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 is used for multiple thermal spraying operations and material usage records document the quantity of material used for each operation, use the applicable emission factors for each operation. If material usage records do not document the quantity of material used for each 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.

Reference: “Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying”, Title 17, California Code of Regulations, Section 93102.5.

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 – Annual Emissions. 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 sprayed][Annual Usage, lbs Cr sprayed/yr]]*

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

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.

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), chromium compounds, nickel (Ni), or nickel compounds.

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

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

Reference: "Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying", Title 17, California Code of Regulations, Section 93102.5.

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 sprayed)	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

Reference: “Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying”, Title 17, California Code of Regulations, Section 93102.5.

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 sprayed/yr)	Emission Factor (lb Cr^{+6}/lb Cr sprayed)	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 sprayed/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**

Reference: "Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying", Title 17, California Code of Regulations, Section 93102.5.

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.

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), chromium compounds, nickel (Ni), or nickel compounds.

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

Reference: "Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying", Title 17, California Code of Regulations, Section 93102.5.

Step 5: Identify the applicable emission factors.

Control Device	Operation	Emission Factor - Hexavalent Chromium (lb Cr^{+6}/lb Cr sprayed)	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 sprayed/yr)	Emission Factor (lb Cr^{+6}/lb Cr sprayed)	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 sprayed/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**

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

Reference: "Airborne Toxic Control Measure to Reduce Emissions of Hexavalent Chromium and Nickel from Thermal Spraying", Title 17, California Code of Regulations, Section 93102.5.

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.)