are the only feasible and cost-effective means of achieving emission reductions of the same magnitude as the federal requirements by 2030. Staff also believes there would be no real incremental cost increase associated with adopting the federal standards as the California standards. Accordingly, the proposed requirements are not expected to result in an overall increase in costs for State and local agencies. The only costs to State government as a result of the proposed amendments would be for administratively implementing the new regulatory requirements. However, the implementation costs may be absorbed with existing ARB resources. ARB is already responsible for verifying the implementation of the existing regulations for off-road diesel engines. Thus, the proposed amendments would not increase the workload to the extent that hiring additional staff would be necessary.

8.4. Potential Costs to Non-Preempt Farm Equipment

As noted previously, the federal Clean Air Act preempts the ARB from regulating new farm equipment with engines rated at less than 175 horsepower (130 kW). This means that new farm equipment at or greater than 175 horsepower would be regulated under the staff's proposal. Under Health and Safety Code, section 43013(c), the ARB is required to hold a public hearing prior to adopting standards and regulations for farm equipment. In the hearing, the ARB shall find and determine that the standards and regulations are necessary, cost-effective, and technologically feasible. The ARB is also required to consider the technological effects of emission control standards on the cost, fuel consumption, and performance characteristics of mobile farm equipment.

8.4.1. Necessity of Proposal for Non-Preempt Farm Equipment

As discussed above in section 7.1 "Air Quality Impacts," it is clear that the Tier 4 standards are needed to achieve significant reductions in PM (particularly diesel PM), NOx, NMHC, and toxic air contaminants. Without these reductions, the public will continue to be exposed to high levels of these air pollutants. Therefore, the Tier 4 standards and this proposal to harmonize ARB's regulations with the U.S. EPA's Tier 4 regulation are necessary to achieve significant emission reductions and protect public health.

8.4.2. Cost-Effectiveness of Proposal for Non-Preempt Farm Equipment

As discussed above in section 7 "Environmental Impacts and Cost-Effectiveness" and Appendix B, the proposal clearly meets established criteria for cost-effectiveness for farm equipment. We are aware of no specific uniqueness to farm equipment that would make the cost analysis presented in this Staff Report inapplicable to new farm equipment.

The cost-effectiveness for aligning with the federal requirements in California is expected to be similar to the national cost-effectiveness (RIA9 2004), with the exception of the PM benefits attributed solely to the use of ultra low-sulfur diesel fuel. The highest federal fleet-wide cost-effectiveness of the NMHC+NOx standards is about $0.51 to $0.58 per pound of ozone precursors reduced. This compares favorably with other adopted emission control measures in California. The range of cost-effectiveness for the PM standards is expected to be $6.70 to $7.55 per pound of PM reduced after adjusting for the federal inclusion of benefits solely from the ultra low-sulfur diesel fuel, for which California has taken credit in a previous rule. The federal cost-effectiveness for PM including the benefits of ultra low-sulfur diesel fuel is $5.60 to $5.90 per pound.

Based on these reasons, we believe the proposal is cost-effective for new farm engines and equipment.

8.4.3. Technological Feasibility of Proposal for Non-Preempt Farm Equipment

The technological feasibility of the proposal is discussed in section 6 "Technological Feasibility." In summary, the U.S. EPA determined that the Tier 4 standards are technologically feasible for all of the regulated engine classes, including new farm engines and equipment at or above 130 kW. We agree with this determination. The various compliance methods and emission control technologies available to farm equipment manufacturers are discussed in section 6. We are aware of no technical reasons why new farm engines and equipment cannot meet the Tier 4 standards. Therefore, we have determined that the proposal is technologically feasible for new, non-preempt farm engines and equipment.

8.4.4. Technological Effects Of Emission Control Standards On The Cost, Fuel Consumption, And Performance Characteristics Of Mobile Farm Equipment

The effect of the emission control standards on the cost of mobile farm equipment was determined by the U.S. EPA and summarized in Tables 8.1 and 8.2. In summary, the compliance costs ranged from $0 to $2,574 (130 ≤ kW ≤ 450) and $0 to $7,679 (> 450 kW) per engine. This compares to base engine prices of $20,000 (130 ≤ kW ≤ 450) to $80,500 (> 450 kW) per engine. Because the U.S. EPA Tier 4 standards applies nationally, these costs should not adversely affect farming costs in California relative to farming outside of California.

The U.S. EPA's analysis of the standards on fuel consumption and performance characteristics is documented in their Regulatory Impacts Analysis, which is incorporated by reference herein. No significant adverse impacts on fuel consumption and performance characteristics were found as a result of the Tier 4 standards.

9. REGULATORY ALTERNATIVES

The staff evaluated various alternatives to the current proposal. A brief description of the alternatives and staff's rationale for finding them unsuitable follows below.

9.1. Maintain Current California Regulations

The first alternative to this proposal would be to simply maintain the current California off-road diesel engine emission standards. Prior to U.S. EPA's adoption of the Tier 4 standards for off-road diesel engines, current California and federal standards were the same. However, with its passage, current California regulations have become less stringent than the federal program. Pursuant to the federal Clean Air Act (CAA), in order for California to enforce its own emissions reduction program the Board must adopt regulations that are, in the aggregate, at least as protective of public health and welfare as applicable federal standards (CAA Section 209(e)(2)(A)). Therefore, staff rejected this alternative.

9.2. Adopt More Stringent Emission Standards

The degree of emissions control proposed by staff is already technology forcing for most of the engines being regulated, and should result in dramatic emission reductions over time. Staff recognizes that more stringent standards may be necessary in the future, especially for engines rated less than 19 kW. However, data are not yet available to suggest a more cost effective way to achieve greater emission benefits. Therefore, staff is not recommending the adoption of standards more stringent than those already proposed. Harmonization with the federal program will spare the industry unnecessary costs and administrative burdens, allowing a greater focus on the technical issues of emissions control. Staff rejects this alternative at this time.

9.3. Accelerate Implementation Schedule of Standards

The staff examined the possibility of accelerating the implementation schedule of standards to get cleaner engines into California earlier. While this alternative would provide emission benefits sooner, manufacturers would have less lead time to develop the necessary technologies since standards for many of the power groups would be changing simultaneously, and manufacturers would have fewer years over which to spread out and recoup the development expenses. This would also make the proposal far less cost-effective. Therefore, staff rejected this alternative.

10. REMAINING ISSUES

10.1. Technical Amendments

U.S. EPA intends to make additional improvements to their Tier 4 test procedures in a separate rulemaking titled "Test Procedures for Testing Highway and Nonroad Engines and Omnibus Technical Amendments," which was proposed on August 16, 2004. These changes will primarily be technical in nature, affecting the language in 40 CFR, Part 1065 mostly, and are intended to incorporate the latest measurement technologies. Staff has participated in varying degrees to the development of these technical amendments, and will likely propose that the Board consider incorporating them into California's off-road diesel program in a 15-day notice should U.S. EPA finalize them prior to the October 15, 2004 deadline and after staff has had sufficient opportunity to review them in finalized context.

10.2. Safety Concerns

Staff is unaware of any safety-related issues being raised by the off-road industry regarding this proposal or during the development of U.S. EPA's similar rule. However, with the likely incorporation of catalyzed materials in the exhaust stream to meet the proposed standards, there is the potential for increased heat dissipation. Although such technology could raise exhaust temperatures, staff does not believe it is likely to result in a fire hazard due to the out-of-reach location of the exhaust stack on most off-road diesel equipment and with the anticipated application of proper shielding by the equipment manufacturer. The majority of catalyzed aftertreatment devices are expected to replace mufflers, which should already necessitate sufficient heat resistant designs.

11. CONCLUSIONS AND RECOMMENDATIONS

Staff's objective in recommending the harmonization of ARB's off-road diesel Tier 4 program with federal requirements is to provide the citizens of California with the most effective approach for achieving major air quality improvements in a technologically feasible and cost effective manner. Staff estimates that in 2020, the statewide benefits of the California proposal and the federal rule would be 72.8 tons per day NOx, 6.9 tons per day PM, and 3.0 tons per day NMHC. The estimated California cost-effectiveness with adoption of the staff's proposal would be approximately $0.58 per pound of NMHC+NOx reduced. This cost-effectiveness is well within the range of other control measures adopted by the Board.

There are some differences, however, between the federal program and the California proposal for Tier 4 off-road engines. These are safeguards for ensuring California's continued ability to identify complying engines quickly, and to enforce the regulations. The proposed differences should not be overly burdensome or costly to the manufacturers, but will help to ensure that off-road engines remain in compliance with emissions standards throughout their useful lives.

No alternative considered by the agency would be more effective in carrying out the purpose for which the regulation is proposed, or would be as effective as, or less burdensome, to affected private persons than the proposed regulation. Therefore, staff recommends that the Board adopt staff's proposal as contained in this report and noted in the attached proposed regulations and test procedures.

12. REFERENCES

Almanac 2004: California Air Resources Board, 2004 California Almanac of Emissions and Air Quality, Chapter 5: Toxic Air Contaminant Emissions, Air Quality, and Health Risk, Planning and Technical Support Division.

ARB 1991: California Air Resources Board, Public Hearing to Consider The Adoption of Regulations Regarding the California Exhaust Emission Standards and Test Procedures for New 1996 and Later Heavy-Duty Off-Road Diesel Cycle Engines and Equipment Engines, November 22, 1991 (Staff Report).

ARB 1994: California Air Resources Board, Public Hearing to Consider Regulations Regarding the California Exhaust Emission Standards and Test Procedures for 1994 and Subsequent Model Utility and Lawn and Garden Equipment Engines, October 22, 1990 (Staff Report).

ARB 1999: California Air Resources Board, Public Hearing to Consider Amendments to Off-Road Compression-Ignition Engine Regulations: 2000 and Later Emission Standards, Compliance Requirements and Test Procedures, December 10, 1999 (Staff Report).

ARB 2001: California Air Resources Board, Public Hearing to Consider Amendments Adopting More Stringent Emission Standards for 2007 and Subsequent Model Year New Heavy-Duty Diesel Engines, September 7, 2001 (Staff Report).

ARB 2001b: California Air Resources Board, Public Hearing to Consider Adoption of Emission Standards and Test Procedures for New 2003 and Later Spark-Ignition Inboard and Sterndrive Marine Engines, June 8, 2001 (Staff Report).

ARB 2003: California Air Resources Board, Public Hearing to Consider Amendments to the California Diesel Fuel Regulations Including Reduction of the Maximum Permissible Sulfur Content of Motor Vehicle Diesel Fuel, June 6, 2003 (Staff Report).

Census 2000: California Department of Finance, Census 2000 Products, State and County Summary, September 17, 2004.

MECA 2003: Manufacturers of Emission Controls Association, Testimony on Proposed Legislation Relating to the Use of Ultra Low Sulfur Diesel Fuel and the Best Available Technology by Nonroad Vehicles in City Construction, Proposed Int. No. 191-A, September 25, 2003.

Kittelson, David. B., Arnold, Megan, Watts, Winthrop. F., Review of Diesel Particulate Matter Sampling Methods, Final Report, University of Minnesota, January 14, 1999.

Krewski, Daniel, Burnett, Richard T., Goldberg, Mark S., Hoover, Kristin, Siemiatycki, Jack, Jerrett, Michael, Abrahamowicz, Michal, White, Warren H., Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality, Health Effects Institute, Cambridge, MA, July 2000.

Lloyd & Cackette: Lloyd, Alan C., Cackette, Thomas A., Diesel Engines: Environmental Impact and Control, Journal of the Air and Waste Management Association, 51:809-847, June 2001.

RIA4 2004: United States Environmental Protection Agency, Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines, Chapter 4: Technologies and Test Procedures for Low-Emission Engines, May 11, 2004.

RIA6 2004: United States Environmental Protection Agency, Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines, Chapter 6: Estimated Engine and Equipment Costs, May 11, 2004.

RIA9 2004: United States Environmental Protection Agency, Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines, Chapter 9: Cost-Benefit Analysis, May 11, 2004.

RRP 2000: California Air Resources Board, Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel Fueled Engines and Vehicles, October, 2000.

SRP 1998: Scientific Review Panel, Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant. Part A, Exposure Assessment, As Approved by the Scientific Review Panel on April 22, 1998.

SSA 2003: State Implementation Plan Settlement Agreement, with amendments, in Coalition for Clean Air, Inc. et al. v. South Coast Air Quality Management District, et al. (U.S. District Court, Central District of CA, Case No. CV-97-6916 JSL (SHx)).

SwRI 2004: Southwest Research Institute, Application of Diesel Particulate Filters to Three Nonroad Engines, Project No. 03.04863, San Antonio, TX, August 2004.

U.S. EPA 1997: United States Environmental Protection Agency, Control of Emissions of Air Pollution From Highway Heavy-Duty Engines; Final Rule, 62 Federal Register 54694-54730, October 21, 1997.

U.S. EPA 1998: United States Environmental Protection Agency, Control of Emissions of Air Pollution From Nonroad Diesel Engines; Final Rule, 63 Federal Register 56967-57023, October 23, 1998.

U.S. EPA 2001: United States Environmental Protection Agency, Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements; Final Rule, 66 Federal Register 5001-5193, January 18, 2001.

U.S. EPA 2004: United States Environmental Protection Agency, Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel; Final Rule, 69 Federal Register 38958-39273, June, 29, 2004.

ATTACHMENT 1: PROPOSED AMENDMENTS TO THE CALIFORNIA REGULATIONS FOR OFF-ROAD COMPRESSION-IGNITION ENGINES AND EQUIPMENT

ATTACHMENT 2: PROPOSED AMENDMENTS TO THE CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR NEW 2008 AND LATER TIER 4 OFF-ROAD COMPRESSION-IGNITION ENGINES AND EQUIPMENT, PART I-C

ATTACHMENT 3: PROPOSED AMENDMENTS TO THE CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR NEW 2000 AND LATER TIER 1, TIER 2, AND TIER 3 OFF-ROAD COMPRESSION-IGNITION ENGINES AND EQUIPMENT, PART I-B

ATTACHMENT 4: PROPOSED AMENDMENTS TO THE CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR NEW 1996 AND LATER TIER 1, TIER 2, AND TIER 3 OFF-ROAD COMPRESSION-IGNITION ENGINES AND EQUIPMENT, PART II

APPENDIX A: LIST OF PREEMPTED OFF-ROAD APPLICATIONS

(a) Equipment types with engines less than 25 horsepower are presumed not to be construction or farm equipment, with the exception of the following equipment types, which have been determined to be construction or farm equipment:

Aerial devices: vehicle mounted
Asphalt recycler/reclaimer, sealer
Augers: earth
Back-hoe
Backpack Compressors
Baler
Boring machines: portable line
Breakers: pavement and/or rock
Brush cutters/Clearing saws 40 cc and above (blade capable only)
Burners: bituminous equipment
Cable layers
Chainsaws 45 cc and above
Chippers
Cleaners: high pressure, steam, sewer, barn
Compactor: roller/plate
Compressors
Concrete buggy, corer, screed, mixer, finishing equipment
Continuous Digger
Conveyors: portable
Crawler excavators
Crushers: stone
Cultivators: powered
Cutting machine
Debarker
Detassler
Drills
Dumper: small on-site
Dusters
Elevating work platforms
Farm loaders: front end
Feed conveyors
Fertilizer spreader
Forage box/Haulage and loading machine
Forklifts: diesel and/or rough terrain
Harvesters, crop
Jackhammer
Light towers
Mixers: mortar, plaster, grout
Mowing equipment: agricultural
Mud jack
Pavers: asphalt, curb and gutter
Pipe layer

Plows: vibratory
Post hole diggers
Power pack: hydraulic
Pruner: orchard
Pumps 40 cc and above
Rollers: trench
Sawmill: portable
Saws: concrete, masonry, cutoff
Screeners
Shredder/grinder
Signal boards: highway
Silo unloaders
Skidders
Skid-steer loaders
Specialized fruit/nut harvester
Sprayers: bituminous, concrete curing, crop, field
Stump cutters, grinders
Stumpbeater
Surfacing equipment
Swathers
Tampers and rammers
Tractor: compact utility
Trenchers
Troweling machines: concrete
Vibrators: concrete, finisher, roller
Welders
Well driller: portable
Wheel loaders

(b) Equipment types with engines 25 horsepower or greater are presumed to be construction or farm equipment, with the exception of the equipment types listed below, which have been determined not to be construction or farm equipment.

Aircraft Ground Power
Baggage Handling
Forklifts that are neither rough terrain nor powered by diesel engines
Generator Sets
Mining Equipment not otherwise primarily used in the construction industry
Off-Highway Recreational Vehicles
Other Industrial Equipment
Refrigeration Units less than 50 horsepower
Scrubbers/Sweepers
Tow/Push
Turf Care Equipment

APPENDIX B: FEDERAL COST-EFFECTIVENESS OF THE OFF-ROAD COMPRESSION-IGNITION EMISSION STANDARDS

The following tables show the federal cost-effectiveness of the emission standards for diesel engines. The estimated cost of complying with the standards varies depending on the model year under consideration. U.S. EPA calculated the cost per ton of the regulations based on the net present value of all costs incurred and all emission reductions generated over a 30-year time window following implementation of the program. This approach captures all the costs and emission reductions from the regulations, including costs incurred and emission reductions generated by both the new and the existing fleet.

Table B.1
Cost-Effectiveness Estimates ($2002)
30-Year Net Present Value at a 3% and 7% Discount Rate

Pollutant	3% discount rate	7% discount rate
	$/ton ($/lb)	
NMHC+NOx	$1,010 ($0.51)	$1,160 ($0.58)
PM w/Fuel	$11,200 ($5.60)	$11,800 ($5.90)
PM w/o Fuel	$13,400 ($6.70)	$15,100 ($7.55)

U.S. EPA also calculated the cost per ton of emissions reduced in the year 2030 using the annual costs and emission reductions in that year alone. This number, shown in Table B.2, approaches the long-term cost per ton of emissions reduced after all fixed costs of the program have been recovered by industry leaving only the variable costs of control (and maintenance costs), and after most of the pre-control fleet has been retired.

Table B.2
Long-Term Cost-Effectiveness ($2002)
Annual Values w/o Discounting

Pollutant	Long-Term Cost in 2030 $/ton ($/lb)
NMHC+NOx	$680 ($0.34)
PM	$9,300 ($4.65)

TITLE 13. CALIFORNIA AIR RESOURCES BOARD

NOTICE OF PUBLIC MEETING TO UPDATE THE BOARD ON THE HEAVY-DUTY DIESEL ENGINE VOLUNTARY SOFTWARE UPGRADE (CHIP REFLASH) PROGRAM

The Air Resources Board (the Board or ARB) will meet publicly at the time and place noted below to evaluate the heavy-duty diesel engine voluntary software upgrade program. In March 2004, the Board adopted the software upgrade regulation which mandates installation of software on 1993-1999 model year heavy-duty trucks, school buses, and motor homes to reduce emissions of oxides of nitrogen (NOx). However, the Board directed staff to withhold filing the adopted regulation with the Office of Administrative Law while the engine manufacturers, dealers, California Trucking Association, and vehicle owners worked together to get low NOx software installed on a voluntary basis.

Staff reported interim voluntary program results to the Board at the October 2004 Board meeting. Staff will report on the further progress of the voluntary program at the December Board hearing. The Board will evaluate whether the voluntary program has met the first target of 35 percent, and whether the program can sustain the rate of progress to meet the next goal of 60 percent. The Board may direct the staff to continue the voluntary program or to file the adopted regulation at this meeting.

DATE: December 9, 2004

TIME: 9:00 a.m.

PLACE: California Environmental Protection Agency
Air Resources Board
1001 I Street
Auditorium, Second Floor
Sacramento, California 95814

The Board will also consider other items at this meeting. Please consult the agenda for the meeting, which will be available at least 10 days before December 9, 2004, to determine the order in which the items will be considered by the Board.

If you have a disability-related accommodation need, please go to http://www.arb.ca.gov/html/ada/ada.htm for assistance or contact the ADA Coordinator at (916) 323-4916. If you are a person who needs assistance in a language other than English, please contact the Bilingual Coordinator at (916) 324-5049. TTY/TDD/Speech-to-Speech users may dial 7-1-1 for the California Relay Service.

Background

In the 1990's, many heavy-duty diesel engines emitted high "off cycle" NOx emissions. Software upgrades, referred to as low NOx software, were developed to correct the high NOx emissions as a result of negotiations between the United States Environmental Protection Agency (U.S. EPA), the ARB, and seven engine manufacturers. The negotiated Consent Decrees and California-specific Settlement Agreements contain requirements to develop and install the low NOx software.

Software upgrades were developed by the engine manufacturers and are available now for most 1993-1998 model year engines. The software upgrade is simply software installed in the engine that reprograms the vehicle's computer and reduces NOx emissions. The installation process typically takes between one-half to one hour.

Only certain engines have low NOx software upgrades available, and only those engines that have low NOx software available need to be upgraded. The ARB staff has prepared a list that can be checked to determine if low NOx software is available for a particular engine. This list is available from our web site at: http://www.arb.ca.gov/msprog/hdsoftware/hdsoftware.htm

Regulation

The ARB has adopted a regulation to reduce air pollution by requiring owners and operators of trucks, school buses, and motor homes with 1993-1998 model year heavy-duty diesel engines to upgrade the software in the electronic control module (ECM) of these engines. When the Board adopted the regulation in March 2004, they directed staff to withhold filing the regulation while the engine manufacturers, the dealers, the California Trucking Association, and the vehicle owners worked together to get low NOx software installed on eligible engines on a voluntary basis.

If the regulation is filed, owners and operators of eligible vehicles that operate in California must ensure that the engines in their vehicles have the appropriate low NOx software installed. Since many 1999 model year vehicles have engines produced in 1998, owners and operators of 1999 model year vehicles will need to check to determine if they are affected. Distributors and dealers must provide the appropriate low NOx software to the vehicle owner or operator upon request.

If this regulation is filed, it will require the low NOx software upgrade to be installed on a schedule that depends on the model year of the engine in the affected vehicle as follows:

1993-1994 model years	By April 30, 2005
1995-1996 model years	By August 31, 2005
1997-1998 model years	By December 31, 2005 (except for medium heavy-duty diesel engines (MHDDEs))
1997-1998 model year MHDDEs	By December 31, 2006

The ARB enforcement staff will verify required installations of the low NOx software through a modified Heavy-Duty Vehicle Inspection Program and modified Heavy-Duty Vehicle Fleet Inspection Program.

Voluntary Program

The Voluntary Program is a cooperative effort between the vehicle owners, California Trucking Association, California dealers, the engine manufacturers, and the ARB staff to install low NOx software upgrades on a voluntary basis. Under the voluntary program, there is no requirement for the vehicle owners to install low NOx software. However, the heavy-duty diesel engine software upgrades are being provided to the vehicle owners at no charge upon request. The ARB staff believes the applicable Consent Decrees and Settlement Agreements require manufacturers to supply the low NOx software at no cost whenever it is requested.

The Voluntary Program has performance targets of 35, 60, 80, and 100 percent of the emission reduction benefits of the regulatory program. Once the Board approved the voluntary program, ARB staff generated an outreach letter and mailed it to over 60,000 owners of 1993-1999 model year heavy-duty diesel vehicles. The engine manufacturers notified their authorized dealers of the program, and the California Trucking Association held outreach events for dealers and vehicle owners. ARB staff initiated telephone calls to dealers and distributors to inform them of the Voluntary Software Upgrade Program and staff responded to telephone calls from numerous vehicle owners about the low NOx software installation program. Interim progress of the voluntary program was reported to the Board at the October 2004 meeting.

Phase I Evaluation

At the December 9, 2004, Board meeting, staff will report on data received and analysis performed to help the Board evaluate the progress of the Voluntary Program. The first target for the Voluntary Program is to achieve 35 percent of the emission reduction benefits of the regulatory program with low NOx software installations performed through October 28, 2004. The Board must also decide if the rate at which low NOx software installations are occurring is sufficient to allow meeting the remaining targets.

<u>AVAILABILITY OF DOCUMENTS AND AGENCY CONTACT PERSONS</u>

Inquiries concerning this matter may be directed to the designated agency contact persons, Ms. Lisa Jennings, Air Pollution Specialist, at (916) 322-6913, or Mr. Earl Landberg, Air Pollution Specialist, at (916) 323-1384. To discuss this notice with someone who speaks **Spanish,** please call **Marivel De La Torre** at **(916) 323-1362.**

SUBMITTAL OF COMMENTS

The public may present comments relating to this matter orally or in writing at the meeting, and in writing or by e-mail before the meeting. To be considered by the Board, written submissions not physically submitted at the meeting must be received **no later than 12:00 noon, December 8, 2004**, and addressed to the following:

Postal mail is to be sent to:

Clerk of the Board
Air Resources Board
1001 I Street, 23rd Floor
Sacramento, California 95814

Electronic mail is to be sent to: chip06@listserv.arb.ca.gov and received at the ARB **no later than 12:00 noon, December 8, 2004.**

Facsimile transmissions are to be transmitted to the Clerk of the Board at (916) 322-3928 and received at the ARB **no later than 12:00 noon December 8, 2004**.

The Board requests, but does not require 30 copies of any written submission. Also, the ARB requests that written and e-mail statements be filed at least 10 days prior to the meeting so that ARB staff and Board members have time to fully consider each comment.

CALIFORNIA AIR RESOURCES BOARD

Catherine Witherspoon
Executive Officer

Date:

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs see our Web –site at www.arb.ca.gov.

No written material available at time of electronic book creation.