IAEG® Materials and Substances Declaration Development

08 July 2026

Version **3.0**

Purpose: This document was created by IAEG to provide methods that can be used for identification, quantification, and communication of materials and substances within products.

Audience: Manufacturers or suppliers of products (including their supply chains)

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Version History

Date	v#	Modified By	Section, Page(s) and Text Revised
12 July 2019	1.0	N/A	N/A
14 July 2021	2.0	ST5 Team	Addition of four appendices with supplemental information, resources, and examples of substance mass calculations.
22 Nov 2021	2.1	ST5 Team	Correction of math error on page 42.
1 July 2022	2.2	ST5 Team	Document title and editorial/formatting changes.
08 July 2026	3.0	ST5 Team	Document reorganized; additional background information added; SDS examples added to Section 5.0; new calculation examples added.

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Introduction

Due to the growing number of international chemical regulatory (and related customer) requirements, companies and their supply chains have an increasing need to obtain, use, and communicate information about materials and substances contained within their products. The International Aerospace Environmental Group (IAEG®) has developed resources to support the Aerospace and Defense (AD) industry with the exchange of information via declarations containing material and substance data. This document was created by IAEG to support the identification and quantification of materials and substances within products (e.g., articles, complex assemblies, hardware). Additional free resources are available at https://www.iaeg.com/chemicalrpt, including a substance reporting tool.

The intent of this document is to provide methods that can be used for identification, quantification, and communication of materials and substances within products.

The information in this document is intended to assist manufacturers or suppliers of products (including their supply chains) to calculate the substance content of materials in products. These steps, tips, and example calculations are based on the knowledge and experience of many IAEG member companies. The intent of this document is to provide methods that can be used by suppliers to meet obligations that depend upon such calculations, including those imposed by direct regulatory requirements, or those used to satisfy other internal or customer needs. It should be noted that this document is not intended to address the requirements of any *specific* global chemical regulation, but rather to provide useful information and calculation examples that may be used to address product reporting requirements against *any* declarable substances list.

Table 1. Topics in Scope/Out of Scope of This Document

In Scope	**Out of Scope**
• Declarations on substances in articles • General considerations • Generic declaration process steps • Calculations of substance mass • Volatile substances	• Declarations on substances in process • Declaring on reactive substances (due to complex nature of chemical reactions) • Hazard classifications (Classification, Labelling, and Packaging [CLP] and Globally Harmonized System [GHS]) • Safety considerations • Interpretation of specific regulations • Reporting using specific formats (e.g., IPC-1754, AD-SRT) • Legal advice or recommendations

For questions and feedback, please contact WG1@iaeg.com.

Definitions of Terms

Acronym	Definition
AD	Aerospace and Defense
AD-DSL	Aerospace and Defense Declarable Substances List (published by IAEG; available at https://www.iaeg.com/chemicalrpt/addsl)
AIA	Aerospace Industries Association
Anodization	Electrolytically coating a metal with a protective oxide
Article	An object, which during production is given a special shape, surface, or design which determines its function to a greater degree than does its chemical composition.[1] An article does not generally undergo further change of state (such as solid to liquid) or change of shape during production and use. Once an object meets the criteria of an article, it remains an article and further assembly would lead to a complex article (see below).
BOM	Bill of Materials (may also be referred to as a parts list)
CAS Number	A CAS (Chemical Abstracts Service) Registry Number is a numerical identifier that can contain up to 10 digits divided by hyphens into three parts. Each CAS RN uniquely identifies a chemical substance.[2]
CAD	Computer Aided Design
Candidate List of Substances of Very High Concern (SVHCs)	A list of chemical substances published by ECHA that have been identified as requiring an EU REACH Article 33 materials and substances declaration
CLP	Classification, Labelling, and Packaging; European legislation implementing the UN GHS on classification and labelling (CLP also includes packaging requirements).
Complex article	An article/product/assembly that is made up of more than one article/ product/assembly, joined with a substance or mixture, or mechanically assembled.
Conversion coating	A type of coating used on metals in which surface atoms are chemically reacted with the coating solution to form a protective layer.
Declarable Substances List (DSL)	A list of substances and/or group(s) of substances that require declaration (not to be confused with the Canadian "Domestic Substances List").
Declaration	Report of product-specific substance data. Several standard schemata exist with specific rules and formats. The selection of a scheme is governed by applicable regulations and/or contractual obligations.
EC Number	European Community number is a unique seven-digit identifier assigned by the European Commission to substances for regulatory purposes within the European Economic Area.
ECHA	European Chemicals Agency

[1] EU REACH regulation – Article 3, "Definitions"

[2] Note that this is a commercial undertaking and some CAS numbers refer to more than one substance, and some substances have more than one CAS Number. Sometimes, substances may not have a CAS number.

Acronym	Definition
EU	European Union
EU REACH	The Registration, Evaluation, Authorisation, and Restriction of Chemicals is a regulation of the EU, adopted to improve the protection of human health and the environment from the risks that can be posed by chemicals.
FMD/FSD	Full Material Declaration, or Full Substance Declaration (a list of *all* materials and substances, along with their quantities, contained in an article/product/assembly).
GB	Great Britain (United Kingdom, excluding Northern Ireland)
GHS	Globally Harmonized System – The UN publication of a framework for classification and labelling of chemicals (sometimes called the "purple book").
HMTL	Hazardous Materials Target List
Homogeneous material	One material of uniform composition though or in a material, consisting of a combination of materials, which cannot be disjoined or separated into different materials by mechanical actions such as unscrewing, cutting, crushing, grinding, and abrasive processes (RoHS). Example, solder part of a solder joint.
Hotmelt	An adhesive that transitions through a liquid molten form during application but sets into a solid form as it cools.
Jurisdiction	A geographical area, country, or region that falls within the legally enforceable scope of a certain regulatory system or framework.
Material	Matter that is made up of one or more chemical substance(s).
MIL-DTL	Military Detail (specification)
Mixture	A combination of two or more substances.
NAS	National Aerospace Standard
Nominal	A stated value that is expected to vary slightly in reality (similar to an average, but is not calculated).
PCB	Printed Circuit Board (not to be confused with Polychlorinated Biphenyls)
Passivation	The process of treating a metal to reduce the chemical reactivity of its surface.
Plating	A process whereby metal is deposited on a surface from a chemical bath.
ppm	parts per million
Product	Any substance, mixture, material, part, subassembly, or assembly up to a finished assembly that is the subject of a declaration.
Requester	The company or other entity requesting a declaration from the supplier; the requester is the default recipient of the supplier's response.
RoHS	Restriction of Hazardous Substances – legislation applicable in the EU[3] and GB.[4]

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011L0065
[4] https://www.gov.uk/guidance/rohs-compliance-and-guidance

Acronym	Definition
Safety Data Sheet (SDS)	A document communicating chemical safety information about a product.
SMD	Surface Mount Device
Subassembly	An article assembled or purchased separately but designed to be incorporated into a larger, more complex manufactured product/assembly.
Substance	Chemical element or compound
Substrate	The surface or base material on which a finish or coating may be applied.
Supplier	A company or other entity responsible for providing a product to a customer.
SVHC	Substance of Very High Concern [see “Candidate List of SVHCs” above]
Threshold	The default concentration above which a substance becomes declarable.
Transformational materials	Materials that have a different final composition of substances after incorporation into a product than the material initially had prior to processing and application to the product.
UK	United Kingdom of Great Britain and Northern Ireland
US	United States
Volatility	A measure of a substance’s tendency to evaporate, given a standard temperature and pressure.

1. Overview of Materials & Substances Declarations

Material and substance data are reported in a “materials and substances declaration” and are referred to simply as a “declaration” throughout this document. The process of gathering declaration information may be managed by an individual company’s internal processes and can include internal information as well as data received from its suppliers. Declarations are subject to the requirements of those business-to-business relationships and regulatory and/or contractual agreements.

This section will provide a brief overview of the driving factors behind declaration development, while Section 2 will outline the general declaration process steps. Section 3 will then walk the reader through a declaration process example for a fictitious complex article. Section 4 discusses special case examples and Section 5 compiles information on substances in products and processes.

1.1. The “Why?”: Declaration Requirements

Material and substance declaration schemes have been established in various industries and companies to obtain product-related substance data from the supply chain. Downstream companies can then use this data to meet chemical reporting requirements, as well as use the information to manage related risks for use, product compliance, and supply chain chemical obsolescence.

Materials and substances declarations may be required for various reasons, including but not limited to:

- compliance with chemical or environmental regulations in the jurisdiction where a product is being shipped, imported into, and/or used in;
- contractual obligations;
- ensuring product safety;
- maintaining transparency in the supply chain; and/or
- obsolescence management.

As significant resources will be needed to develop a declaration, specific needs and goals should be determined at the start of the declaration process.

1.2. The “Who?”: Suppliers and Customers

Obtaining accurate product/process materials and substances data largely depends on the ability to source data from as far upstream in the supply chain as possible. At every supplier level where hardware/components (“articles”) are produced, added materials and substances may affect the composition of a final product at the lower (downstream) tiers of the supply chain. Thus, the requirements for data may be “flowed” up through the supply chain and acquired data must flow down supply chain and be summarized at each lower level to provide an accurate representation of the composition of final products.

In a business-to-business relationship, the data gathering process usually starts with downstream companies imposing declaration requirements on their direct suppliers. These suppliers may then impose similar requirements on their direct suppliers, and this approach may be repeated at each level in the supply chain and is illustrated on Figure 1 below.

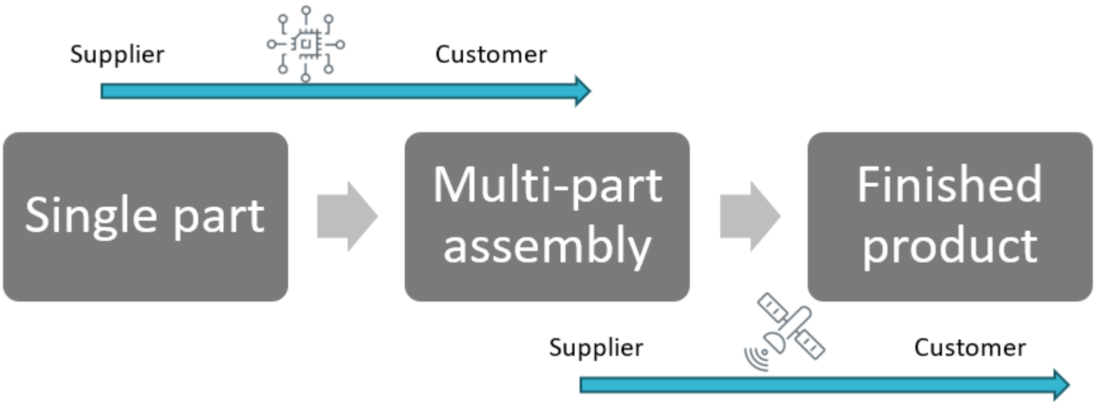

Figure 1. Example of Levels within the Supply Chain

1.3. The "What?": Products (Simple and Complex)

It is important that declaration developers be reasonably knowledgeable about the product and its material content. The product may be a "simple" article (defined as an object which during production is given a special shape, surface, or design which determines its function to a greater degree than its chemical composition[5]), or it may be a "complex" object or product that is made up of several articles. In complex objects/products, several articles can be joined or assembled either by mechanical means or by using substance(s)/mixture(s). If the product is a complex article, some jurisdictions or contracts may require a declaration for each article contained in the product.

Figure 2 is a typical example of a complex product/assembly (a light-emitting diode [LED] lamp). Figure 3 is a general representation of the various components of a complex product/assembly with multiple subassemblies (and articles) within it.

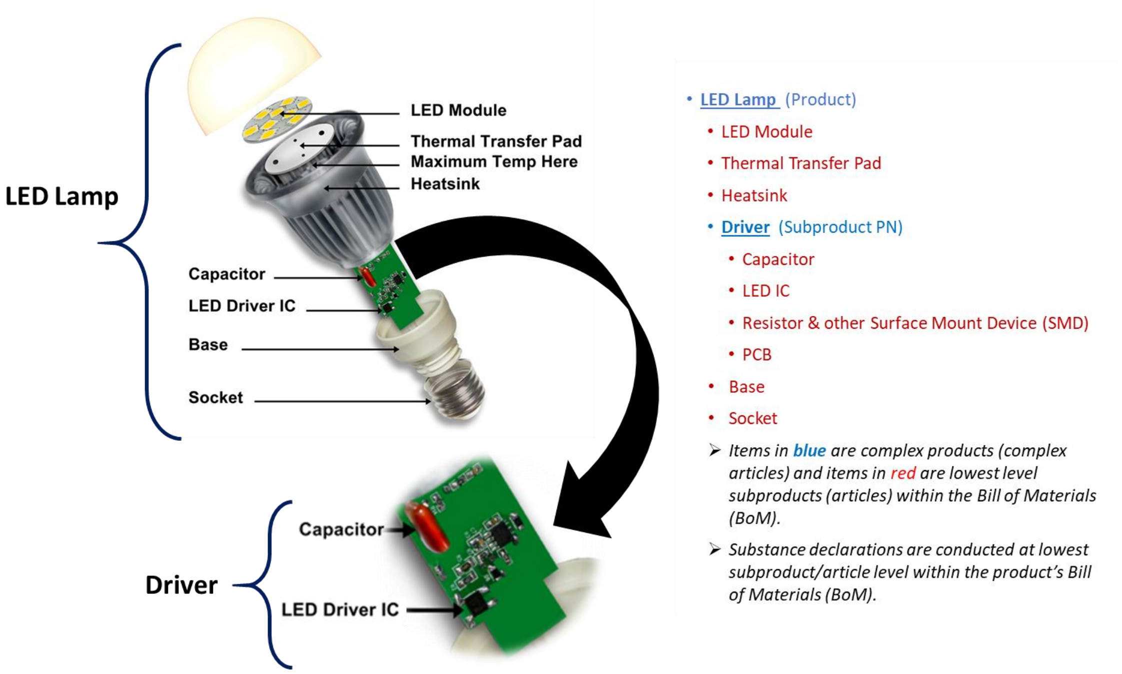

Figure 2. Typical Example of a Complex Product (LED Lamp)

[5] REACH regulation – Article 3, "Definitions"

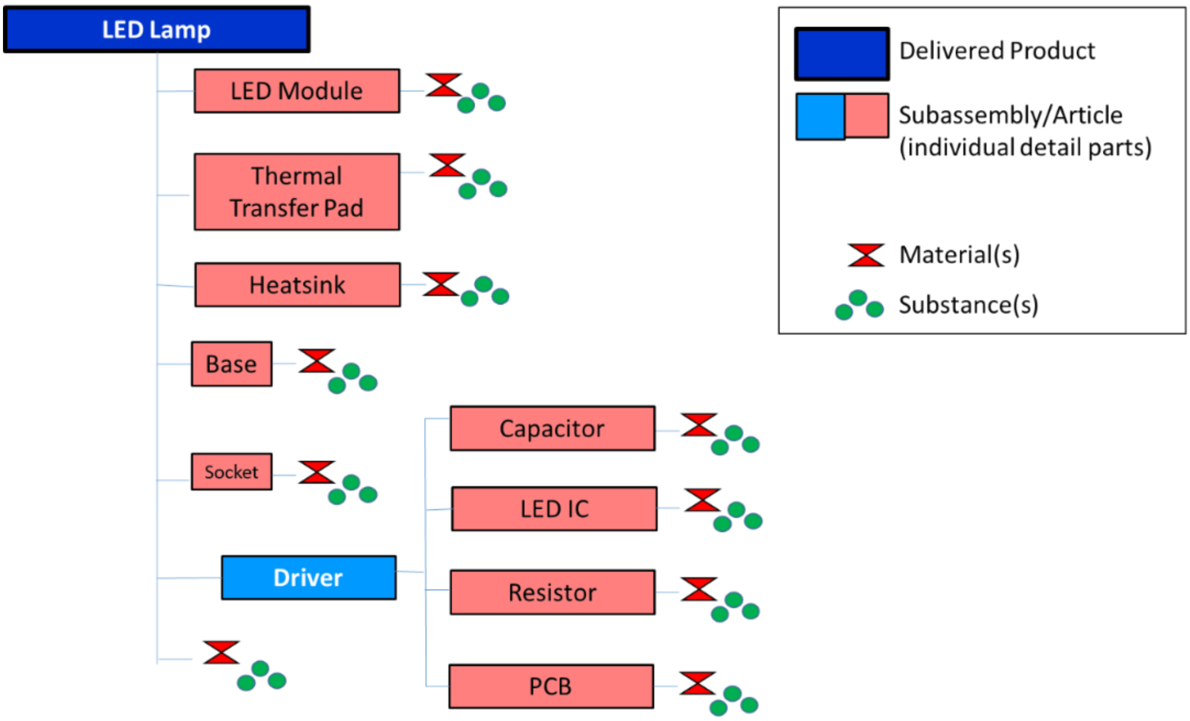

Figure 3. Graphical Representation of a Product with Multiple Subassemblies/Articles

1.4. The "How?": Declaration Process Overview

The declaration process is managed by each company, and procedures may vary from company to company. In general, the supplier will need to identify what is required and what substances are present in the product for which the declaration is generated.

Some factors to consider when determining the requirements for the declaration include:

- legislated/regulatory information
- contractual agreements
- Declarable Substance(s) List(s)
- process substances
- agreed-upon reporting standards or formats
- electronic reporting solutions

This information is then brought together to provide the relevant substance data to stakeholders, both internal (supporting compliance and obsolescence management processes) and external (supporting customers). The sections below (along with Section 5 and the appendices) highlight some potential sources of information and detail the steps that can be taken to generate a materials and substances declaration.

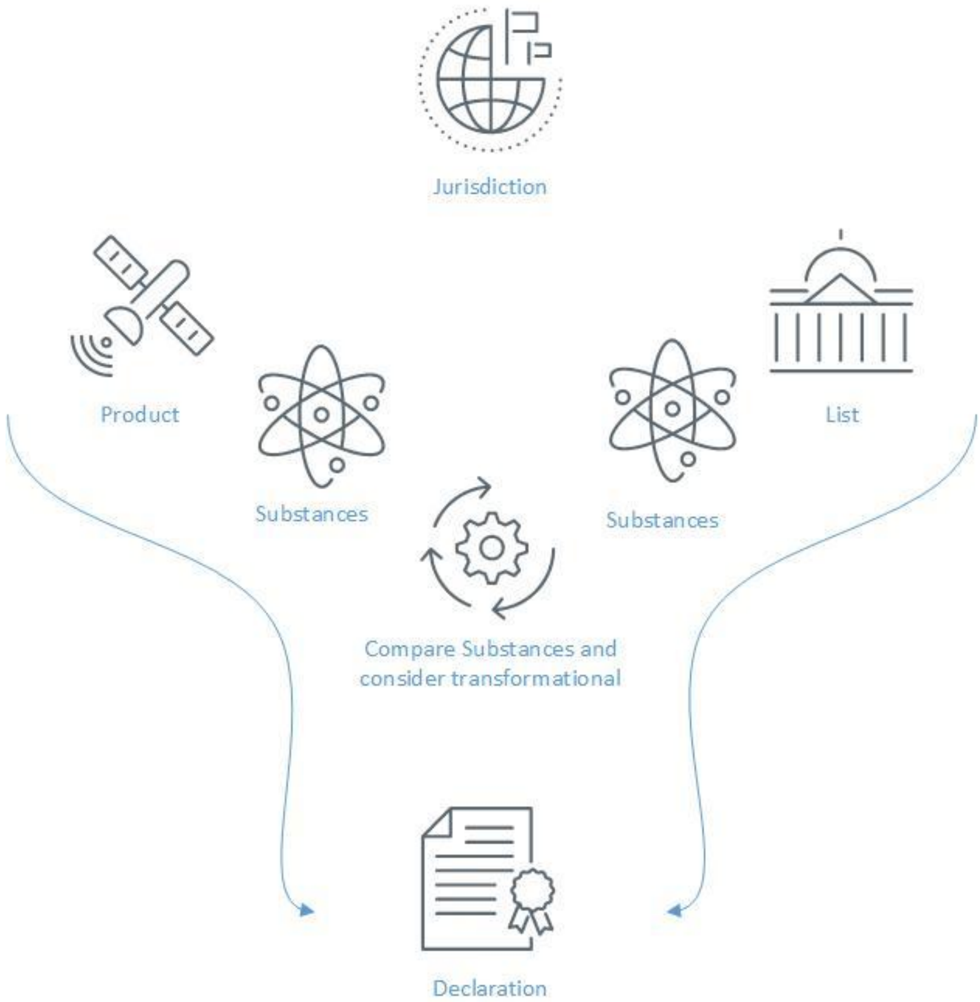

Figure 4. Illustration of how the Various Information Elements Come Together to Form a Materials and Substances Declaration

2. Materials and Substances Declarations Process

This section outlines the steps to develop a materials and substances declaration. Figure 5 is a high-level representation of the typical process a supplier might follow upon receiving a declaration request.

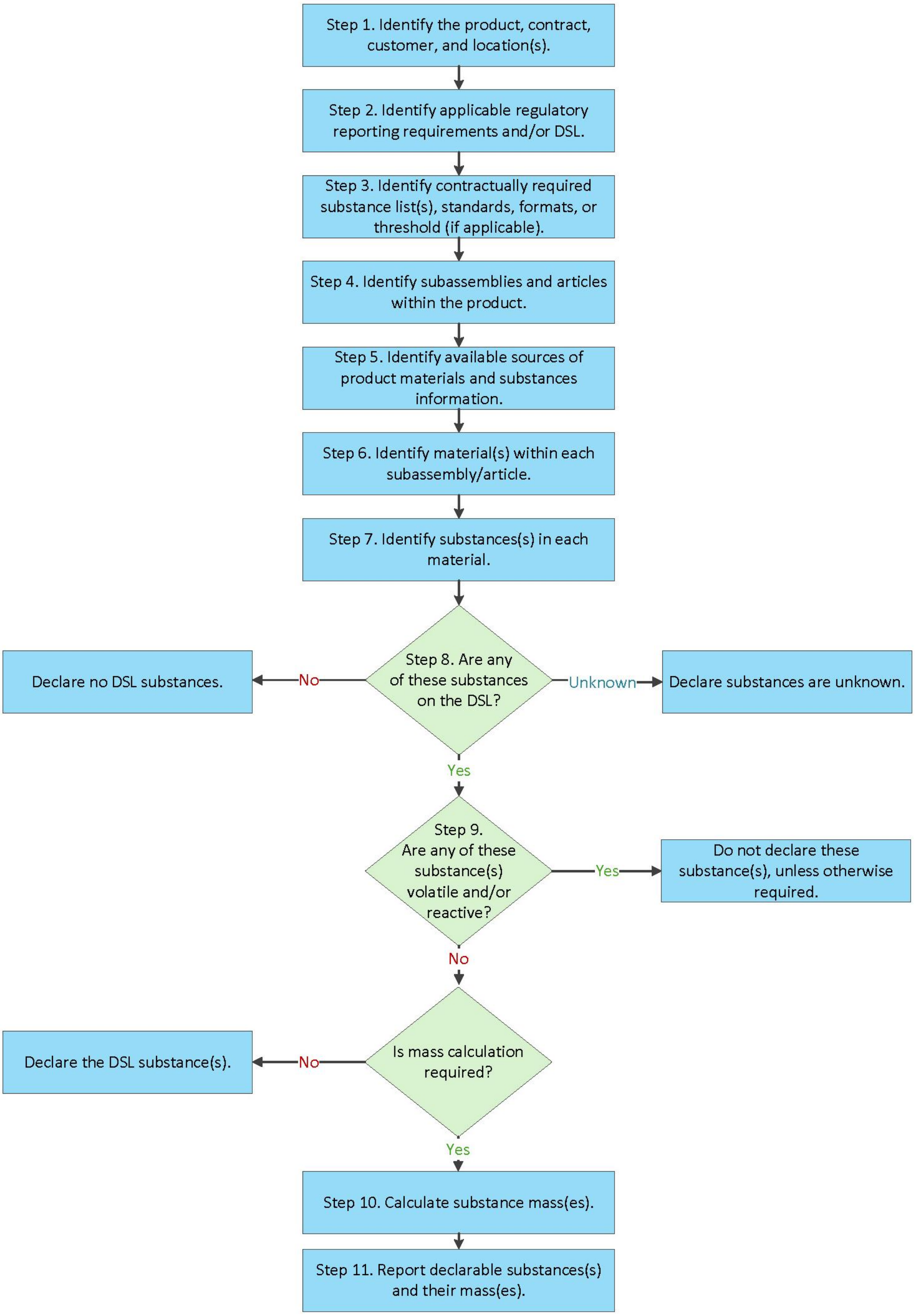

Figure 5. Materials and Substances Declaration Process Flow Chart

2.1. Step 1. Identify the Product, Contract, Customer, and Location(s)

Clearly identify:

- product;
- contract (for agreed-upon obligations);
- customer; and
- shipment locations (for potential import/export/transport/reporting legal requirements).

2.2. Step 2. Identify Applicable Regulatory Reporting Requirements and/or Declarable Substances List

Determine the list(s) of substances that must be declared when present. These will depend on local regulations in all relevant jurisdictions. Note that different regulations require substance reporting at different levels within the product (e.g., European Union [EU] Restriction of Hazardous Substances [RoHS] requires substance calculation at the homogeneous material level, while EU REACH requires substance reporting at the simple article level). Multiple pieces of legislation and contractual obligations may apply to the same product. Determine which are relevant for the current activity.

Some examples of common Declarable Substances Lists (DSLs) include:

- IAEG Aerospace and Defense Declarable Substances List (AD-DSL)
- EU Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) Candidate List of Substances of Very High Concern (SVHCs)
- Aerospace Industries Association (AIA) National Aerospace Standard (NAS) 411-1 Hazardous Materials Target List (HMTL)

2.3. Step 3. Identify Contractually Required Substance List(s), Standards, Formats, and Thresholds (If Applicable)

Identify customer or contract required substance information in addition to what may be legally required. Contracts may also stipulate specific reporting thresholds and/or formats that should be followed when preparing the declaration.

Output: list of requirements for the declaration including product(s), DSL(s), thresholds, and reporting formats, as applicable.

2.4. Step 4. Identify Subassemblies and Articles Within the Product

Determine if the product(s) is composed of subassemblies, if any, from the relevant Bill of Materials (BOM), engineering documentation, or other logical product structure. A subassembly may have additional levels of subassemblies. This information could be obtained internally or by requesting a declaration(s) from the supply chain.

Further information on simple and complex products can be found in Section 1.3.

Output: list of subassemblies and/or articles present in the product for which the declaration is being developed.

2.5. Step 5. Identify Available Sources of Product/Process Materials and Substances Information

Input: list of subassemblies and/or articles present in the product for which the declaration is being developed.

Potential sources of information on materials and substances (not exhaustive):

- internal company resources (e.g., engineering drawings, Computer Aided Design [CAD] data)
- supplier declarations
- specifications
- test data
- Safety Data Sheets (SDS)
- Subject-Matter Experts
- technical data sheets

Output: gathered sources of material composition information.

2.6. Step 6. Identify Material(s) Within Each Subassembly/Article (and Process, if Required)

Input: list of subassemblies and/or articles present in the product for which the declaration is being developed, along with gathered sources of product composition information.

Identify the unique materials (e.g., plastics, metals, ceramics, coatings, adhesives) in the product/assembly (within any subassemblies or articles that may make up the delivered product.)

Output: list of materials contained in each subassembly/article.

2.7. Step 7. Identify Substance(s) in Each Material

Input: list of materials contained in each subassembly/article.

Identify the substance composition of each material using the best available information. Note that in some cases, it may not be possible to determine 100% of the composition. In some cases, the supplier may provide their own declaration that the "unknown" portion does not contain declarable substances.

Some common assumptions and tips for substance identification can be found in Section 5.1.1, p.59.

Output: list of substances in each material.

2.8. Step 8. Identify Declarable Substances

Input: DSL(s) (from Steps 2 and 3) and list of substances in each material (from Step 7).

After identifying the materials and constituent substances, determine if any substances on the DSL(s) were found.

If the customer has requested a Full Material Declaration/Full Substance Declaration (FMD/FSD) alongside a referenced DSL (from Step 2), skip Steps 8 to 11 and declare all identified substances.

Output: list of declarable substances in the material(s) or declare that no DSL substances are present.

2.9. Step 9. Consider which Substance(s) (if any) Would be Present in the Final Product

Input: list of declarable substances in the materials (from Step 8).

Typically, the composition of an outgoing product is the sum of the compositions of the constituent incoming articles and materials used. However, when the incoming constituents undergo transformation as part of the process, the declaration author must determine if any substances are transformed or removed during processing. If so, they may not be present in the outgoing product and should not be included in the materials and substances declaration unless otherwise required by the contract.

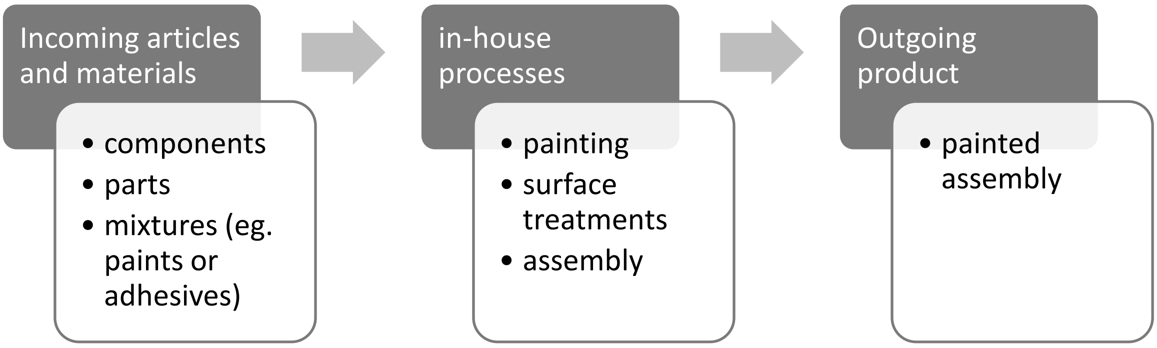

Figure 6. Product/Article Production Process

The section, Information on Substances in Products (Section 5.2, p.60), provides information on typical AD processes that involve transformational materials and how to address them when developing declarations.

Output: list of declarable substances in the final/outgoing product (excluding any transformational substances, unless required by contract).

2.10. Step 10. Calculate Substance Mass(es)

Input: list of declarable substances in the final/outgoing product.

Determine if specific substance quantity/mass data is required. In some cases, substances are not required to be declared if they are only present below a certain threshold (caution – this threshold may be at the top product level, subassembly level, or at the article level.)

Unless otherwise required by the requestor, the substance mass may be reported as a minimum, maximum, minimum to maximum range, or nominal values in relative (e.g., percent) or absolute (e.g., grams) units of measure. Substance mass reported as a percentage of substance in the article is preferred for EU REACH declarations.

Table 2 below illustrates examples of how substance mass data may be provided. Refer to sections 3 and 4 for examples of substance mass calculations.

Table 2. Examples of Substance Mass Data Reporting

Substance Mass				**Cases**
Minimum	**Maximum**	**Nominal**	**Unit of Measure**	
		430	ppm	Mass = 430 ppm
1	7		%	Mass is between 1 to 7%
	27.3		%	Mass is less than or equal to 27.3%
9.6			g	Mass is greater than or equal to 9.6 g
12.1	15.6		kg	Mass is between or equals 12.1 kg and 15.6 kg
			unknown	Mass is unknown

Notes:
% = percent
kg = kilogram
ppm = parts per million

Section 5.1.2 contains several tips for substance mass calculations.

Output: Masses of all declarable substances.

2.11. Step 11. Report Declarable Substance(s) and Their Mass(es)

Input: Declarable substances and their masses.

Provide the declarable substance(s) and associated mass(es) information, as required, to the requester (using the required or agreed-upon format).

3. Example Declaration Process for a Small Complex Assembly (Using AD-DSL)

For the purposes of this declaration process example, several hypothetical parts have been compiled, which will be calculated individually and then mechanically joined as a complex article.

Note that Figure 7 below is a fictitious "product" provided for illustrative purposes only and is not intended to represent any specific supplier product or assembly.

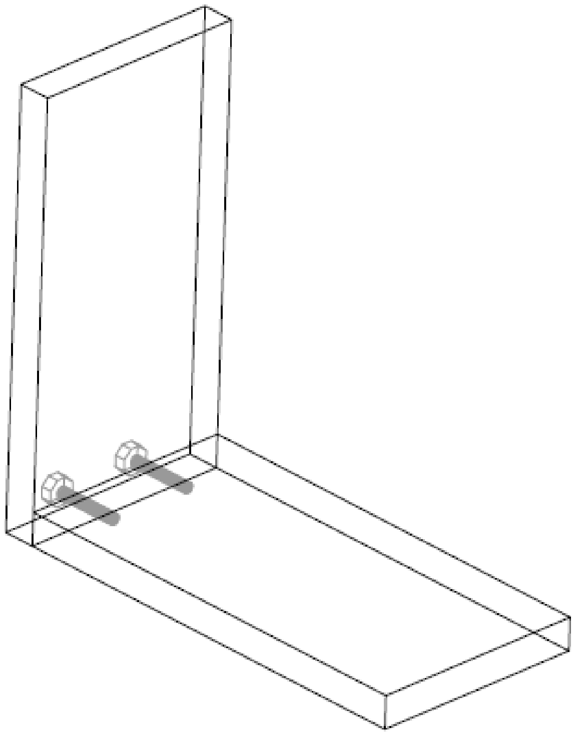

Figure 7. Schematic of Fictitious "Product" Assembly for Declaration Example

3.1. Step 1: Identify the Product, Contract, Customer, Location(s):

Instrument bracket, Contract # 1225SC, Customer is Santa Claus, Location is North Pole.

3.2. Step 2: Identify Applicable Regulatory Reporting Requirements and/or DSL:

AD-DSL version 9

3.3. Step 3: Identify Contractually Required Substance List(s), Standards, Formats, or Threshold (if applicable):

Customer has requested declaration of masses of all declarable substances contained in the product, with no applicable thresholds or required reporting format. Further, the customer has not required the reporting of any impurities, contaminants, or unintentionally added substances.

3.4. Step 4: Identify Subassembly(s) and Articles Within the Product:

Articles include:

3.4.1. Two Cadmium-Plated ISO 4762 (Din 912) M8x16mm A2 Stainless Steel Bolts (Wet-Installed with Threadlocking Compound)

Figure 8. Cadmium-Plated M8x16mm A2 Steel Bolt

3.4.2. Two Anodized/Painted Aluminum Panels with Sealant Applied (Post-Assembly)

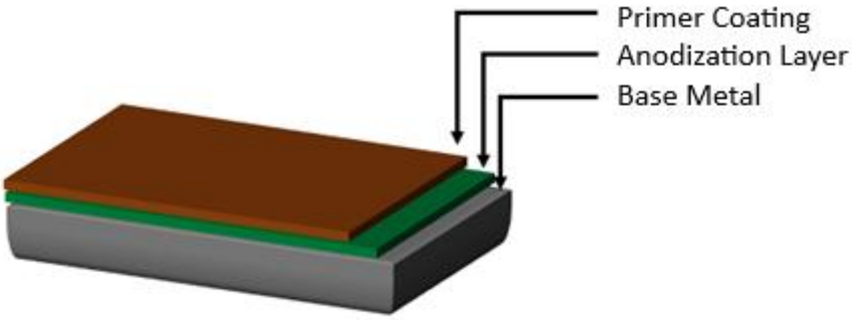

Figure 9. Anodized and Painted Aluminum Plate

3.5. Step 5: Identify Available Sources of Product/Process Materials and Substances Information:

These sources could include, but are not limited to, the following:

- specification that defines bolt steel material and dimensions;
- specification that defines cadmium plating and supplementary surface treatment materials;
- SDS for threadlocking compound;
- specification that defines aluminum panel material;
- engineering drawing that defines aluminum panel dimensions;
- specification and/or SDS that define aluminum anodizing seal process and materials;
- SDS for aluminum primer; and
- reference sources/tables that define material and substance densities.

3.6. Step 6: Identify Material(s) Within Each Subassembly/Article (and Process, if Required):

3.6.1. Bolts

- Substrate(s)
  - Austenitic steel Grade A4-80 per the ISO 3506-1 specification
- Coating(s)
  - Cadmium plating per AMS-QQ-P-416, Type II, Class 2
  - Threadlocking compound (applied to threads)

3.6.2. Panels

- Substrate(s)
  - Aluminum alloy 2024 per AMS-QQ-A-250/4
  -
- Coating(s)
  - Anodization per MIL-PRF-8625, Type IB in chromic acid,
  - Anodize seal (with sodium dichromate supplemental sealing solution)
  - Strontium chromate-based corrosion inhibiting primer per MIL-PRF-23377, Type I (standard pigments), Class C2 (Base and activator)
  - Single-component polyether sealant per ASTM C920, Type S, Grade NS (applied along panels joint/seam**)**

3.7. Step 7: Identify Substance(s) in Each Material:

As required by the requestor in this fictional example, substances that are either used in the manufacturing process (i.e., process substances) and/or the final hardware/product will be identified. With respect to substances present in the hardware, only those that are known to be intentionally added (and with measurable concentrations) will be identified, as allowed by the requestor.

It is important to note, however, that even trace amounts of substances might be subject to restrictions and reporting requirements, depending on the relevant regulation, jurisdiction, and/or contract terms.

3.7.1. Bolts

3.7.1.1 Substrate(s)

- ISO 3506-1, Grade A4-80 – contains carbon, silicon, manganese, phosphorus, sulfur, chromium, molybdenum, nickel, and copper. (Note that alloys are mixtures of metals and other materials. The constituents of an alloy are mixed but not chemically joined.)

3.7.1.2 Coating(s)

- AMS-QQ-P-416, Type II (with supplementary chromate treatment), Class 2 (0.0003-to-0.0005-inch plating thickness) – contains the cadmium-plated layer (Chemical Abstracts Service [CAS] # 7440-43-9) and supplemental surface treatment with hexavalent chromium compounds.

With respect to the composition of the supplementary chromate layer, only a small number of coatings and chromate processes have been characterized by surface analysis techniques. Most of the studies reached conclusions about the chemical composition of the coating from some method of chemical identification. Some of the chemical formulas most ascribed to the compounds in chromate coatings include substrate oxides and hydroxides, substrate chromates, and chromium oxides and hydroxides, to name a few. [6,7] Using this fact, along with results of a typical analysis of a chromate film over zinc or cadmium,[8] the composition of the supplemental chromate layer on cadmium may be deduced to be the following:

Table 3. Substances Present in the Supplementary Chromate Coating on Cadmium (Cd)-Plated Bolt

Substance Name	CAS #	Percentage
Cadmium chromate	14312-00-6	19%
Chromium trioxide	1333-82-0	42%
Cadmium formate	4464-23-7	8%
Cadmium oxide	1306-19-0	8%
Cadmium hydroxide	21041-95-2	8%
Chromium hydroxide	1308-14-1	8%
Water and other compounds	-	7%

Threadlocking compound contains (example composition; may vary between different formulators):

Table 4. Substances in Example Threadlocking Compound (from SDS)

Substance Name	CAS #	Percentage
Silica, surface treated with hexamethyldisilazane – nano	7631-86-9	5 to less than 10%
Cumene hydroperoxide	80-15-9	1 to less than 2.5%
n,n-diethyl-p-toluidine	613-48-9	0.1 to less than 1%
1,4-naphthalenedione	130-15-4	0.01 to less than 0.1%

In this case, the example threadlocking compound supplier discloses less than 13.6% of the total composition. According to the supplier's declaration, the rest of the material (i.e., remaining 86.4%) does not contain any AD-DSL substances.

3.7.2. Panels

3.7.2.1 Substrate(s)

- Aluminum AMS QQ-A-250/4 alloy – contains aluminum, copper, magnesium, manganese, silicon, iron, zinc, and chromium. (Note that alloys are mixtures of metals and other materials. The constituents of an alloy are mixed but not chemically joined.)

3.7.2.2 Coating(s)

- Aluminum anodic coating is a porous aluminum oxide layer (CAS # 7429-90-5).
- Sodium dichromate residue from supplemental sealing solution used to seal the porous anodic coating typically contains a concentration of 65 g/L sodium dichromate (CAS # 10588-01-9).
- MIL-PRF-23377, Type I, Class C2 primer is a two-component mixture with the following substance content (example composition from SDS; may vary between different formulators) as noted in Table 5 and Table 6.

[6] Zhang, Wenping (2002). *Formation and Corrosion Inhibition Mechanisms of Chromate Conversion Coatings on Aluminum and AA2024-T3* [Doctoral dissertation, Ohio State University]. ProQuest Dissertations and Theses Database.
[7] Pokorny, P., Tej, P., and Szelag, P.(2016). Chromate Conversion Coatings and Their Current Application. *Metalurgija, 55*(2), 253-256.
[8] Lowenheim, F.A. (1978). *Electroplating*. McGraw-Hill. 444.

Table 5. Substances in Primer Activator Component

Substance Name	CAS #	Percentage
Polyaminoamide	68082-29-1	20 – 50%
Benzyl alcohol	100-51-6	10 – 16%
Formaldehyde, polymer with hydrogenated	135108-88-2	10 – 20%
4-methylpentan-2-one	108-10-1	10 – 20%
Cyclohexanone	108-94-1	5.0 – 10%
Heptan-2-one	110-43-0	5.0 – 10%
2,4,6-tris(dimethylaminomethyl)phenol	90-72-2	5.0 - 8.3%
Benzyldimethylamine	103-83-3	0.10 - 2.7%
N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine	35141-30-1	1.0 - 5.0%
3,6-diazaoctanethylenediamin	112-24-3	≤1.9%
Salicylic acid	69-72-7	1.0 - 5.0%
4,4'-methylenebis(cyclohexylamine)	1761-71-3	≤1.9%
Bis[(dimethylamino)methyl]phenol	71074-89-0	1.0 - 5.0%

Table 6. Substances in Primer Base Component

Substance Name	CAS #	Percentage
Strontium chromate	7789-06-2	20 to 34%
Phenol, polymer with formaldehyde, glycidyl ether	28064-14-4	10 to 20%
Titanium dioxide	13463-67-7	5.0 to 10%
Heptan-2-one	110-43-0	5.0 to 10%
Butanone	78-93-3	5.0 to 8.0%
Talc: hydrated magnesium silicate	14807-96-6	1.0 to 5.0%
Barium sulfate	7727-43-7	1.0 to 5.0%
4-methylpentan-2-one	108-10-1	1.0 to 4.1%
Cashew, nutshell liq., oligomeric reaction products with 1-chloro-2,3-epoxypropane	68413-24-1	1.0 to 5.0%
Xylene	1330-20-7	less than or equal to 1.6%
Toluene	108-88-3	less than or equal to 1.2%
Barium chromate	10294-40-3	less than 1.0%
Ethylbenzene	100-41-4	less than 1.0%

- Single-component polyether sealant per ASTM C920, Type S, Grade NS with the following substance content (example composition; may vary between different formulators) and are summarized in Table 7 below:

Table 7. Substances in Single-Component Polyether Sealant

Substance Name	CAS #	Percentage
Calcium carbonate	471-34-1	25 to 50%
Natural limestone	1317-65-3	25 to 50%
Diisodecyl phthalate	68515-49-1	15 to 35%
Stearic acid, pure	57-11-4	5 to 10%
Titanium dioxide	13463-67-7	2 to 12%
Trimethoxyvinylsilane	2768-02-7	less than or equal to 2.5%
Methanol	67-56-1	less than or equal to 2.5%

Table 7. Substances in Single-Component Polyether Sealant

Substance Name	CAS #	Percentage
n-(3-(trimethoxysilyl)propyl)ethylenediamine	1760-24-3	less than or equal to 2.5%
2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol	25973-55-1	less than or equal to 2.5%
Quartz (SiO_2)	14808-60-7	less than or equal to 2.5%

3.8. Step 8: Identify Declarable Substance(s):

Compare the substances from Step 7 to the substances on the AD-DSL v9 (as specified in Step 3).

3.8.1. Bolts

- Substrate(s)
  - Copper (CAS # 7440-50-8)
  - Manganese (CAS # 7439-96-5)

- Coating(s)
  - Cadmium plating
    - Cadmium (CAS # 7440-43-9)
    - Cadmium chromate (CAS # 14312-00-6)
    - Chromium trioxide (CAS # 1333-82-0)
    - Cadmium formate (CAS # 4464-23-7)
    - Cadmium oxide (CAS # 1306-19-0)
    - Cadmium hydroxide (CAS # 21041-95-2)
    - Chromium hydroxide (CAS # 1308-14-1)
  - No AD-DSL substances are present in threadlocker.

3.8.2. Panels

- Substrate(s)
  - Copper (CAS # 7440-50-8)
  - Manganese (CAS # 7439-96-5)
  - Zinc (CAS # 7440-66-6)
  - Chromium (CAS # 7440-47-3)
- Anodization layer
  - None
- Coating – Anodization Seal
  - Sodium dichromate (CAS # 10588-01-9)
- Coating – Primer
  - Activator
    - Benzyl alcohol (CAS # 100-51-6)
    - Heptan-2-one (CAS # 110-43-0)
    - N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine (CAS # 35141-30-1)
    - Salicylic acid (CAS # 69-72-7)
  - Base
    - Strontium chromate (CAS # 7789-06-2)
    - Phenol, polymer with formaldehyde, glycidyl ether (CAS # 28064-14-4)

- Titanium dioxide (CAS # 13463-67-7)
- Heptan-2-one (CAS # 110-43-0)
- Butanone (CAS # 78-93-3)
- Talc: hydrated magnesium silicate (CAS # 14807-96-6)
- Xylene (CAS # 1330-20-7)
- Toluene (CAS # 108-88-3)
- Barium chromate (CAS # 10294-40-3)
- Ethylbenzene (CAS # 100-41-4)

- Coating – Sealant
  - Calcium carbonate (CAS # 471-34-1)
  - Limestone (CAS # 1317-65-3)
  - Diisodecyl phthalate (CAS # 68515-49-1)
  - Titanium dioxide (CAS # 13463-67-7)
  - Methanol (CAS # 67-56-1)
  - n-(3-(trimethoxysilyl)propyl)ethylenediamine (CAS # 1760-24-3)
  - 2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol (CAS # 25973-55-1)
  - Quartz (CAS # 14808-60-7)

3.9. Step 9: Consider Which Substance(s), if any, Would be Present in the Final Product:

By searching through literature and data on substance boiling points, the volatile substances can be excluded from the declaration and mass calculations (and are crossed out with a single line on the substance lists below). These substances are present during the manufacturing process, but due to their volatility, they would not typically remain on the finished product.

In addition to volatility, some substances may not be present in significant amounts in the final product due to transformation into other substances or compounds, through chemical reactions like polymerization or curing. These situations typically occur in multi-component systems or those requiring thermal or UV activation. Suppliers are usually the best resource to identify which (if any) substances react during curing (if reacted/cured in compliance with manufacturer guidelines.)

In the example below, the reactive substances are crossed out with double lines.

3.9.1. Bolts

- Substrate(s)
  - Copper (CAS # 7440-50-8)
  - Manganese (CAS # 7439-96-5)

- Coating(s)
  - Cadmium (CAS # 7440-43-9)
  - Cadmium chromate (CAS # 14312-00-6)
  - Chromium trioxide (CAS # 1333-82-0)
  - Cadmium formate (CAS # 4464-23-7)
  - Cadmium oxide (CAS # 1306-19-0)
  - Cadmium hydroxide (CAS # 21041-95-2)
  - Chromium hydroxide (CAS # 1308-14-1)

3.9.2. Panels

- Substrate(s)
    - Copper (CAS # 7440-50-8)
    - Manganese (CAS # 7439-96-5)
    - Zinc (CAS # 7440-66-6)
    - Chromium (CAS # 7440-47-3)
- Anodization layer
    - None
- Coating – Anodization Seal

  Sodium dichromate (CAS # 10588-01-9)
- Coating - Primer
    - Activator
        - Benzyl alcohol (CAS # 100-51-6)
        - ~~Heptan-2-one (CAS # 110-43-0)~~
        - N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine (CAS # 35141-30-1)
        - Salicylic acid (CAS # 69-72-7)
    - Base
        - Strontium chromate (CAS # 7789-06-2)
        - ~~Phenol, polymer with formaldehyde, glycidyl ether (CAS # 28064-14-4)~~
        - Titanium dioxide (CAS # 13463-67-7)
        - ~~Heptan-2-one~~ (CAS # ~~110-43-0)~~
        - ~~Butanone (CAS # 78-93-3)~~
        - Talc: hydrated magnesium silicate (CAS # 14807-96-6)
        - ~~Xylene (CAS # 1330-20-7)~~
        - ~~Toluene (CAS # 108-88-3)~~
        - Barium chromate (CAS # 10294-40-3)
        - ~~Ethylbenzene~~ (CAS # ~~100-41-4)~~
- Coating - Sealant
    - Calcium carbonate (CAS # 471-34-1)
    - Limestone (CAS # 1317-65-3)
    - Diisodecyl phthalate (CAS # 68515-49-1)
    - Titanium dioxide (CAS # 13463-67-7)
    - ~~Methanol (CAS # 67-56-1)~~
    - n-(3-(trimethoxysilyl)propyl)ethylenediamine (CAS # 1760-24-3)
    - 2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol (CAS # 25973-55-1)
    - Quartz (CAS # 14808-60-7)

3.10. Step 10: Calculate Substance Mass(es):

For more detailed information and derivation of substance mass calculation equations used throughout this section, please refer to Appendix D.

3.10.1. Bolts

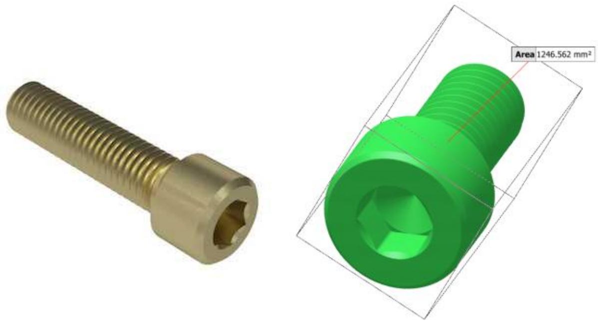

Figure 10. Cadmium-Plated Steel Bolt

3.10.1.1 Substrate Alloy

According to literature[9], the composition of the A4-80 steel is listed below in Table 8:

Table 8. Composition of A4-80 Steel

Substance Name	Mass % (maximum)
Carbon	0.08
Manganese	2.00
Phosphorus	0.045
Sulfur	0.03
Silicon	1.00
Chromium	18.5
Nickel	15.0
Molybdenum	3.0
Copper	4.00
Iron	56.345

From Section 3.8.1, p.26, we know that only copper and manganese are reportable.

Since the mass of the bolt is 11.6g, the mass of each listed substance in the bolt can be calculated using their maximum mass % values as listed below in Table 9.

Table 9. Mass of Substances in Each Bolt

Substance Name	Mass in Each Bolt (maximum)
Manganese	0.23g
Copper	0.46g

[9] https://www.lsfe.com/specification/bs-en-iso-3506-1-a4-80-bolting-nuts/

Finally, since there are two bolts in the assembly, the total substance masses can be reported listed below in Table 10:

Table 10. Mass of Substances in Two Bolts

Substance Name	Mass in Two Bolts
Manganese	0.46g
Copper	0.92g

3.10.1.2 Cadmium Plating

<u>Basis:</u>

Surface area *Article* (surface area of each bolt) = ***Surface area*** *Coating*

Mass *Article* = 11.6 g

Thickness *Coating* **(**AMS-QQ-P-416 Class 2 maximum cadmium thickness**) =** 0.0127 mm (0.00127 cm)

Density *Coating* **(density of cadmium) =** 8.65 g/cm^3

Substance fraction *Substance in coating* = 1 (assume plating is 100% cadmium)

<u>Calculations:</u>

In general, the most accurate and often the most efficient method for calculating surface area is using 3D CAD modeling or precision metrology.

In some cases, CAD drawings of standard parts are available online from the supplier.

If a CAD drawing is not available, certain properties may be estimated using standard geometric formulas. However, be aware that the more complicated the article geometry (particularly surface details) the farther an estimation is likely to be from the true value. A comparison of the surface area of a bolt calculated by CAD and geometric simplification is provided below.

Surface area *Bolt* **(from CAD)**: 1246.53 mm^2

Surface Area : Step-by-Step Calculation Method

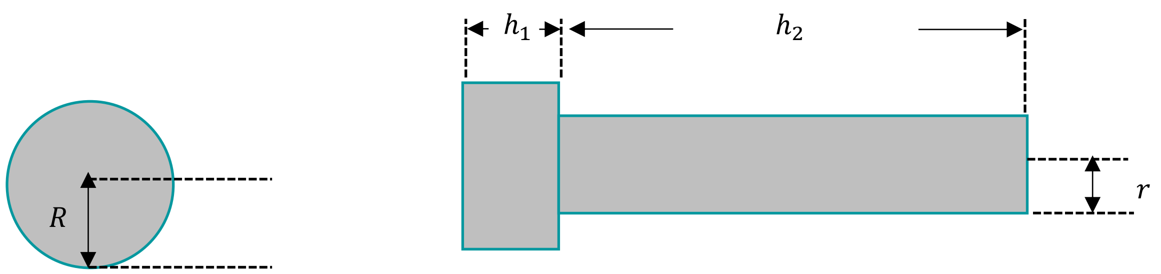

Figure 11. Schematic of Steel Bolt

To estimate the total surface area of the fully threaded socket cap head bolt, both the bolt head and the threaded length can be approximated as two cylinders, for which the surface areas can be calculated as follows:

$$\boldsymbol{A_{Bolt\ head} = 2\pi R h_1 + 2\pi R^2}$$

$$\boldsymbol{A_{Bolt\ shank/threads} = 2\pi r h_2 + 2\pi r^2}$$

The total bolt surface area (A) will then be:

$$\boldsymbol{A_{Bolt} = A_{Bolt\ head} + A_{Bolt\ shank/threads}}$$

When estimating the bolt surface area using these two joined cylinders, the calculation will only include the surfaces that would be exposed if the cylinders were fixed to each other. By removing an endcap with the small radius from each cylinder's individual calculation, the final equation for estimating a bolt's surface area can be determined.

$$\boldsymbol{A_{Bolt\ head,exposed} = 2\pi R h_1 + 2\pi R^2 - \pi r^2}$$

$$\boldsymbol{A_{Bolt\ shank/threads,exposed} = 2\pi r h_2 + 2\pi r^2 - \pi r^2}$$

$$= 2\pi r h_2 + \pi r^2$$

$$\boldsymbol{A}_{Bolt} = \boldsymbol{A}_{Bolt\ head,exposed} + \boldsymbol{A}_{Bolt\ shank/threads,exposed}$$

$$\boldsymbol{A_{Bolt} = \left(2\pi R h_1 + 2\pi R^2 - \pi r^2\right) + \left(2\pi r h_2 + \pi r^2\right)}$$

$$\boldsymbol{A_{Bolt} = 2\pi R h_1 + 2\pi R^2 + 2\pi r h_2}$$

$$\therefore\ \boldsymbol{A_{Bolt} = 2\pi(R h_1 + r h_2) + 2\pi R^2}$$

<u>Bolt Head</u>

R = 6.5mm
h_1 = 8mm

<u>Bolt Shank/Threads</u>

r = 3mm
h_2 = 16mm

$$\boldsymbol{A}_{Bolt} = 2\pi(R h_1 + r h_2) + 2\pi R^2$$

$$\boldsymbol{A}_{Bolt} = 2\pi(6.5mm\ x\ 8mm + 3mm\ x\ 16mm) + 2\pi(6.5mm)^2$$

$$\boldsymbol{A}_{Bolt} = 2\pi(52 + 48) + 2\pi(42.25) = 893.33\ \text{mm}^2$$

Thus,

Surface area $_{\textit{\textbf{Bolt}}}$ = ***Surface area*** $_{\textit{\textbf{Coating}}}$ = 893.33 mm^2

However, the CAD model had calculated the surface area as: 1246.53 mm^2 (or 12.47 cm^2), making the estimated value almost 30% lower than the "true" value. There are studies[10] that show that using basic/cylindrical models to approximate the geometry of a threaded bolt can greatly underestimate the actual surface area, and it is therefore preferred to use CAD dimensions when available.

Next, to calculate the cadmium mass:

Mass *Cadmium in bolt* = ***Mass*** *Cadmium in plating* (because cadmium is only present in the plating)

From **3.10.1.2**,

$$\boldsymbol{Volume_{coating}} = \boldsymbol{Surface\ area_{coating}} \times \boldsymbol{Thickness_{coating}}$$

$$\boldsymbol{Volume_{coating}} = 12.47\ cm^2 \times 0.00127\ cm = 0.0158\ cm^3$$

Using the volume and the density of cadmium, calculate the mass:

Mass *Cadmium in bolt* = ***Mass*** *Cadmium in plating* (because cadmium is only present in the plating)

$$\boldsymbol{Mass}\ \%_{\boldsymbol{substance\ in\ coating}} = \frac{\boldsymbol{Mass_{substance\ in\ coating}}}{\boldsymbol{Mass_{bolt}}} \times \mathbf{100}$$

$$\boldsymbol{Mass}_{Cadmium\ in\ plating} = \boldsymbol{Substance\ fraction}_{Cadmium\ in\ plating} \times \boldsymbol{Volume}_{Plating} \times \boldsymbol{Density}_{Cadmium}$$

$$\boldsymbol{Mass}_{Cadmium\ in\ plating} = 1 \times 0.0158\ cm^3 \times 8.65\ \frac{g}{cm^3} = 0.14g$$

Since there are two bolts present in this assembly, the total cadmium mass would be declared as **0.28g**.

Table 11. Amount of Cadmium Present in Plating of Two Bolts

Substance Name	Mass in Two Bolts
Cadmium	0.28 g

If required/desired, the quantity can be calculated as a mass %:

$$\boldsymbol{Mass}\ \%_{\boldsymbol{substance\ in\ coating}} = \frac{\boldsymbol{Mass_{substance\ in\ coating}}}{\boldsymbol{Mass_{article}}} \times \mathbf{100}$$

$$\boldsymbol{Mass}\ \%_{\boldsymbol{Cadmium\ in\ article}} = \left(\frac{\boldsymbol{mass_{Cadmium\ in\ plating}}}{\boldsymbol{mass_{bolt}}}\right) \times \mathbf{100}$$

= (0.14g/11.6g) * 100 = 1.2%

3.10.1.3 Supplemental Chromate Treatment/Coating

The cadmium-plated bolt is treated with a chromate solution for additional protection. The mass of the declarable substances remaining on the bolt follows is calculated below.

[10] Rammer, D.R. and Zelinka, S.L. (2008). Analytical Determination of the Surface Area of a Threaded Fastener. *Journal of Testing and Evaluation, 36(1)*, 1-9.

As discussed in step 7 (3.7.1.2, p.23) above, the substances below could be expected to be present in the supplementary chromate layer over cadmium plating with approximate mass percentages shown in Table 12 below.

Table 12. Substances Present in the Supplementary Chromate Coating on Cd-Plated Bolt

Substance Name	Mass % $_{\text{Substance in coating}}$
Cadmium chromate	19%
Chromium trioxide	42%
Cadmium formate	8%
Cadmium oxide	8%
Cadmium hydroxide	8%
Chromium hydroxide*	8%
Water and other compounds*	7%

*Not declarable in this example (i.e., not on the AD-DSL)

Given the mass percentages shown in Table 12 above, it is easy to see how much of each substance would be present in a hypothetical 1 gram (g) quantity of supplemental chromate coating (i.e., substance fraction) as shown in Table 13 below:

Table 13. Mass of Substances Present in 1 g of Supplementary Chromate Coating

Substance Name	Mass %	Substance Mass in 1 g of Coating (g)
Cadmium chromate	19%	0.19
Chromium trioxide	42%	0.42
Cadmium formate	8%	0.08
Cadmium oxide	8%	0.08
Cadmium hydroxide	8%	0.08
Chromium hydroxide	8%	0.08
Water and other compounds	7%	0.07
Sum	**100%**	**1.00g**

Using each of the substance masses in the hypothetical 1 g of coating, along with their densities (from literature), the volume of each substance in the hypothetical 1 g of coating can be calculated (and shown in the last column of Table 14 below):

$$\boldsymbol{Volume\ (cm^3) = \frac{Mass\ (g)}{Density\ (\frac{g}{cm^3})}}$$

Table 14. Calculation of Substance Volumes in 1 g of Supplementary Chromate Coating

Substance Name	Substance Mass in 1 g of Coating (g)	Density (g/cm³)	Substance Volume in 1 g of Coating (cm³)
Cadmium chromate	0.19	4.5	0.042
Chromium trioxide	0.42	2.7	0.16
Cadmium formate	0.08	2.34	0.034
Cadmium oxide	0.08	8.15	0.0098
Cadmium hydroxide	0.08	4.79	0.017
Chromium hydroxide	0.08	3.11	0.026
Water & other compounds	0.07	1.01	0.069
Sum	**1.00 g**	**-**	**0.35 cm³**

As shown in the bottom line of the table, adding all of the constituent substance volumes yields a total coating volume of 0.35 cm^3. Using the volume of 1 g of coating, the coating density is calculated as:

$$\boldsymbol{Density} = \frac{\boldsymbol{Mass}}{\boldsymbol{Volume}}$$

$$\boldsymbol{Density} = \frac{1g}{0.35\ cm^3} = 2.8\ \frac{g}{cm^3}$$

Thicknesses of supplementary chromate treatments on plating materials such as cadmium are not generally measured or controlled. However, these coatings are somewhat like chromate passivation of steels, so based on the thickness of passivation coatings (0.00005 inch maximum = 1.27µm) the substance calculations would be as follows:

Surface area $_{Bolt}$ = 12.47 cm^2

Thickness $_{Coating}$ = 0.000127 cm

$$\boldsymbol{Volume_{coating}} = \boldsymbol{Surface\ area_{coating}} \times \boldsymbol{Thickness_{coating}}$$

$$= 12.47\ cm^2 \times 0.000127\ cm = 0.00158\ cm^3$$

$$\boldsymbol{Mass_{coating}} = \boldsymbol{Volume_{coating}} \times \boldsymbol{Density_{coating}}$$

$$\boldsymbol{Mass}_{coating} = 0.0158\ cm^3 \times 2.8\ \frac{g}{cm^3} = 0.00448g$$

Using this total coating mass along with each of the substance mass percentages (i.e., substance fractions), the mass of each substance can be calculated with formula below and detailed in Table 15 below:

$$\boldsymbol{Mass_{substance\ in\ coating}} = \boldsymbol{Mass_{coating}} \times \boldsymbol{Substance\ fraction_{substance\ in\ coating}}$$

Table 15. Declarable Substances (and Their Masses) in the Supplementary Chromate Coating on Cd-Plated Bolts

Substance Name	Mass %	Substance Mass in Each Bolt (g)	Substance Mass in Two Bolts (g)
Cadmium chromate	19%	0.000851	0.0017
Chromium trioxide	42%	0.00188	0.0038
Cadmium formate	8%	0.000358	0.00072
Cadmium oxide	8%	0.000358	0.00072
Cadmium hydroxide	8%	0.000358	0.00072

Since there are two bolts present in this assembly, the total mass of each of the declarable substances in Table 15 will be doubled on the final declaration (as shown in the right-most column above).

If required/desired, the substance quantities can be calculated as mass % (where the bolt mass is 11.6 g) and shown in Table 16:

$$\boldsymbol{Mass}\ \%_{\boldsymbol{substance\ in\ coating}} = \frac{\boldsymbol{Mass_{substance\ in\ coating}}}{\boldsymbol{Mass_{article}}} \times \mathbf{100}$$

Table 16. Declarable Substances (and Their Mass Percentages) in the Supplementary Chromate Coating on Cd-Plated Bolts

Substance Name	Substance Mass in Each Bolt (g)	Substance Mass % of Bolt
Cadmium chromate	0.000851	0.0073%
Chromium trioxide	0.00188	0.016%
Cadmium formate	0.000358	0.0030%
Cadmium oxide	0.000358	0.0030%
Cadmium hydroxide	0.000358	0.0030%
~~Chromium hydroxide~~[1]	~~0.000358~~	~~0.0030%~~
~~Water & other compounds~~	~~0.000314~~	~~0.0027%~~
Sum	**0.00448 g**	**0.038%**
Note: *1. The non-AD-DSL substances will be excluded from the declaration and are therefore stricken out.*		

As an added check, the sum of the Mass % is equal to the total mass of the coating divided by the weight of the bolt. (0.00448 g / 11.6 g x 100 = 0.038%).

3.10.2. Panels

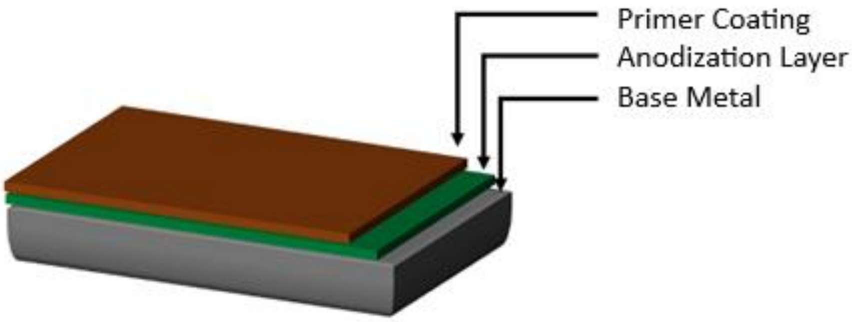

Figure 12. Anodized and Painted Aluminum Plate

3.10.2.1 Panel substrate

Two identical Panels:
Panel dimensions = 50 cm x 25 cm x 1 cm
Mass $_{Article}$ (each aluminum panel, from CAD data*)* = 3375 g (3.4 kg)

According to AMS QQ A-250/4 the aluminum alloy used in the panels consists of the elements listed in Table 17.

Table 17. Composition of AMS QQ A-250/4 Aluminum Alloy

Substance	CAS #	Mass % Range
Copper	7440-50-8	3.8-4.9%
Manganese	7439-96-5	0.3-0.9%
Zinc	7440-66-6	0.25%
Chromium	7440-47-3	0.1%

For calculation purposes, the "worst case" (highest) value is used. The masses of declarable substances in each panel are shown in Table 18.

Table 18. Total Masses of AD-DSL Substances in Aluminum Panels

Substance	Mass %	Mass in Each Panel (g)	Mass in Two Panels (g)
Copper	4.90%	165	330
Manganese	0.90%	30.4	60.8
Zinc	0.25%	8.5	17
Chromium	0.10%	3.4	6.8

3.10.2.2 Anodizing Seal on Aluminum Panel (Sodium dichromate)

Basis:

Surface area *Article* (each aluminum panel) = ***Surface area*** *Anodic coating*

Thickness *Anodic coating* (maximum anodic coating thickness from specification) = 0.01778 mm

Concentration *Sodium dichromate* (maximum concentration of sodium dichromate in sealant solution)

= 65 g/L = 6.5×10^{-5} g/mm^3

Calculations:

Using the formula for surface area of a rectangular prism:

Surface area *Article* (each aluminum panel) = ***Surface area*** *Anodic coating* = 2 (w*l + h*l + h*w)

Where:

l = length = 50 cm
w = width = 25 cm
h = height = 1 cm

Surface area *Article* (each aluminum panel) = ***Surface area*** *Anodic coating*

= 2 (25*50 + 1*50 + 1*25) = 2650 cm^2 (2.65×10^5 mm^2)

The anodize process creates a porous coating on the base material. The dichromate sealing process involves reactions with the porous anodic surface where the Cr^{+6} is entrapped in the walls of the anodize coating as a reservoir for a self-healing type of corrosion protection. One can assume that the pores are completely filled with the dichromate solution and that all the Cr^{+6} present remains (worst-case situation, as rinsing will remove some Cr^{+6}). Lab data shows a typical/visible porosity of 10 to 50% in the coating[11], but from the view of corrosion protection, it is suggested by some[12] that the porosity of anodic films should be controlled below 30%. For this reason, a conservative porosity value of 40% will be used for this calculation.

[11] Petukhov, D. I.; Buldakov, D. A., Tishkin, A. A.; Lukashin, A. V.; Eliseev A. A(2017). *Beilstein Journal of Nanotechnology*, 8, 561-570.
[12] Zhang, P. and Zuo, Y. (2019). *Materials Chemistry and Physics,* 231, 9-20.

Substance fraction *Sodium dichromate* = Porosity of Anodized Layer = 0.4 (all pores are filled with sodium dichromate solution)

Mass *Sodium dichromate in article* = ***mass*** *Sodium dichromate in anodic coating* (because the substance is only present in the anodized porous protective layer)

Mass *Sodium dichromate in anodic coating* **=** ***Substance fraction*** *Sodium dichromate* ***** ***thickness*** *Anodic coating* ***** ***concentration*** *Sodium dichromate* ***** ***surface area*** *Anodic coating*

= 0.4 * 0.01778 mm * 6.5×10^{-5} g/mm^3 * 2.65×10^5 mm^2

= 0.12 g

Since there are 2 panels in this assembly, the total sodium dichromate mass would be declared as 0.24g.

Table 19. Total Masses of AD-DSL Substances in Anodized Layer on Aluminum Panels

Substance	CAS #	Mass in Each Panel (g)	Mass in Two Panels (g)
Sodium dichromate	10588-01-9	0.12	0.24 g

If required/desired, the quantities can be calculated as a mass %:

$$\boldsymbol{Mass\ \%_{substance\ in\ coating}} = \frac{\boldsymbol{Mass_{substance\ in\ coating}}}{\boldsymbol{Mass_{article}}} \times \mathbf{100}$$

Mass % *Sodium dichromate in article* = **(*mass*** *Sodium Dichromate in anodic coating* **/ *mass*** *article***)** *100

= (0.12/3375) * 100 = 3.6×10^{-3}% (0.0036%)

3.10.2.3 Primer

Step 9 determined that the following substances are declarable and present on the final product (Substances that have been crossed out are declarable, but are volatile or reactive and not present on the final article):

- Activator
  - Benzyl alcohol (CAS # 100-51-6)
  - ~~Heptan-2-one (CAS # 110-43-0)~~
  - N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine (CAS # 35141-30-1)
  - Salicylic acid (CAS # 69-72-7)
- Base
  - Strontium chromate (CAS # 7789-06-2)
  - ~~Phenol, polymer with formaldehyde, glycidyl ether (CAS # 28064-14-4)~~
  - Titanium dioxide (CAS # 13463-67-7)
  - ~~Heptan-2-one (CAS # 110-43-0)~~
  - ~~Butanone (CAS # 78-93-3)~~
  - Talc: hydrated magnesium silicate (CAS # 14807-96-6)
  - ~~Xylene (CAS # 1330-20-7)~~
  - ~~Toluene (CAS # 108-88-3)~~
  - Barium chromate (CAS # 10294-40-3)
  - Ethylbenzene (CAS # 100-41-4)

This section will calculate the amounts of these substances on the aluminum panel, using the following values:

Surface area **panel** = ***Surface area*** **primer** = 2650cm^2 (2.65x10^5 mm^2)

Thickness **primer**= 50µm

$$\boldsymbol{Volume_{coating}} = \boldsymbol{Surface\ area_{coating}} \times \boldsymbol{Thickness_{coating}}$$

$$\boldsymbol{Volume}_{primer} = \boldsymbol{Surface\ area}_{panel} \times \boldsymbol{Thickness}_{primer}$$

$$= 2650\ cm^2 \times 50\mu m \times (1 \times 10^{-4}\ cm/\mu m) = 13.25\ cm^3$$

The most accurate (and therefore preferable) way to determine the dry film density of an applied coating is to obtain that value directly from the coating manufacturer or formulator. For this example, the formulator has stated that the dry film density of the mixed and cured primer is 1.76 g/cm^3.

The mass of the "dry/cured" primer can thus be calculated as:

$$\boldsymbol{Mass_{coating}} = \boldsymbol{Volume_{coating}} \times \boldsymbol{Density_{coating}}$$

$$\boldsymbol{Mass}_{primer} = \boldsymbol{Volume}_{primer} \times \boldsymbol{Density}_{primer}$$

$$\boldsymbol{Mass}_{primer} = 13.25\ cm^3 \times 1.76\ \frac{g}{cm^3} = 23.3g$$

Although the supplier has provided a density of the dry film, the percentage of each substance in the dry film has not been provided. The next calculation considers the difference between substances present in the "as supplied" (i.e., "wet") form and the "cured" (i.e., "dry") form.

SDS (and suppliers) do not often provide a complete material composition, and substance concentrations are often provided in ranges or limits. To continue the substance calculations, the declaration author will need to use judgement and expert advice to estimate the percentage of each declarable substance remaining in the "dry" film. In some cases, it might be sensible to use the maximum of the concentration range for the most hazardous substances (i.e., worst case scenario). In most cases, information will not be available regarding the quantities of undisclosed substances.

In Table 20 and Table 21 below, the primer substance concentrations (in both the activator and base) have been normalized to 100%. The right-most column lists the assumed condition/state of each substance.

Table 20. Normalized Mass Percentages and Physical States of Substances in Primer Activator

Substance	**CAS #**	**Percentage (from SDS)**	**Mass %** Substance in primer **(normalized to 100%)**	**Assumed Condition (Volatile or non-volatile)**
polyaminoamide	68082-29-1	20 to 50%	32.1%	Non-volatile
benzyl alcohol	100-51-6	10 to 16%	10.5%	Non-volatile
Formaldehyde, polymer with benzenamine, hydrogenated	135108-88-2	10 to 20%	12.8%	Non-volatile
4-methylpentan-2-one	108-10-1	10 to 20%	12.8%	Volatile
cyclohexanone	108-94-1	5.0 to 10%	6.4%	Volatile
heptan-2-one	110-43-0	5.0 to 10%	6.4%	Volatile

Table 20. Normalized Mass Percentages and Physical States of Substances in Primer Activator

Substance	CAS #	Percentage (from SDS)	Mass % Substance in primer (normalized to 100%)	Assumed Condition (Volatile or non-volatile)
2,4,6-tris (dimethylaminomethyl) phenol	90-72-2	5.0 to 8.3%	5.3%	Non-volatile
benzyldimethylamine	103-83-3	0.10 to 2.7%	1.7%	Non-volatile
N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine	35141-30-1	1.0 to 5.0%	3.2%	Non-volatile
3,6-diazaoctanethylenediamin	112-24-3	less than or equal to 1.9%	1.2%	Non-volatile
salicylic acid	69-72-7	1.0 to 5.0%	3.2%	Non-volatile
4,4'-methylenebis (cyclohexylamine)	1761-71-3	less than or equal to 1.9%	1.2%	Non-volatile
bis[(dimethylamino)methyl]phenol	71074-89-0	1.0 to 5.0%	3.2%	Non-volatile

Table 21. Normalized Mass Percentages and Physical States of Substances in Primer Base

Substance	CAS #	Percentage (from SDS)	Mass % Substance in primer (normalized to 100)	Assumed Condition (Volatile or non-volatile)
strontium chromate	7789-06-2	20 to 34%	34.00%	Non-volatile
phenol, polymer with formaldehyde, glycidyl ether	28064-14-4	10 to 20%	18.00%	Non-volatile
titanium dioxide	13463-67-7	5.0 to 10%	9.00%	Non-volatile
heptan-2-one	110-43-0	5.0 to 10%	9.00%	Volatile
butanone	78-93-3	5.0 to 8.0%	7.50%	Volatile
talc: hydrated magnesium silicate	14807-96-6	1.0 to 5.0%	4.70%	Non-volatile
barium sulfate	7727-43-7	1.0 to 5.0%	4.75%	Non-volatile
4-methylpentan-2-one	108-10-1	1.0 to 4.1%	4.00%	Volatile
Cashew, nutshell liq., oligomeric reaction products with 1-chloro-2,3-epoxypropane	68413-24-1	1.0 to 5.0%	4.75%	Non-volatile
xylene	1330-20-7	less than or equal to 1.6%	1.50%	Volatile
toluene	108-88-3	less than or equal to 1.2%	1.00%	Volatile
barium chromate	10294-40-3	less than or equal to 1.0%	0.90%	Non-volatile
ethylbenzene	100-41-4	less than or equal to 1.0%	0.90%	Volatile

According to the primer formulator's technical data sheet, the mix ratio between the base and activator should be 3:1 (by volume). Therefore, a hypothetical 1 liter (L) mixture would be comprised of (by volume) 0.75L base and 0.25L activator.

Density $_{Base}$ (from SDS, section 9) = 1.58 g/cm^3

Density $_{Activator}$ (from SDS, section 9) = 0.95 g/cm^3

1 L of mixed ("wet") primer would be comprised of (by weight):

$$\boldsymbol{Mass}_{Base} = \boldsymbol{Volume}_{Base} \times \boldsymbol{Density}_{Base}$$

$$\boldsymbol{Mass}_{Base} = 750mL \times 1.58\frac{g}{mL} = 1185\ g\ or\ 1.185kg$$

Similarly,

$$\boldsymbol{Mass}_{Activator} = 250mL \times 0.95\frac{g}{mL} = 238\ g\ or\ 0.238\ kg$$

Using Table 20 and Table 21 above, the mass of each substance in 1 L can be calculated (and shown in Table 22.)

$$\boldsymbol{Mass}_{Substance}\ in\ 1L = \boldsymbol{Mass}\ \%_{Wet} \times \boldsymbol{Mass}\ in\ 1L\ (either\ 1185g\ or\ 238g\ from\ above)$$

Table 22. Mass of Substances in 1 L of Mixed Wet Primer

Substance	CAS #	Mass % (wet)	Mass in 1 L wet	Assumed Condition (Volatile or non-volatile)
strontium chromate	7789-06-2	34.00%	402.9 g	Non-volatile
phenol, polymer with formaldehyde, glycidyl ether	28064-14-4	18.00%	213.3 g	Non-volatile
titanium dioxide	13463-67-7	9.00%	106.7 g	Non-volatile
heptan-2-one[13]	110-43-0	9.00%	106.7 g	Volatile
butanone	78-93-3	7.50%	88.9 g	Volatile
talc : hydrated magnesium silicate	14807-96-6	4.70%	55.7 g	Non-volatile
barium sulfate	7727-43-7	4.75%	56.3 g	Non-volatile
4-methylpentan-2-one	108-10-1	4.00%	47.4 g	Volatile
Cashew, nutshell liq., oligomeric reaction products with 1-chloro-2,3-epoxypropane	68413-24-1	4.75%	56.3 g	Non-volatile
xylene	1330-20-7	1.50%	17.8 g	Volatile
toluene	108-88-3	1.00%	11.9 g	Volatile
barium chromate	10294-40-3	0.90%	10.7 g	Non-volatile
ethylbenzene	100-41-4	0.90%	10.7 g	Volatile
polyaminoamide	68082-29-1	32.1%	76.4 g	Non-volatile
benzyl alcohol	100-51-6	10.5%	25.0 g	Non-volatile
Formaldehyde, polymer with benzenamine, hydrogenated	135108-88-2	12.8%	30.5 g	Non-volatile
4-methylpentan-2-one	108-10-1	12.8%	30.5 g	Volatile
cyclohexanone	108-94-1	6.4%	15.2 g	Volatile
heptan-2-one[13]	110-43-0	6.4%	15.2 g	Volatile
2,4,6-tris(dimethylaminomethyl)phenol	90-72-2	5.3%	12.6 g	Non-volatile
benzyldimethylamine	103-83-3	1.7%	4.0 g	Non-volatile
N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine	35141-30-1	3.2%	7.6 g	Non-volatile
3,6-diazaoctanethylenediamin	112-24-3	1.2%	2.9 g	Non-volatile
salicylic acid	69-72-7	3.2%	7.6 g	Non-volatile
4,4'-methylenebis(cyclohexylamine)	1761-71-3	1.2%	2.9 g	Non-volatile
bis[(dimethylamino)methyl]phenol	71074-89-0	3.2%	7.6 g	Non-volatile
Note: Base components are shown in the blue rows, while activator components are in green).				

[13] Note that heptan-2-one is listed twice; therefore, masses should be added together.

Using the mass of each substance in 1 L, the mass % of the substances in the mixed, wet primer can be calculated as show in calculation below and further detailed in Table 23 below.

$$\boldsymbol{Mass}\ \%_{Substance\ in\ 1L\ wet} = \frac{\boldsymbol{Mass}\ _{Substance\ in\ 1L\ wet}}{\boldsymbol{Total\ Mass}\ _{1L\ wet\ primer}} \times 100$$

Table 23. Mass Percent of Substances in 1 L of Mixed, Wet Primer

Substance	CAS #	Mass in 1 L wet (g)	Mass % in 1 L wet	Assumed Condition (Volatile or non-volatile)
strontium chromate	7789-06-2	402.9	28.3%	Non-volatile
phenol, polymer with formaldehyde, glycidyl ether	28064-14-4	213.3	15.0%	Non-volatile
titanium dioxide	13463-67-7	106.7	7.5%	Non-volatile
heptan-2-one	110-43-0	121.9	8.6%	Volatile
butanone	78-93-3	88.9	6.2%	Volatile
talc : hydrated magnesium silicate	14807-96-6	55.7	3.9%	Non-volatile
barium sulfate	7727-43-7	56.3	4.0%	Non-volatile
4-methylpentan-2-one	108-10-1	47.4	3.3%	Volatile
Cashew, nutshell liq., oligomeric reaction products with 1-chloro-2,3-epoxypropane	68413-24-1	56.3	4.0%	Non-volatile
xylene	1330-20-7	17.8	1.3%	Volatile
toluene	108-88-3	11.9	0.8%	Volatile
barium chromate	10294-40-3	10.7	0.8%	Non-volatile
ethylbenzene	100-41-4	10.7	0.8%	Volatile
polyaminoamide	68082-29-1	76.4	5.4%	Non-volatile
benzyl alcohol	100-51-6	25.0	1.8%	Non-volatile
Formaldehyde, polymer with benzenamine, hydrogenated	135108-88-2	30.5	2.1%	Non-volatile
4-methylpentan-2-one	108-10-1	30.5	2.1%	Volatile
cyclohexanone	108-94-1	15.2	1.1%	Volatile
2,4,6-tris(dimethylaminomethyl)phenol	90-72-2	12.6	0.9%	Non-volatile
benzyldimethylamine	103-83-3	4.0	0.3%	Non-volatile
N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine	35141-30-1	7.6	0.5%	Non-volatile
3,6-diazaoctanethylenediamin	112-24-3	2.9	0.2%	Non-volatile
salicylic acid	69-72-7	7.6	0.5%	Non-volatile
4,4'-methylenebis(cyclohexylamine)	1761-71-3	2.9	0.2%	Non-volatile
bis[(dimethylamino) methyl]phenol	71074-89-0	7.6	0.5%	Non-volatile

Using the percentages in the table above, the volatile substances are removed, as they no longer contribute to the weight of primer on the product. (Though reactive substances go through a chemical change, the mass remains on the article. To simplify, the mass here is calculated as if they did not change, but the substance is not declared at the end.) The mass % of each substance in the *dry film* can now be calculated.

$$\boldsymbol{Mass\%}_{dry\ substance} = \frac{\boldsymbol{Mass\%}\ _{wet\ substance}}{\boldsymbol{Total\ Mass\%}\ _{wet}} \times 100$$

Table 24. Mass Percent of Substances in Mixed, Dry Primer

Substance	CAS #	Mass % Wet	Mass % Dry	Assumed Condition (Volatile or non-volatile)
strontium chromate	7789-06-2	28.3%	37.3%	Non-volatile
phenol, polymer with formaldehyde, glycidyl ether	28064-14-4	15.0%	19.8%	Non-volatile
titanium dioxide	13463-67-7	7.5%	9.9%	Non-volatile
talc : hydrated magnesium silicate	14807-96-6	3.9%	5.1%	Non-volatile
barium sulfate	7727-43-7	4.0%	5.3%	Non-volatile
Cashew, nutshell liq., oligomeric reaction products with 1-chloro-2,3-epoxypropane	68413-24-1	4.0%	5.3%	Non-volatile
barium chromate	10294-40-3	0.8%	1.1%	Non-volatile
polyaminoamide	68082-29-1	5.4%	7.1%	Non-volatile
benzyl alcohol	100-51-6	1.8%	2.4%	Non-volatile
Formaldehyde, polymer with benzenamine, hydrogenated	135108-88-2	2.1%	2.8%	Non-volatile
2,4,6-tris(dimethylaminomethyl)phenol	90-72-2	0.9%	1.2%	Non-volatile
benzyldimethylamine	103-83-3	0.3%	0.4%	Non-volatile
N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine	35141-30-1	0.5%	0.7%	Non-volatile
3,6-diazaoctanethylenediamin	112-24-3	0.2%	0.3%	Non-volatile
salicylic acid	69-72-7	0.5%	0.7%	Non-volatile
4,4'-methylenebis(cyclohexylamine)	1761-71-3	0.2%	0.3%	Non-volatile
bis[(dimethylamino)methyl] phenol	71074-89-0	0.5%	0.7%	Non-volatile
	Sum	75.9%	100%	

Now by multiplying the dry mass % of each substance with the panel mass, we can determine the actual mass of each substance in each aluminum panel.

Table 25. Total Masses of Primer Substances on Each Aluminum Panel

Substance	CAS #	Mass % Dry	Mass on Each Panel (g)
strontium chromate	7789-06-2	37.3%	8.69
phenol, polymer with formaldehyde, glycidyl ether	28064-14-4	19.8%	4.60
titanium dioxide	13463-67-7	9.9%	2.30
talc : hydrated magnesium silicate	14807-96-6	5.1%	1.20
barium sulfate	7727-43-7	5.3%	1.23
Cashew, nutshell liq., oligomeric reaction products	68413-24-1	5.3%	1.23
barium chromate	10294-40-3	1.1%	0.25
polyaminoamide	68082-29-1	7.1%	1.66
benzyl alcohol	100-51-6	2.4%	0.55
Formaldehyde, polymer with benzenamine,	135108-88-2	2.8%	0.64
2,4,6-tris(dimethylaminomethyl)phenol	90-72-2	1.2%	0.28
benzyldimethylamine	103-83-3	0.4%	0.09
N-(2-aminoethyl)-N'-[3-	35141-30-1	0.7%	0.15
3,6-diazaoctanethylenediamin	112-24-3	0.3%	0.06
salicylic acid	69-72-7	0.7%	0.15
4,4'-methylenebis(cyclohexylamine)	1761-71-3	0.3%	0.06
bis[(dimethylamino)methyl]phenol	71074-89-0	0.7%	0.15

Lastly, we can report the total mass of each substance in both panels (by multiplying by two) for only the AD-DSL declarable substances, as shown below in Table 26.

Table 26. AD-DSL Declarable Primer Substances

Substance	CAS #	Mass on Each Panel (g)	Mass on Two Panels (g)
benzyl alcohol	100-51-6	0.55	1.1
N-(2-aminoethyl)-N'-[3-(trimethoxysilyl)propyl]ethylenediamine	35141-30-1	0.15	0.30
salicylic acid	69-72-7	0.15	0.30
strontium chromate	7789-06-2	8.69	17.38
Titanium dioxide	13463-67-7	2.3	4.6
talc: hydrated magnesium silicate	14807-96-6	1.20	2.40
barium chromate	10294-40-3	0.25	0.50

3.10.2.4 Sealant

<u>Basis:</u>

Panel length along seam being sealed = L = 25cm

Width or gap of seam = W = 1mm (0.1cm)

Depth of seam = D = 0.5cm

Density $_{\text{Sealant}}$ = 1.67g/cm^3

<u>Calculations:</u>

Approximating the geometry of the bead of sealant as a rectangular prism, its volume can be calculated as:

Volume $_{\text{Sealant}}$ = L * W * D = 25 * 0.1 * 0.5 = 1.25 cm^3

The information in Table 27 is used to “normalize” or estimate the percentages to total 100%, as displayed in Table 28.

Table 27. Substances Present in the Single-Component Polyether Sealant

Substance	CAS #	Percentage (from SDS)
Calcium carbonate	471-34-1	25 to 50%
Natural limestone	1317-65-3	25 to 50%
Diisodecyl phthalate	68515-49-1	15 to 35%
Stearic acid, pure	57-11-4	5 to 10%
Titanium dioxide	13463-67-7	2 to 12%
Trimethoxyvinylsilane	2768-02-7	less than or equal to 2.5%
Methanol	67-56-1	less than or equal to 2.5%
n-(3-(trimethoxysilyl)propyl)ethylenediamine	1760-24-3	less than or equal to 2.5%
2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol	25973-55-1	less than or equal to 2.5%
Quartz (SiO_2)	14808-60-7	less than or equal to 2.5%

Table 28. Normalized Mass Percentages and Physical States of Substances in Polyether Sealant

Substance	CAS #	Mass % (normalized to 100%)	Assumed Condition (Volatile or non-volatile)
Calcium carbonate	471-34-1	25.0%	Non-volatile
Natural limestone	1317-65-3	25.0%	Non-volatile
Diisodecyl phthalate	68515-49-1	25.0%	Non-volatile
Stearic acid, pure	57-11-4	7.0%	Non-volatile
Titanium dioxide	13463-67-7	8.0%	Non-volatile
Trimethoxyvinylsilane	2768-02-7	2.0%	Non-volatile
Methanol	67-56-1	2.0%	Volatile
n-(3-(trimethoxysilyl)propyl)ethylenediamine	1760-24-3	2.0%	Non-volatile
2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol	25973-55-1	2.0%	Non-volatile
Quartz (SiO_2)	14808-60-7	2.0%	Non-volatile

Assuming methanol is the only volatile substance, the percentages are re-normalized to 100% and shown in Table 29 below.

Table 29. Re-Normalized Mass Percentages and Physical States of Substances in Polyether Sealant (once volatile substances were removed)

Substance	CAS #	Mass %
Calcium carbonate	471-34-1	25.5%
Natural limestone	1317-65-3	25.5%
Diisodecyl phthalate	68515-49-1	25.5%
Stearic acid, pure	57-11-4	7.1%
Titanium dioxide	13463-67-7	8.2%
Trimethoxyvinylsilane	2768-02-7	2.0%
Methanol	67-56-1	0.0%
n-(3-(trimethoxysilyl)propyl)ethylenediamine	1760-24-3	2.0%
2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol	25973-55-1	2.0%
Quartz (SiO_2)	14808-60-7	2.0%

Now we can look at only the declarable AD-DSL substances, as shown below in Table 30:

Table 30. Declarable Substances in Cured Polyether Sealant

Substance	CAS #	Mass %
Calcium carbonate	471-34-1	25.5%
Natural limestone	1317-65-3	25.5%
Diisodecyl phthalate	68515-49-1	25.5%
Titanium dioxide	13463-67-7	8.2%
n-(3-(trimethoxysilyl)propyl)ethylenediamine	1760-24-3	2.0%
2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol	25973-55-1	2.0%
Quartz (SiO_2)	14808-60-7	2.0%

Using the density and the volume of the sealant, the mass of each declarable substance can be calculated.

$$\boldsymbol{Mass_{coating}} = \boldsymbol{Volume_{coating}} \times \boldsymbol{Density_{coating}}$$
$$\boldsymbol{Mass_{Sealant}} = \boldsymbol{Density_{Sealant}} \times \boldsymbol{Volume}_{\ Sealant}$$
$$\boldsymbol{Mass_{Sealant}} = 1.67\ \frac{g}{cm^3} \times 1.25\ cm^3 = 2.09\ g$$

The mass of the individual substances in the assembly can now be calculated:

$$\boldsymbol{Mass_{Substance}} = \boldsymbol{Mass_{Sealant}} \times \boldsymbol{Mass}\ \%_{Substance}$$

Table 31. Total Masses of AD-DSL Declarable Sealant Substances

Substance	CAS #	Mass %	Mass
Calcium carbonate	471-34-1	25.5%	0.533g
Natural limestone	1317-65-3	25.5%	0.533g
Diisodecyl phthalate[14]	68515-49-1	25.5%	0.533 g
Titanium dioxide	13463-67-7	8.2%	0.171 g
n-(3-(trimethoxysilyl)propyl)ethylenediamine	1760-24-3	2.0%	0.042 g
2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol[15]	25973-55-1	2.0%	0.042 g
Quartz (SiO_2)	14808-60-7	2.0%	0.042 g

3.11. Step 11: Report Declarable Substance(s) and Mass(es):

The AD-DSL declaration for this example would be as follows in Table 32 below:

Table 32. Complete AD-DSL Declaration for Fictitious Product/Assembly

Substance	CAS #	Total Mass (g)	Article/Location
Manganese	7439-96-5	0.46	Bolt (substrate) p.30
Copper	7440-50-8	0.92	Bolt (substrate) p.30
Cadmium	7440-43-9	0.28	Bolt (plating) p.32
Cadmium chromate	14312-00-6	0.0017	Bolt (supplementary chromate coating) p.34
Chromium trioxide	1333-82-0	0.0038	Bolt (supplementary chromate coating) p.34
Cadmium formate	4464-23-7	0.00072	Bolt (supplementary chromate coating) p.34
Cadmium oxide	1306-19-0	0.00072	Bolt (supplementary chromate coating) p.34
Cadmium hydroxide	1308-14-1	0.00072	Bolt (supplementary chromate coating) p.34
Manganese	7439-96-5	60.8	Panel (substrate) p.36
Copper	7440-50-8	330	Panel (substrate) p.36
Zinc	7440-66-6	17	Panel (substrate) p.36
Chromium	7440-47-3	6.8	Panel (substrate) p.36
Sodium dichromate	10588-01-9	0.24	Panel (anodized seal) p.37
Benzyl alcohol	100-51-6	1.1	Panel (primer) p.43
N-(2-aminoethyl)-N'-[3-(trimethoxysilyl) propyl]ethylenediamine	35141-30-1	0.30	Panel (primer) p.43
Salicylic acid	69-72-7	0.30	Panel (primer) p.43
Strontium chromate	7789-06-2	17.38	Panel (primer) p.43
Titanium dioxide	13463-67-7	4.6	Panel (primer) p.43
Talc: hydrated magnesium silicate	14807-96-6	2.40	Panel (primer) p.43
Barium chromate	10294-40-3	0.50	Panel (primer) p.43
Calcium carbonate	471-34-1	0.533	Panel (sealant) p.45

[14] Note that in addition to being an AD-DSL declarable substance, Diisodecyl phthalate is also on the EU REACH Annex XVII ("Substances Restricted under REACH"), which would require additional attention/action had this supplier been concerned with EU REACH as well.

[15] Note that in addition to being an AD-DSL declarable substance, 2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol is also on the EU REACH Annex XIV ("Authorisation List"), which would require an approved Authorisation for its use in "raw" form in the EU (i.e., not on *finished* hardware).

Table 32. Complete AD-DSL Declaration for Fictitious Product/Assembly

Substance	CAS #	Total Mass (g)	Article/Location
Natural limestone	1317-65-3	0.533	Panel (sealant) p.45
Diisodecyl phthalate	68515-49-1	0.533	Panel (sealant) p.45
Titanium dioxide	13463-67-7	0.171	Panel (sealant) p.45
n-(3-(trimethoxysilyl)propyl) ethylenediamine	1760-24-3	0.042	Panel (sealant) p.45
2-(2H-benzotriazol-2-yl)-4,6-di-tert-pentylphenol	25973-55-1	0.042	Panel (sealant) p.45
Quartz (SiO_2)	14808-60-7	0.042	Panel (sealant) p.45

Note: Several substances appear more than once above (in multiple articles/locations). Depending on the level of reporting required (e.g., article, subassembly) they may be added together rather than reported separately.

4. Additional Examples and Special Cases

This section will highlight a few additional types of calculations:

- 4.1 EU RoHS declaration, as it differs from other regulatory declaration processes.
- 4.2 NAS411-1 declaration for a simple article (jacketed cable).
- 4.3 Threshold calculation examples - to determine when there is a risk of substance mass exceeding a given reporting threshold.

4.1. EU RoHS Declaration for Lead in Solder

4.1.1. Step 1: Identify the Product, Contract, Customer, and Location(s):

Complex electronic assembly, Contract # 54321, Customer is Easter Bunny, Location is Enchanted Garden.

4.1.2. Step 2: Identify Applicable Regulatory Reporting Requirements and/or DSL:

EU RoHS list. The RoHS regulation requires calculation/reporting by "homogeneous material," not by article. A homogeneous material is one that cannot be separated by grinding, scraping, or similar mechanical methods (see Definitions of Terms section). In this case, homogeneous materials may include solder, wire, coating, board material, and similar components.

4.1.3. Step 3: Identify Contractually Required Substance List(s), Standards, Formats, or Threshold (if applicable):

No additional requirements beyond what is covered by the EU RoHS directive.

4.1.4. Step 4: Identify Subassembly(s) and Articles Within the Product:

In this example below, a complex article (product) is produced by soldering three articles with a solder (mixture).

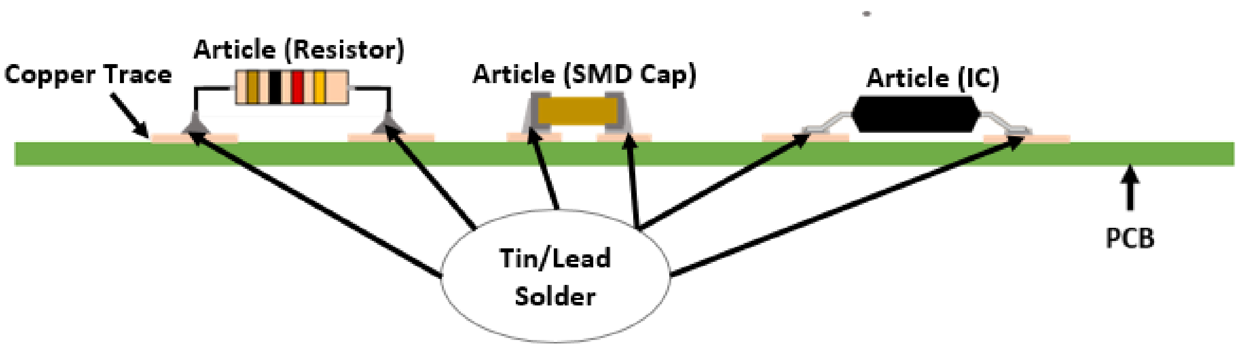

Figure 13. Complex Article (Product) Produced by Soldering Three Simple Articles to a Circuit Board with a Solder (Mixture)

4.1.5. Step 5: Identify Available Sources of Product/Process Materials and Substances Information:

- Bills of Materials (or materials declarations) for subassembly articles (i.e., resistor, Surface Mount Device [SMD] capacitor, IC, and Printed Circuit Board [PCB]).
- SDS for tin/lead solder.

4.1.6. Step 6: Identify Material(s) Within Each Subassembly/Article (and Process, if required):

- The resistor, SMD cap, IC, and PCB are composed of raw materials that do not contain any DSL substances.
- The solder (mixture) is composed of 60 percent tin and 40 percent lead.

4.1.7. Step 7: Identify Substance(s) in Each Material:

- Tin (CAS # 7440-31-5) and lead (CAS # 7439-92-1) are part of the solder (mixture) composition.

4.1.8. Step 8: Identify Declarable Substance(s):

- Lead (CAS # 7439-92-1)

4.1.9. Step 9: Consider Which Substance(s), if any, Would be Present in the Final Product:

- Lead (CAS # 7439-92-1)

4.1.10. Step 10: Calculate Substance Mass(es):

EU RoHS sets limits on percentages of substances in homogeneous materials (such as lead in the solder). The solder in this example contains 40% lead, and in the RoHS directive, lead is limited to 0.1%. No additional calculations are required in this case. Unless otherwise exempted, this solder would not be permitted in RoHS-compliant equipment. Note that there are numerous categories of exemptions under this directive. Also, there may be some deviations between different jurisdictions.

4.1.11. Step 11: Report Declarable Substance(s) and Mass(es):

This product contains 40% lead (CAS # 7439-92-1) in its (homogenous) solder material and is therefore not RoHS-compliant (unless an appropriate exemption applies).

4.2. NAS411-1 Declaration for Jacketed Cable

4.2.1. Step 1: Identify the Product, Contract, Customer, and Locations

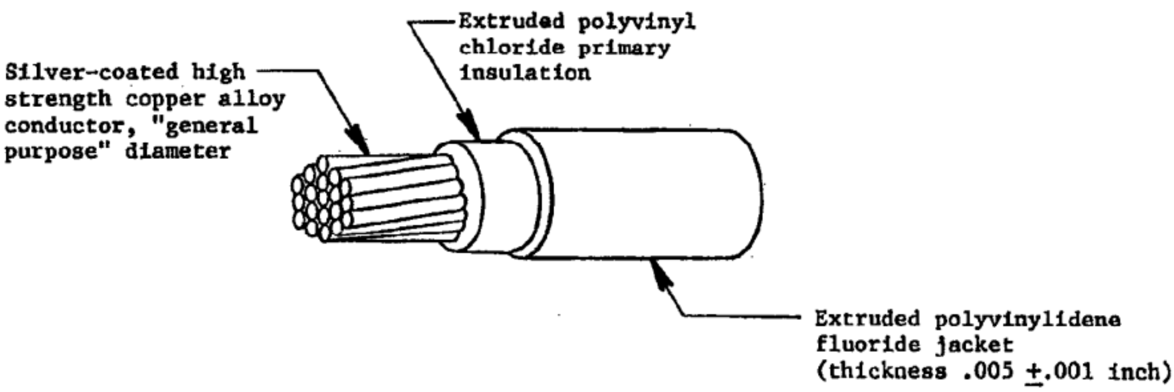

Figure 14. M5086/6-28 Configuration (Image from SAE AS50861/6A Specification)

M5086/6-28 (28AWG) aircraft wire, Contract #12345, Customer is Santa Claus, Location is North Pole

4.2.2. Step 2: Identify Applicable Regulatory Reporting Requirements and/or DSL:

NAS411-1 HMTL, revision 3.

4.2.3. Step 3: Identify Contractually Required Substance List(s), Standards, Formats, or Threshold (if applicable)

Customer has requested declaration of masses of all declarable substances contained in the product, with no applicable thresholds or required reporting format. Further, the customer has not required the reporting of any impurities, contaminants, or unintentionally added substances.

4.2.4. Step 4: Identify Subassembly(s) and Articles Within the Product:

The product itself is a simple article (no subassemblies).

4.2.5. Step 5: Identify Available Sources of Product Materials and Substances Information:

- Specification that defines cable materials and dimensions
- Specification that defines copper conductor material
- Specification that defines silver plating material
- SDS for insulation material
- SDS for jacket material
- Reference sources/tables that define material and substance densities

4.2.6. Step 6: Identify Material(s) Within Each Subassembly/Article:

- Conductor
  - High-strength copper alloy per SAE AS50861/6A. A typical high-strength copper alloy is C11000.
- Plating
  - Silver plating meeting SAE AS29606 requirements, having a coating thickness of at least 40 microinches of silver.
- Insulation
  - Extruded polyvinyl chloride (PVC).
- Jacket
  - Extruded polyvinylidene fluoride (PVDF).

4.2.7. Step 7: Identify Substance(s) in Each Material:

- Conductor
  - Copper (C11000 alloy is 99.9% minimum copper; assumed in this example that conductor is 100% copper, CAS # 7440-50-8).
- Plating
  - Silver (CAS # 7440-22-4).
- Insulation
  - A typical PVC insulation includes PVC as well as a plasticizer such as bis(2-ethylhexyl) phthalate (DEHP) enclosed in the polymeric PVC matrix. The concentration of DEHP in PVC varies between 10% and 50% w/w, with a typical concentration of 30% w/w often reported. [16] For purposes of this example, a 30% w/w concentration of DEHP will be used.

[16] European Chemicals Agency (ECHA), “Adopted Opinions and Previous Consultations on Applications for Authorisation”, https://echa.europa.eu/applications-for-authorisation-previous-consultations/-/substance-rev/5650/term.

Table 33. Composition of a Typical PVC Insulation Material

Substance	CAS #	Mass %	Assumed Condition (Volatile or non-volatile)
polyvinyl chloride	9002-86-2	70	Non-volatile
bis(2-ethylhexyl) phthalate (DEHP)	117-81-7	30	Non-volatile

- Jacket
  - According to a typical SDS shown below, the PVDF jacket contains 96% of a PVDF copolymer (CAS # 9010-75-7) and 4% of a trade secret (brominated) fire retardant. While unable to provide the exact composition of this fire retardant, the formulator has disclosed that it is a NAS411-1 declarable "restricted" substance.

Table 34. Composition of Jacket Material

Substance	CAS #	Mass %	Assumed Condition (Volatile or non-volatile)
PVDF CTFE copolymer	9010-75-7	96	Non-volatile
Trade-secret brominated fire retardant (balance)	Trade Secret	4	Non-volatile

4.2.8. Step 8: Identify Declarable Substance(s):

- Insulation
  - DEHP (CAS # 117-81-7) – "restricted" NAS411-1 substance on Appendix B.
- Jacket
  - PVDF copolymer (CAS # 9010-75-7) – "restricted" NAS411-1 PFAS substance on Appendix E.
  - Brominated fire retardant (CAS # undisclosed) – "restricted NAS411-1 substance on Appendix B.

4.2.9. Step 9: Consider Which Substance(s), if any, Would be Present in the Final Product:

Neither of these NAS411-1 substances would be expected to evaporate or transform and will therefore be present in the final product.

4.2.10. Step 10: Calculate Substance Mass(es):

4.2.10.1 Insulation

The volume of insulation is equal to the area x length. In a cable, the area occupied by the conductor is subtracted from the larger circle.

$$\boldsymbol{Area}_{Insulation} = (\pi R^2 - \pi r^2)$$

To get the volume, the area is multiplied by the length:

$$\boldsymbol{Volume}_{Insulation} = (\pi R^2 - \pi r^2) \times L$$

Mass is volume x density:

$$\boldsymbol{Mass}_{Insulation} = (\pi R^2 - \pi r^2) \times L \times G$$
$$= \pi(R^2 - r^2) \times L \times G$$

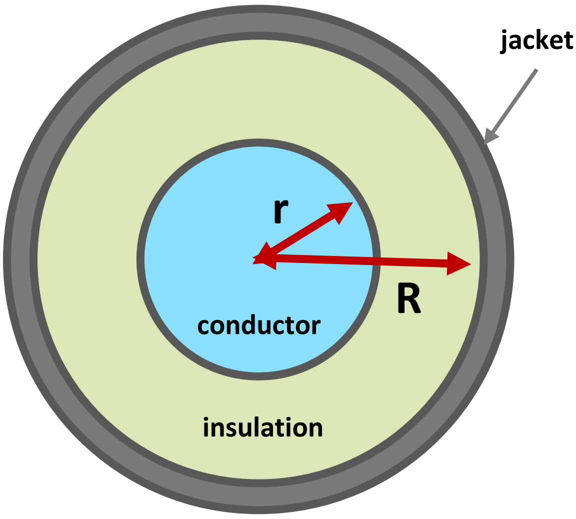

Figure 15. Cable Cross Section

where

R = radius over insulation (mm)

r = radius over conductor (mm)

G = density of insulation material (g/cm^3), using typical cable design values[17] for the weight of the insulation layer

In the PVC insulation layer:

Substance fraction $_{\textit{DEHP in insulation}}$ = 0.3

R = 0.5 mm (0.039 in diameter, from SAE AS50861/6A spec)

r = 0.19 mm (0.015 in diameter, from SAE AS50861/6A spec)

G = 1.4 g/cm^3 (for PVC)

$$\boldsymbol{Mass}_{Insulation}\left(\frac{g}{m}\right) = \pi((0.5\ mm)^2 - (0.19\ mm)^2) \times \frac{1000mm}{m} \times 1.4\frac{g}{cm^3} \times \frac{cm^3}{1000\ mm^3}$$

$$\boldsymbol{Mass}_{Insulation}\left(\frac{g}{m}\right) = 3.14 \times (0.25\ mm^2 - 0.036\ \mathrm{mm}^2) \times 1000mm \times 1.4\frac{g}{cm^3} \times \frac{cm^3}{1000\ mm^3}$$

Mass $_{\textit{Insulation}}$ = 0.94 g/m

[17] Standard Wire & Cable Co. website: http://www.standard-wire.com/cable_design_formulas.html.

Mass *DEHP in insulation* (g/m) = ***substance fraction*** *DEHP in insulation* x ***Mass*** *Insulation*

= 0.3 x 0.94 g/m

= 0.28 g/m

Mass % *DEHP in article*= ***mass %*** *DEHP in insulation* = (***mass*** *DEHP in insulation* / ***mass*** *Article*) *100

From the AS50861/6A specification, the finished weight of the M5086/6-28 wire is 2.4 g/m (1.8 lbs/1000 ft)

Mass % *DEHP in article*= ***mass %*** *DEHP in insulation* = (0.28 / 2.4) *100

Mass % *DEHP in article* **=** 11.7 %

4.2.10.2 Jacket

The calculations for PVDF mass will be the same as for DEHP above. First, we must determine the substance fractions for each of the solid substances present in the PVDF jacket.

Substance fraction *Solid substance in PVDF* = ***Mass %*** *Solid substance in Jacket* / ***Mass %*** *Jacket*

where ***Mass %*** *Jacket* = 100%

Table 35. PVDF Jacket Material Substance Fractions

Substance	Mass % Substance in jacket	Substance Fraction Substance in jacket
PVDF CTFE copolymer	96	0.96
Trade secret brominated fire retardant (balance)	4	0.04

Using typical cable design values[18] and the equations above for the mass of the jacket layer:

$$\boldsymbol{Mass}_{Jacket}(\frac{g}{m}) = \pi(R^2 - r^2)\ \times L\ \times G$$

where

R = radius over jacket (in mm)

r = radius over insulation (in mm)

G = density of jacket material

In the PVDF jacket layer:

Substance fraction *PVDF in jacket* = 0.01

R = 0.55 mm (0.044 in, from SAE AS50861/6 spec)

r = 0.5 mm (0.039 in, from SAE AS50861/6 spec)

G = 1.76 (for PVDF)

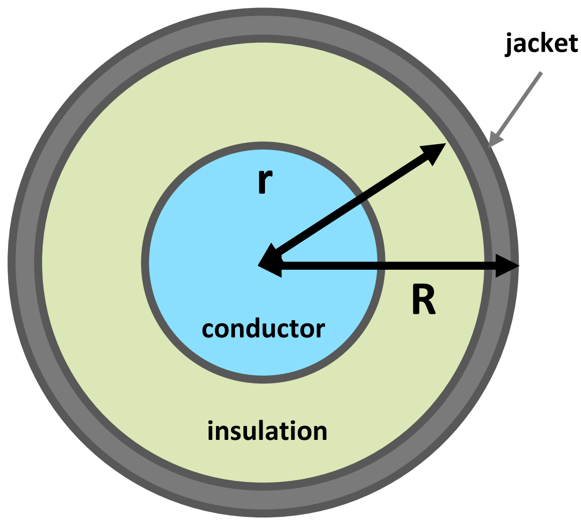

Figure 16. Cable Cross Section

[18] Standard Wire & Cable Co. website: http://www.standard-wire.com/cable_design_formulas.html.

$$\boldsymbol{Mass}_{Jacket}\left(\frac{g}{m}\right) = \pi((0.55\ mm)^2 - (0.5\ mm)^2) \times \frac{1000mm}{m} \times 1.76\frac{g}{cm^3} \times \frac{cm^3}{1000\ mm^3}$$

$$\boldsymbol{Mass}_{Jacket}\left(\frac{g}{m}\right) = 3.14 \times (0.3025\ mm^2 - 0.25\ \mathrm{mm}^2) \times 1000mm \times 1.76\frac{g}{cm^3} \times \frac{cm^3}{1000\ mm^3}$$

$$\boldsymbol{Mass}_{Jacket}\left(\frac{g}{m}\right) = 0.29\ \mathrm{g/m}$$

Mass $_{\textit{PVDF in jacket}}$ (g/m) = ***substance fraction*** $_{\textit{PVDF in jacket}}$ x ***Mass*** $_{\textit{Jacket}}$

= 0.96 x 0.29 g/m

= 0.28 g/m

Mass % $_{\textit{PVDF in article}}$= ***mass %*** $_{\textit{PVDF in jacket}}$ = (***mass*** $_{\textit{PVDF in jacket}}$ / ***mass*** $_{\textit{article}}$) *100

From the AS50861/6A specification, the finished weight of the M5086/6-28 wire is 2.4 g/m (1.8 lbs/1000 ft).

Mass % $_{\textit{PVDF in article}}$= ***mass %*** $_{\textit{PVDF in jacket}}$ = (0.28 / 2.4) *100

Mass % $_{\textbf{PVDF in article}}$ = 11.7 %

Similarly for the brominated fire-retardant substance:

Mass $_{\textit{Fire retardant in jacket}}$ (g/m) = ***substance fraction*** $_{\textit{Fire retardant in jacket}}$ x ***Mass*** $_{\textit{Jacket}}$

= 0.04 x 0.29 g/m

= 0.012 g/m

Mass % $_{\textit{Fire retardant in article}}$= ***mass %*** $_{\textit{Fire retardant in jacket}}$ = (***mass*** $_{\textit{Fire retardant in jacket}}$ / ***mass*** $_{\textit{article}}$) *100

From the AS50861/6A specification, the finished weight of the M5086/6-28 wire is 2.4 g/m (1.8 lbs/1000 ft).

Mass % $_{\textit{Fire retardant in article}}$= ***mass %*** $_{\textit{Fire retardant in jacket}}$ = (0.012 / 2.4) *100

Mass *%* $_{\textit{Fire retardant in article}}$ = 0.5 %

4.2.11. Step 11: Report Declarable Substance(s) and Mass(es):

Table 36. Complete NAS411-1 Declaration for M5086/6-28 Jacketed Cable

Substance	CAS #	Mass %	Location
DEHP	117-81-7	11.7	Insulation
PVDF	9010-75-7	11.7	Jacket
Brominated fire retardant	Trade Secret	0.5	Jacket

4.3. Minimum Substrate Thickness Needed to Fall Below Substance Mass Percent Reporting Threshold (EU REACH Regulation Examples)

In some cases, it is helpful to know the parameters under which a substance might approach a threshold. For any given coating and substrate, it is possible to calculate the substrate thickness necessary to provide sufficient mass so that the substance mass of the article is equal to a threshold (e.g., 0.1% by weight/weight for some reporting obligations under the EU REACH regulation). Therefore, any article where the substrate thickness exceeds this number will not contain a substance mass above the threshold. The analyst can then compare the article in question to a single sheet of the substrate to get a feel for whether there is risk of exceeding the mass % threshold of the substance.

The thickness at which a substance in a surface treatment or coating reaches a threshold depends on a number of factors. The equation is derived here; then specific cases are demonstrated.

4.3.1. Plate

4.3.1.1 General

This section will describe the method for calculating the thickness of a plate-shaped substrate required, so that when applied with a substance-containing coating, the substance mass fraction will be equal to or below the relevant reportable threshold.

Basis:

Thickness *Coating* = t (maximum coating thickness)

Density *Coating* = d (density of the coating)

Substance fraction *Coating* = f (maximum mass fraction of substance in coating)

Density *Substrate* = D (density of the substrate)

Thickness *Substrate* = T (thickness of substrate)

Surface area *Coating* = S (surface area of the substrate)

Substance fraction *Article* = F (substance fraction in the article)

With respect to the thin sheet, the total coating area can be estimated as total surface area of the substrate:

***Surface area** Substrate = **surface area** top face **+ surface area** bottom face*

***Mass** Substrate = **thickness** Substrate *** 0.5 surface area** Substrate *** density** Substrate*

***Mass** Coating **= thickness** Coating *** density** Coating *** surface area** Substrate*

***Substance mass** Coating **= substance fraction** Coating *** Mass** Coating*

***Mass** Article**= mass** Substrate **+ mass** Coating*

***Substance fraction** article **= Substance mass** Coating **/ Mass** article*

Substance mass %** article **(mass percent of coating) = Substance fraction** article *** 100

Solving for the substrate thickness using the above equations:

$$\boldsymbol{F(Substance\ fraction\ in\ article)} = \frac{\boldsymbol{f * t * d * S}}{\boldsymbol{(T * 0.5S * D\ +\ t * d * S)}}$$

Simplifying this equation results in a correlation of substrate thickness to the coating thickness, densities, and substance mass fractions:

$$\boldsymbol{T(thickness\ of\ substrate)}\ =\ \frac{\boldsymbol{2td}}{\boldsymbol{D}}\ [\frac{\boldsymbol{f}}{\boldsymbol{F}} - \boldsymbol{1}]$$

Basically, any substrate plate that exceeds the thickness **T** would not constitute a reportable article (due to a reportable substance present in its coating) even if covered on both sides with a coating of the above properties.

4.3.1.2 Chromate Conversion Coating (containing CAS # 1333-82-0) on Aluminum Substrate

The equation above is used to calculate the minimum thickness required of the aluminum substrate for the mass % of the substance in the coating (CAS # 1333-82-0) to be below a 0.1% threshold (0.001 fraction).

Note: CAS # 1333-82-0 is referred to as chromium (VI) oxide, chromium trioxide, or chromium (VI) trioxide. In this example this substance is present in the chromate conversion coating on the article.

Case 1 and case 2 examples are provided below using 1.29 g/m^2 (120 mg/ft^2) and 0.59 g/m^2 (55 mg/ft^2) coating weight of the chromate conversion coating, respectively. The Case 1 calculation using a coating weight of 1.29 g/m^2 represents a maximum, or "worst case", value while the Case 2 calculation with 0.59 g/m^2 represents a more "typical" chemical conversion coating weight, where a primer is subsequently applied over the chromate layer.

The reader should note that many coating specifications utilize mixed SI/imperial units for coatings weights such as that shown in this example (i.e., mg/ft^2).

<u>Case 1 - Coating weight of 1.29 g/m^2 for Class 1A MIL-DTL-81706 chromate conversion coating ("worst case" weight)</u>

Basis:

Thickness $_{\text{Coating}}$ = t = 0.76 µm maximum (equivalent to 1.29 g/m^2)

Density $_{\text{Coating}}$ = d = 1.49 g/cm^3 (specific gravity of chromate conversion coating)

Substance fraction $_{\text{Coating}}$ = f = 0.6 (dimensionless mass fraction) worst case of **CAS # 1333-82-0**

Density $_{\text{Substrate}}$ = D = 2.70 g/ cm^3 (specific gravity of aluminum)

Substance fraction $_{\text{Article}}$ = F = 0.001 (dimensionless fraction of substance in article, is 0.1%)

$$\boldsymbol{T(thickness\ of\ substrate)}\ =\ \frac{\boldsymbol{2td}}{\boldsymbol{D}}\ [\frac{\boldsymbol{f}}{\boldsymbol{F}} - \boldsymbol{1}]$$

$$\boldsymbol{T\ (thickness\ of\ substrate)}\ =\ \frac{2 \times 0.76\mu m\ \times 1.49\ g/cm^3}{2.70\ g/cm^3}\ [\frac{0.6}{0.001} - 1]$$

= 502 µm (0.05 cm)

Thus, if using 1.29 g/m^2 (120 mg/ft^2) chemical conversion coating weight, any sheet of aluminum exceeding 502 µm (0.05 cm) thickness would have a mass % of chromium (VI) oxide below a substance mass threshold of 0.1% if coated on both sides with the chromate conversion coating as described above.

Case 2 – Coating weight of 0.59 g/m^2 for Class 1A MIL-DTL-81706 chromate conversion coating (“typical” weight)

Basis:

Thickness $_{Coating}$ = t = 0.33 µm maximum (equivalent to 55 mg/ft^2)

Density $_{Coating}$ = d = 1.49 g/cm^3 (specific gravity of chromate conversion coating)

Substance fraction $_{Coating}$ = f = 0.6 (dimensionless mass fraction) as worst case of CAS # 1333-82-0

Density $_{Substrate}$ = D = 2.70 g/ cm^3 (specific gravity of aluminum)

Substance fraction $_{Article}$ = F = 0.001 (dimensionless fraction of substance in article, is 0.1%)

$$\boldsymbol{T(thickness\ of\ substrate)} = \frac{\boldsymbol{2td}}{\boldsymbol{D}}\left[\frac{\boldsymbol{f}}{\boldsymbol{F}} - \mathbf{1}\right]$$

$$\boldsymbol{T(thickness\ of\ substrate)} = \frac{2 \times 0.33\mu m \times 1.49\ g/cm^3}{2.70\ g/cm^3}\left[\frac{0.6}{0.001} - 1\right]$$

= 218 µm (0.02 cm)

Thus, if using 0.59 g/m^2 (55 mg/ft^2) chemical conversion coating weight, any thin sheet of aluminum exceeding 218 µm (0.02 cm) thickness would have a mass % of chromium (VI) oxide below a substance mass threshold of 0.1% when coated on both sides with chromate conversion coating as described above.

4.3.1.3 Epoxy Primer Coating Containing Strontium Chromate (CAS # 7789-06-2) on Aluminum Substrate

Epoxy primer dry film coating thickness per MIL-PRF-23377 is 15-23 µm (0.0006 – 0.0009 inch) on an aluminum alloy plate. (Note: this is the thickness range required by this specification for one coat of primer applied to a substrate used in an exterior environment. For parts used in interior environments, or for other types/specifications of coatings, the required thicknesses may be different and should be taken into consideration accordingly.) The primer used has a content of 21% by mass strontium chromate in the dry primer.

Basis:

Thickness $_{Coating}$ = t = 23µm (0.0009-inch maximum)

Density $_{Coating}$ = d = 2.33 g/cm^3 (0.0840 lb/in^3) (specific gravity of dry film epoxy primer based on SDS)

Substance fraction $_{Coating}$ = f = 0.21 (dimensionless) as worst case of strontium chromate

Density $_{Substrate}$ = D = 2.70g/cm^3 (0.0976 lb/in^3) (specific gravity of aluminum alloy)

Substance fraction $_{Article}$ = 0.001 (dimensionless fraction of substance in article)

Again, using the equation above, the simplified correlation is:

$$\boldsymbol{T(thickness\ of\ substrate)\ =\ \frac{2td}{D}\ [\frac{f}{F} - 1]}$$

$$\boldsymbol{T(thickness\ of\ substrate)}\ =\ \frac{2 \times 23\mu m\ \times 2.33\ g/cm^3}{2.70\ g/cm^3}\ [\frac{0.21}{0.001} - 1]$$

= 8300 µm (8.3mm)

Therefore, for articles having a primer containing 21% by mass strontium chromate, any sheet of aluminum greater than 8.3mm in thickness would have a mass % of strontium chromate below 0.1%.

Conversely, articles having aluminum substrate thicknesses below 8.3mm would need to be specifically evaluated for the mass % of strontium chromate substance on the article as it is likely to be greater than 0.1%.

4.3.2. Cadmium Plating on Aluminum Sphere

A sphere provides the maximum surface area for a specified volume. Consider a sphere with a coating that contains 100% of a certain substance (such as cadmium in cadmium plating).

Thickness $_{Coating}$ = t (maximum/worst case coating thickness) = 15µm (0.0015 cm)

Density $_{Coating}$ = d (density of the coating) = 8.65 g/cm^3

Substance fraction $_{Coating}$ = f (maximum mass fraction of substance in coating) = 1

Density $_{Substrate}$ = D (density of the substrate) = 2.7 g/cm^3

Thickness $_{Substrate}$ = T (thickness of substrate) = Volume of a sphere = $\frac{4}{3}\pi r^3$

Surface area $_{Coating}$ = S (surface area of the substrate) = Surface area of a sphere = $4\pi r^2$

Threshold = ***Substance fraction*** $_{Article}$ = 0.001

In general, for a sphere with a coating, the threshold can be estimated to be the mass of the coating divided by the mass of the article:

$$\boldsymbol{Threshold} = \frac{4\pi r^2\ \times\ t\ \times\ d}{\frac{4}{3}\pi r^3\ \times\ D}$$

This can be simplified to:

$$\boldsymbol{Threshold} = \frac{3td}{rD}$$

For cadmium plating on an aluminum substrate, the equation above can be solved for r (sphere radius):

$$r = \frac{3td}{D\ \times threshold}$$

$$r = \frac{3\ \times 0.0015\,cm\ \times 8.65}{2.7\ \times 0.001}$$

$$r =\ 14.4\,cm$$

Based on this calculation, an aluminum sphere plated with 15µm of cadmium would need to be greater than 28.8 cm in diameter to be an article with less than 0.1% of cadmium (and render the cadmium unreportable in this regulatory example).

Key Takeaways

- For chromate conversion coated aluminum greater than 0.05 cm thick, the presence of hexavalent chromium compounds is less than 0.1% on the coated article.
- For supplementary chromate film on cadmium plating, the presence of hexavalent chromium compounds is less than 0.1%.

5. Additional Information on Substances in Products and Processes

In this section, some helpful information on substance identification and mass calculations will be provided, along with more detailed discussions about volatile, reactive, and transformational substances. It also includes a section on some of the challenges faced when seeking information about substance content on SDSs. The intent of this chapter is to provide a deeper understanding of some of the concepts and background related to developing clear and accurate declarations.

5.1. Common Tips and Assumptions

Below is a non-exhaustive list of common assumptions and tips for identifying substances in materials:

5.1.1. Declaration Process Step 7 (Substance Identification)

5.1.1.1 Surface Cleaning and Processes

- Substances in etchants, deoxidizers, and pickling chemical processes typically do not remain on the metal surface after chemical processing is completed.

5.1.1.2 Passivation

- Substances used during the passivation of corrosion resistant steels per ASTM A967 or SAE AMS2700 typically do not remain on the metal surface after chemical processing is completed.

5.1.1.3 Metal Plating

- Metal plated finishes such as cadmium plating, chromium plating, and nickel plating contain only the plated metal(s), not all chemical constituents of the plating bath.
- Plated finishes may have an underplating layer or supplemental surface treatment which should also be reviewed for DSL substances (e.g., cadmium plating with a supplementary chromate coating.)

5.1.1.4 Anodizing

- Although anodized aluminum is composed of an aluminum oxide film, some chemicals used during the surface treatment can remain on the metal surface after processing is completed. “The incorporation of anions into anodic alumina from the electrolytes is a commonly known effect.”[19] (e.g., those meeting MIL-PRF-8625 Types I and IB requirements). Additionally, anodized aluminum is often sealed and the anodize seal may contain declarable substances such as hexavalent chromium compounds (e.g., sodium dichromate seal).

5.1.1.5 Post-Treatment

- Secondary surface treatment processes (e.g., post treatment, sealing, and conversion coating) typically leave substances on the product surface as delivered and should be checked for the presence of declarable substances.

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[19] K. Tomczyk and S. WJ (2024). Incorporation of Anions into Anodic Alumina - a new track in Cr (VI) anodizing substitution?, Materials, vol. 17, p. 2938.

5.1.1.6 Solvents

- Solvents listed on the SDS that are present during cleaning, chemical processing or application will usually evaporate and not be present on the hardware/product as delivered (e.g., carrier paint solvents evaporate, but the paint pigment/solids remain on the article). A consultation with the material manufacturer or supplier could be helpful in determining if declarable substances are present after processing or application to the finished hardware/product.

5.1.1.7 Multi-Part Reactive Materials (e.g., Coatings, Adhesives, and Polymers)

- Multi-part materials composed of a base and activator (e.g., curing agent, catalyst) typically have a chemical reaction such that the substances on the product as delivered are usually different than the substances present in the unmixed base and/or activator as listed on the SDS(s). A consultation with the material manufacturer or supplier could be helpful in determining if declarable substances are present in the cured mixture.
- Polymers are made of monomer units that are generally present in only trace amounts. It may not be necessary to calculate very small amounts of substances unless required by the requester. For example:
    - vinyl chloride used to make PVC;
    - phenol monomer used to make phenolic resins;
    - styrene monomer used to make polymerized styrene (polystyrene); and
    - cyanide compounds used to make nitrile rubber.

5.1.1.8 Solder and Electrical Materials

- Solder for AD applications often contains lead (Pb) to meet the environmental and mission requirements and should be checked for the presence of declarable substances.
- MIL-DTL-38999 type electrical connectors contain beryllium copper pins.

5.1.2. Declaration Process Step 10 (Substance Mass Calculations)

Below is a non-exhaustive list of tips for substance mass calculations:

- When using an SDS to estimate substances in materials that contain volatile substances (e.g., paints), ensure the volatile substance(s) weight percent is removed.
- If the part is physically available, it may be weighed before and after application of any coating(s) in order to determine coating weight.
- Densities of dried/cured coatings can sometimes be found on the formulator's technical data sheet for the product.
- Surface area calculators (e.g., https://www.calculator.net/surface-area-calculator.html) may be helpful in estimating surface area.
- When available, computer models can provide more accurate physical data (e.g., surface area or volume) to be used for substance mass calculations.

5.2. Information on Substances in Products

Typically, the composition of a produced item or assembly is the sum of the compositions of the constituent articles and materials that make up the final product. These discrete articles and materials are composed of substances that may then need to be declared to customers in the supply chain. As a helpful resource, Appendix A lists some common substances used in the AD industry, based on IAEG member input.

5.2.1. Simple Composition

In cases where no substances undergo any transformation or reaction, all declarable constituent substances will be reported on the materials and substances declaration.

5.2.2. Transformational Materials

When transformational materials are present, the supplier must determine which substances remain a part of the final product to develop an accurate materials and substances declaration. This section provides information on typical AD processes that involve transformational materials and how to address them when developing "substance in product" declarations.

Transformational materials change composition during processing. Some examples of transformational materials include, but are not limited to, the following:

- substances that evaporate (e.g., volatile liquids);
- substances used in processing that do not remain as a part of the product (e.g., acid used to deoxidize a metal surface); and
- substances that react to form new substances (e.g., isocyanates that polymerize to form polyurethane).

The use of transformational materials complicates the determination of which substance(s) remain on the as-delivered article. Examples of materials or mixtures that contain transformational substances include primers, paints, adhesives, and sealants, to name a few.

In addition to considering the changes the substances may undergo; it is necessary to consider that the concentration of the remaining substance(s) usually increases in the final product/mixture due to the removal of other substances due to reaction or evaporation (while the paint pigments/solids remain on the finished article). It is recommended to consult with a knowledgeable individual, such as the material manufacturer/formulator, a chemist, or a regulatory or engineering subject matter expert, prior to reporting potential transformational substances on a declaration. Note that substances that do not remain on finished hardware may still be required to be reported as "substances in process," if required to do so (see Section 5.3).

Figure 17. Illustration of the Changes to Mass and Ratio after the Evaporation of a Solvent

5.2.2.1 Volatile Substances

The *volatility* of a substance is a measure of its tendency to evaporate. To estimate the chemical content of products and components, it is important to consider volatility to determine which substances may have evaporated from product surfaces and use that information to estimate the concentrations of remaining substances. Many substances used as solvents to develop products are volatile (e.g., acetone, toluene) and their loss to the air must be accounted for; their presence would not typically be reported as a chemical constituent of an article. In fact, many substances used in chemical formulations (e.g., organic solvents, water) are intended to readily vaporize under processing conditions.

Multiple factors can contribute to a substance's tendency to evaporate during processing (e.g., temperature, airflow, and substance interactions). The boiling point (temperature) is an indicator that is commonly used to indicate the tendency of a substance to vaporize (i.e., the lower the boiling point, the higher the volatility of a substance.) The US Environmental Protection Agency (EPA) provides some helpful guidance on how a substance's boiling point can give an indication of its volatility.

Table 37. Classification of Organic Pollutants[20]

Description	Abbreviation	Boiling Point Range (degrees Celsius)	Example Compounds
Very Volatile (Gaseous) Organic Compounds	VVOC	Less than 0 and 50 to 100	Propane, butane, methyl chloride
Volatile Organic Compounds	VOC	50 to 100 and 240 to 260	Formaldehyde, d-Limonene, toluene, acetone, ethanol (ethyl alcohol), 2-propanol (isopropyl alcohol), hexanal
Semi Volatile Organic Compounds	SVOC	240 to 260 and 380 to 400	Pesticides (DDT, chlordane, plasticizers [phthalates], fire retardants [PCBs, PBBs])

In general, the "very volatile" substances would be expected to evaporate while the "semi-volatile" substances would usually stay in the product. For the middle range of Volatile Organic Compounds (VOCs), the extent of a substance's evaporation may not always be clear. In these cases, a consultation with the material manufacturer or supplier could be helpful in determining if volatile substances are present after processing or application to the finished article. To aid such a discussion, one could consider environmental conditions, application methods, and curing processes during manufacturing.

While the US mainly uses boiling point to classify VOCs, the EU defines a volatile substance as having a vapor pressure of 0.01 kPa or more at 293.15K or having corresponding volatility under particular conditions of use.[21] For example, for materials that are cured in an oven, its constituent substances would be considered volatile if their vapor pressure was equal to or greater than 0.01 kPa at the oven temperature. Vapor pressure measures the pressure of the vapor of a substance over a sample of that

[20] US Environmental Protection Agency *Technical Overview of Volatile Organic Compounds,* https://www.epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds.

[21] European Parliament and Council of the European Union. (2010). *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast). Official Journal of the European Union, L 334*, 17–119. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0075 Article 1(45).

substance in a sealed container at a specific temperature.[22] It is a measure of the fraction of molecules that have a kinetic energy greater than the amount needed to vaporize. Note that it is possible (but uncommon) for a solid to have a measurable vapor pressure. In general, as temperature increases, the vapor pressure also increases. Vapor pressure curves are published for many common substances.

5.2.2.2 Reactive Substances

Some products (often coatings or adhesives) may have multiple liquid components that are mixed and applied to form a solid. These would generally undergo a chemical reaction that causes the substances on the as-delivered article to be different (in composition and/or quantity) than the substances present in the unmixed base and/or activator.

The manufacturer may have more detailed information on the composition of the cured (reacted) material. Note that the addition of a solvent thinner does not typically initiate a chemical reaction, though the solvent thinner may be considered volatile (see 5.2.2.1).

Materials that are stored/shipped in dry ice or controlled temperatures may also be reactive, in that the substances react and form different substances on the article as shipped.

Examples of reactive materials may include:

- structural adhesive film
- pre-impregnated composites (pre-pregs)
- adhesives and sealants
- filament winding materials
- resin fusion materials (resin injection)
- two-component systems (e.g., coatings, adhesives, sealants)
- heat-cured systems
- frozen premix (of multiple components sent by dry ice or controlled temperatures)
- reactive hotmelts

Material stabilizers, fillers, polymers, and flame retardants are expected to be present in the article as shipped.

For example, in a simple solvent-containing paint, the solvent evaporates once the paint is applied to the part and would not be present on the finished item:

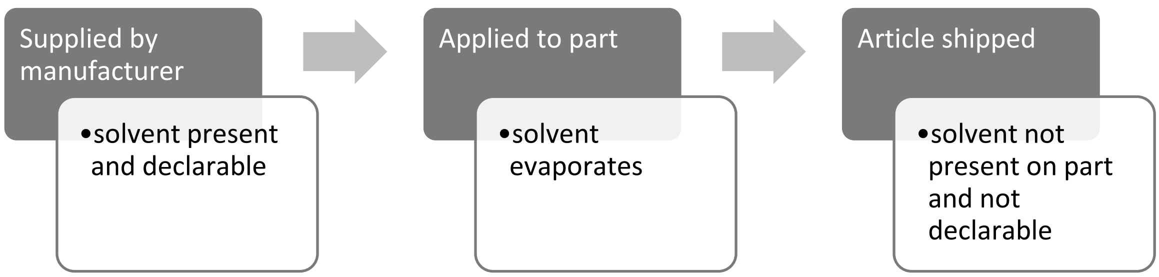


Figure 18. Example Stages of a Transformational Substance that Evaporates

[22] Ebbing (1996). General Chemistry, 5th edition; Houghton Mifflin, p.434.

However, if the same paint is supplied as part of a touch-up kit, the solvent has not evaporated and would be present in a declaration, as illustrated below on Figure 19.

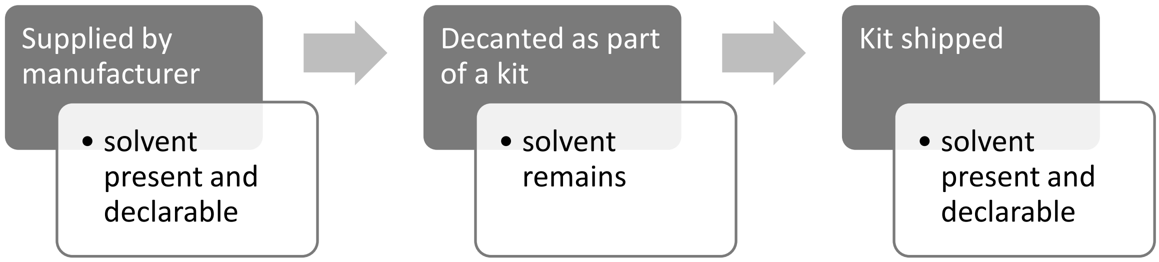


Figure 19. Example of Stages of a Transformational Substance that Has Not Yet Evaporated

5.3. Information on Substances in Processes

In addition to substances that remain on a finished product, a variety of substances are used in manufacturing processes. Process substances are typically chemical products that are applied in one or more steps during the manufacturing of an article. It is not uncommon for substances used in processes to be reactive, evaporative, or transformational and not remain on the delivered product. Therefore, these process substances cannot be identified from a “substances in product” declaration, making their visibility critical for global enterprises to identify and manage their substance related risks.

Historically, materials and substances declarations have focused on the content of the delivered *product*. However, as global regulations change, some of these process substances may become restricted or phased out. Companies and/or customers may be unaware that a product depends on substances with a compliance or obsolescence risk. This creates greater challenges related to manufacturing, operation, maintenance, and repair of products. Recognizing these increasing risks, some customers and suppliers are requesting declarations of substances in *processes*.

5.3.1. Surface Cleaning Substances

Common applications for process chemicals throughout manufacturing can include preparation of a surface for future processing (e.g., cleaning and degreasing fluids) or modification of one or more properties of the surface of the article(s). Solvent, mechanical, or chemical cleaning of surfaces is not expected to leave a substance from the cleaning process on the surface of the product as delivered. Substances in etchants, deoxidizers, and pickling chemical processes are not intended to remain on the metal surface after chemical processing is completed.

5.3.2. Surface Treatment Substances

Metals may have a surface treatment applied to enhance performance such as improving corrosion resistance. A surface treatment may be composed of multiple layers of materials, and substances in all layers must be identified. Refer to the coating specification to identify the layers and material content.

Common metal alloys and their surface treatments are noted below in Table 38:

Table 38. Common Surface Treatments for Metal Alloys

Metal Alloy	Common Surface Treatment(s)
Aluminum	anodization, conversion coating/passivation, plating
Corrosion Resistant Steel	passivation
Low Alloy Steel	plating
Titanium	usually none required (conversion coating for coated parts)

See Appendix B Common Surface Finishes and Specifications for more information.

5.4. Substance Information on SDSs

SDSs may contain useful information on substances in products and are commonly used as a method of hazard communication. However, there are some limitations to note.

5.4.1. Variation in SDS Information

Caution should be used when referencing an SDS to determine the presence of substances in the product. For example, the SDS may ***not*** indicate:

- non-hazardous substances;
- the substances formed from chemical reactions during processing;
- substances that are lost or consumed during production, such as those that are volatile or reactive;
- substance(s) present, but below an applicable regulatory concentration threshold (e.g., less than 1% for non-carcinogenic substances in the US); or
- all substances contained in the material (e.g., some may be proprietary and are exempted from disclosure requirements in certain jurisdictions).

Also note that:

- Substances may be referred to by different names or CAS numbers in different jurisdictions.
- SDSs created for certain jurisdictions may differ in their reporting of substances than those from other geographical locations (e.g., an EU SDS may report certain substances that are only of concern within the EU, and thus a US version of the same SDS may not report those same substances if they are not considered hazardous in the US. This can be an issue when reporting EU declarations using data from a US SDS.).
- Although the GHS has improved uniformity across jurisdictions, the selection of clauses (or lists of mandatory classifications) by participating governments can lead to different classifications, and therefore different disclosures.
- Some companies choose to sell different formulas in various jurisdictions due to compliance and/or environmental factors.

Figure 20 is an example of what might be encountered when searching for SDSs on a supplier's website:

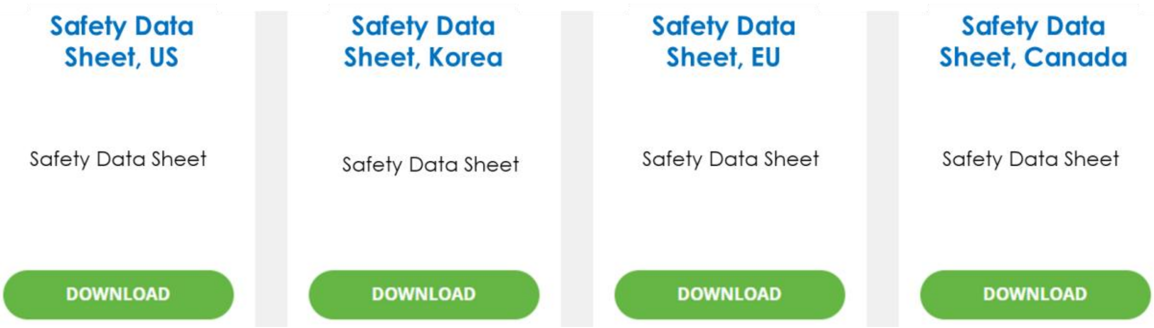


Figure 20. Examples of Different SDSs for the Same Product on a Supplier's Website

All four of these SDSs are for the same common thread sealant product, but depending on the country or region's requirements, different substances may be disclosed. In this case, the US and Canada SDSs show only one or two substances (totaling less than 5% of the total material composition). The EU SDS lists three hazardous substances, and the South Korea SDS discloses seven different substances and CAS #s, several of which do not appear on the other three SDSs. In addition, be aware that the same product may be formulated differently in each region, depending on local requirements, as illustrated in Figures 21 to 24.

SECTION 3: Composition/information on ingredients

3.1. Substances

Not applicable

3.2. Mixtures

Name	Chemical name / Synonyms	Product identifier	%	Classification (GHS CA)
Cumene hydroperoxide	Cumyl hydroperoxide / .alpha.,.alpha.-Dimethylbenzyl hydroperoxide / Hydroperoxide, .alpha.,.alpha.-dimethylbenzyl- / Isopropylbenzene hydroperoxide / Hydroperoxide, 1-methyl-1-phenylethyl- / 1-Methyl-1-phenylethyl hydroperoxide / 1-Methyl-1phenylethyl-hydroperoxide / Trimethylhydroquinone / 2-Hydroperoxy-2-phenylpropane	(CAS-No.) 80-15-9	<= 1	Flam. Liq. 3, H226 Org. Perox. G, H242 Acute Tox. 4 (Oral), H302 Acute Tox. 3 (Dermal), H311 Acute Tox. 2 (Inhalation), H330 HHNOC 1, HHNOC Skin Corr. 1, H314 Eye Dam. 1, H318

Figure 21. Canada SDS for Thread Sealant Product

SECTION 3: Composition/information on ingredients

3.1. Substances

Not applicable

3.2. Mixtures

Name	Product identifier	%	GHS-US classification
TITANIUM DIOXIDE	(CAS-No.) 13463-67-7	1 - 5	Carc. 2, H351
Cumene hydroperoxide	(CAS-No.) 80-15-9	<= 1	Flam. Liq. 4, H227 Org. Perox. E, H242 Acute Tox. 4 (Oral), H302 Acute Tox. 4 (Dermal), H312 Acute Tox. 3 (Inhalation:dust,mist), H331 Skin Corr. 1B, H314 STOT RE 2, H373 Aquatic Chronic 2, H411

Figure 22. US SDS for Thread Sealant Product

SECTION 3: Composition/Information on ingredients

3.1. Substances

Not applicable

3.2. Mixtures

Name	Product identifier	%	Classification according to Directive 67/548/EEC	Classification according to Regulation (EC) No. 1272/2008 [CLP]
Poly(oxy-1,2-ethanediyl), .alpha.,.alpha.'-[(1-methylethylidene)di-4,1-phenylene]bis[.omega.-[(2-methyl-1-oxo-2-propenyl)oxy]-	(CAS-No.) 41637-38-1 (EC-No.) 609-946-4	30 - 40	Not classified	Skin Irrit. 2, H315 Eye Irrit. 2, H319 Skin Sens. 1, H317 STOT SE 3, H335 Aquatic Chronic 4, H413
Polyethylene glycol	(CAS-No.) 25322-68-3 (EC-No.) 500-038-2	20 - 30	Not classified	STOT SE 3, H335
Cumene hydroperoxide	(CAS-No.) 80-15-9 (EC-No.) 201-254-7 (EC Index-No.) 617-002-00-8	<= 1	Not classified	Org. Perox. E, H242 Acute Tox. 4 (Oral), H302 Acute Tox. 4 (Dermal), H312 Acute Tox. 3 (Inhalation:dust,mist), H331 Skin Corr. 1B, H314 STOT RE 2, H373 Aquatic Chronic 2, H411

Specific concentration limits:

Name	Product identifier	Specific concentration limits: DSD/DPD	Specific concentration limits: CLP
Cumene hydroperoxide	(CAS-No.) 80-15-9 (EC-No.) 201-254-7 (EC Index-No.) 617-002-00-8		(C < 10) STOT SE 3, H335 (1 =<C < 3) Eye Irrit. 2, H319 (3 =<C < 10) Eye Dam. 1, H318 (3 =<C < 10) Skin Irrit. 2, H315 (C >= 10) Skin Corr. 1B, H314

Figure 23. EU SDS for Thread Sealant Product

SECTION 3: COMPOSITION/INFORMATION ON INGREDIENTS

3.1. Mixture/Substance

Distinction of Substance or Mixture : Mixture

Substance Name	CAS-No.	Formula	Concentration
Polytetrafluoroethylene	9002-84-0	(C2F4)x	30 - 40%
Poly(oxy-1,2-ethanediyl), .alpha.,.alpha.'-[(1-methylethylidene)di-4,1-phenylene]bis[.omega.-[(2-methyl-1-oxo-2-propenyl)oxy]-	41637-38-1	(C2H4O)n(C2H4O)nC23H24O4	30 - 40%
Nonanedioic acid, polymer with 1,2-propanediol	29408-67-1	(C9H16O4.C3H8O2)x	20 - 30%
Polyethylene glycol	25322-68-3	(C2H4O)nH2O	1 - 5%
Titanium dioxide	13463-67-7	O2Ti	1 - 5%
Silica, amorphous, fumed, crystalline-free	112945-52-5	Unspecified	< 1%
Cumene hydroperoxide	80-15-9	C9H12O2	< 1%

Figure 24. South Korea SDS for Thread Sealant Product

Appendix A Common Declarable Substances Used in AD Industry Products

Based on IAEG member input, below are examples of some common AD-DSL substances encountered in the AD industry.

Table A-1. Common AD-DSL Substances in the AD Industry

CAS #	EC Number	Substance Name	Synonyms	Typical Applications
142844-00-6	604-314-4	Refractories, fibers, aluminosilicate		Heatshield/insulation media, solenoid valves, insulated ducting, thin layer inside aluminum casing (to prevent melting), heat barrier in batteries, adhesives, thermal barrier coatings, insulating/potting fillers
1317-36-8	215-267-0	Lead oxide	Lead monoxide, Lead (2+) oxide, Lead protoxide, Plumbous oxide	Piezoceramic components, batteries, absorbents, catalysts, lubricants, corrosion inhibitors, explosives, and rubber products
110-71-4	203-794-9	1,2-Dimethoxyethane	Ethylene glycol dimethyl ether (EGDME)	Lithium-ion batteries
117-81-7	204-211-0	Bis(2-ethylhexyl) phthalate (DEHP)	Di-(2-ethylhexyl) phthalate (DEHP)	Plasticizer in manufacture of polymer products (such as polyvinyl chloride [PVC]), coatings (lacquer, paint, ink)
68-12-2	200-679-5	N,N-Dimethylformamide	Dimethyl formamide (DMF)	Adhesives, coatings - solvents
12141-20-7	235-252-2	Trilead dioxide phosphonate	Lead oxide phosphite; Dibasic lead phosphite; Trilead dioxide phosphonate	Coatings (e.g., solid film lubricants)
49663-84-5	256-418-0	Pentazinc chromate octahydroxide	Trizinc bis(oxidanidyl)-dioxo-chromium dihydroxide, trizinc diketo(dioxido)chromium dihydroxide, trizinc dioxido(dioxo)chromium dihydroxide, zinc tetraoxychromate, zinc tetroxy chromate, zinc chromate hydroxide, basic zinc chromate, zinc chromate	Resin catalysts, corrosion-resistant primers, and paints
556-67-2	209-136-7	Octamethylcyclotetrasiloxane (D4)	Dimethylsiloxane cyclic tetramer, octamethyltetrasiloxane	Intermediate for molded silicones
7440-43-9	231-152-8	Cadmium (Cd)		Fasteners, connectors/connector housings, solder, corrosion protection plating (steel parts), ball bearings, welding, soldering, brazing, batteries
1333-82-0	215-607-8	Chromium (VI) trioxide	Chromic anhydride, chromium (VI) oxide, chromic acid, chromium trioxide (CrO_3), trioxochromium	Surface treatment against corrosion (chromic acid anodizing, chromate conversion coating) for aluminum parts, wave guides, radio frequency parts (e.g., adapters, filters, switches), high temperature cements, adhesives
872-50-4	212-828-1	1-Methyl-2-pyrrolidone	N-Methyl-2-pyrrolidone; N-methylpyrrolidone (NMP)	Outer sheath of insulation covers, aerospace adhesives, hardeners and sealing compounds, styrene-butadiene rubber latex production, PCB manufacture. Critical use for manufacture of space Li-ion batteries.
80-05-7	201-245-8	Bisphenol A (BPA)	4,4'-Isopropylidenediphenol	PCB-layer, epoxy adhesives, hardeners, polycarbonate
7789-06-2	232-142-6	Strontium chromate	Chromic acid (H2CrO4), strontium salt (1:1), chromium diolatodioxo-strontium salt (1:1), C.I. Pigment Yellow 32, Deep Lemon Yellow, strontium chromate (VI), Strontium Yellow, Citron Yellow, Delta Strontium Chromate, Micronized Strontium Chromate, Strontaine Yellow, Strontium Chrome Yellow, Strontium chromate 12170, Ultramarine Yellow	Paint primers, adhesive bonding primers, fuel tank coating, sealant, adhesive bonding primer

Table A-1. Common AD-DSL Substances in the AD Industry

CAS #	EC Number	Substance Name	Synonyms	Typical Applications
7439-92-1	231-100-4	Lead (Pb)		Welding, soldering, brazing or flux (e.g., solder and associated solder pastes and finishes), base metals or alloys, batteries, lubricants and greases (e.g., anti-seize compounds)
1306-19-0	215-146-2	Cadmium oxide		Cadmium plating, pigments, electrical contacts, batteries, wire insulation, coatings/paints
61788-32-7	262-967-7	Terphenyl, hydrogenated		Polysulfide sealants, polythioether sealants
9016-45-9	500-024-6; 931-562-3; 931-756-8; 931-755-2; 93154-7; 931-753-1	Nonylphenol ethoxylated		Polysulfide sealants, surfactant
127-19-5	204-826-4	N,N-Dimethylacetamide (DMAC)		Insulating plates, adhesive tape for electronics, industrial coatings, polyimide films (space thermal blanket material), paint strippers, ink removers, wire insulation
13560-89-9	236-948-9	Dechlorane plus	Dechlorane+; 1,6,7,8,9,14,15,16,17,17,18,18-dodecachloropentacyclo[12.2.1.16,9.02,13.05,10]octadeca-7,15-diene	Adhesives, flame retardant addition to epoxy compounds
84-74-2	201-557-4	Dibutyl phthalate	Di-n-butyl phthalate (DBP)	Softener and solvent in propellant powder for ammunition, sealants, nitrocellulose paints, film coatings and glass fibers, glass or ceramic (e.g., glass fibers). Plasticizer in polymers (such as PVC).

Appendix B Common Surface Finishes and Specifications

Anodization involves electrolytically coating a metal with a protective oxide, and chemicals used during the chemical processing may or may not remain on the surface after processing is completed. However, after chromic acid anodizing of aluminum, there could be some hexavalent chromium compound(s) remaining on the anodized surface, depending on porosity (e.g., 10-50%[11]). Anodized aluminum is often subsequently sealed and the anodize seal itself may contain declarable substances such as hexavalent chromium compounds (e.g., those meeting MIL-A-8625 Types I and IB requirements). Section 3.10.2.2 illustrates a calculation for a sodium dichromate sealing treatment on a chromic acid anodic coating.

Aluminum conversion coating (also typically called "chem film" or referred to by its trademarked names Alodine®, Iridite®, or Yellow Iridite®) can involve different formulations that contain different substances. For example, Military Detail Specification 5541, or MIL-DTL-5541, coatings can be either "Type I" or "Type II". Type I (hexavalent chromium) conversion coating leaves residual hexavalent chromium compounds on the conversion coated surface. "Chromate conversion coatings (CCC) formed by immersion of aluminum alloys in an acidic solution of chromate and fluoride have been used for years to inhibit aluminum corrosion. Such films have been shown to contain both Cr(III) and Cr(VI), with relative concentrations depending on the pretreatment procedure."[23] If the type is not specified, then MIL-DTL-5541 (Version F) states to apply Type I conversion coating. Check with source documentation to identify the materials used if a Type is not specified.

Passivation of corrosion resistant steel is the process of treating a metal to reduce the chemical reactivity of its surface in order to prevent corrosion and should not leave a substance on the metal surface after chemical processing is completed.

Plating is a process whereby metal is deposited on a surface from a chemical bath. Metal plated finishes contain only the plated metal – not the chemical constituents of the plating bath. Plated finishes may have an underplating layer or supplemental surface treatment which should also be reviewed for substance content.

For example, **cadmium plating per SAE AMS-QQ-P-416** may contain three layers as follows:

- **Underplating** such as nickel, copper or a zincate process that may be necessary on some types of base metals.
- **Cadmium layer** (SAE AMS-QQ-P-416 "class" specifies the thickness of the cadmium layer)

Supplemental treatment (SAE AMS-QQ-P-416 "type" specifies the surface treatment. Commonly the treatment is Type II chromate treatment).

[23] J. Zhao, G. Frankel and R. McCreery (1998), Corrosion Protection of Untreated AA-2024-T3 in Chloride Solution by a Chromate Conversion Coating Monitored with Raman Spectroscopy. *J. Electrochem. Soc,* vol. 145, p. 2258.

Table B-1. Common Surface Finishes and Specifications

Surface Finish	Example Specifications
Anodization	MIL-A-8625
	SAE AMS 2482
	EN 2101
	EN 2284
	SAE AMS 2470
	SAE AMS 2471
Conversion Coating/Passivation	MIL-DTL-5541
	MIL-DTL-81706
	SAE AMS 03-18
	SAE AMS-C-5541
	SAE AMS 2473
	SAE AMS 2477
	EN 2437
	EN 4729
Corrosion Resistant Steel Passivation	ASTM A967
	SAE AMS 2700
	SAE AMS-QQ-P-35
Cadmium Plating	SAE AMS-QQ-P-416
	SAE AMS-C-8837
	SAE AMS 03-19
	SAE AMS 2400
	SAE AMS 2416
	SAE AMS 2401
	SAE AMS 2451 (brush plating)
	SAE AMS 24128 (used with QQ-P-416)
	EN 2133
	EN 2535
Chromium Plating	MIL-DTL-14538
	SAE AMS 2460
	SAE AMS-QQ-C-320
	SAE AMS 03-14
	EN 2132
Nickel Plating	ASTM B733
	SAE AMS-QQ-N-290
	SAE AMS-C-26074
	SAE AMS 2424
	SAE AMS 2451 (brush plating)
	SAE AMS 2404
	EN ISO 1456
	ISO 4526
Tin-Lead Plating	SAE AMS-P-81728
	ASTM B579
Zinc-Nickel Plating	AMS 2417
Copper Plating	MIL-C-14550
	SAE AMS 2418

Appendix C Helpful Websites and References

Below we have provided a few examples of helpful websites and references; this is not an exhaustive list and there may be others not listed:

C.1. Substrate and Material Content Information

C.1.1. Copper in Aerospace Applications

C51000 - Aircraft bushings and bearings

AMS 4640-C63000 - Aircraft parts, pump shafts, structural members, landing gear parts

AMS 4590-C63020 - Aircraft parts, pump shafts, structural members, landing gear parts

AMS 4634-C64200 - Aircraft parts, landing gear parts

AMS 4596-C72900; AMS 4597-C72900; AMS 4598-C72900 - Landing gear bushings and bearings, control surface and actuator bushings and bearings, wing flap bearings, wheel bearings, brakes, door hardware, hydraulic actuators, valves, steering joints, helicopter controls, compression fit airframe fasteners, electronic system connectors

C86300 - High load gear, bearing applications

C86500 - High load gear, bearing applications

C90300 - Aircraft landing gear bushings

C90500 - Aircraft bushings and bearings

C90700 - Aircraft accessory drives

C93700 - Aircraft control bushings

C94100 - Aircraft carburetor bearings

C94300 - Aircraft carburetor bearings

C95400 - Bearings brushes, landing gear components, engine components

C95500 - Aircraft components, landing gear parts

AMS 4880-C95510 - Aircraft components, landing gear parts

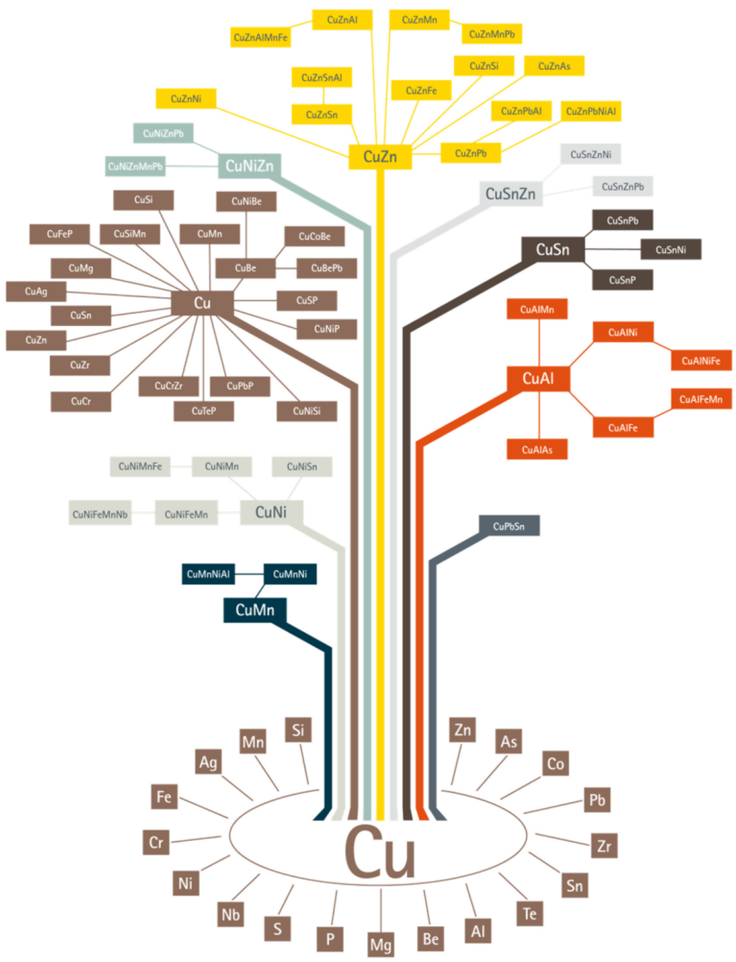


***Figure 25. Copper Alloy Tree*[24]**

Copper Reference Websites

https://internationalcopper.org/sustainable-copper/about-copper/copper-attributes-and-alloys/

https://www.elecmat.com/alloys/

C.1.2. Aluminum in Aerospace Applications

The following alloys were specially designed to meet the requirements of aircraft specifications:

Aluminum Alloy 2014 – aircraft landing gears and hydraulic cylinders

Aluminum Alloy 2219 – structural aerospace components

Aluminum Alloy 7475 – aircraft wing spars, wing skins, fuselage bulkheads

Aluminum Alloy 7178 – aircraft skins

[24] Figure from European Copper Institute's Copper Alliance website (https://copperalliance.eu/about-copper/copper-and-its-alloys/alloys/)

Aluminum Reference Websites

1. https://en.wikipedia.org/wiki/Aluminum_alloy
2. https://continentalsteel.com/blog/aerospace-aluminum-guide/
3. http://www.makeitfrom.com/

C.1.3. Plastics in Aerospace Applications

Polymer compositions can vary tremendously due to the incorporation of additives such as plasticizers, anti-aging stabilizers, flame retardants, and colorants. As such, consulting with a formulator or supplier might be helpful in determining material and substance compositions.

C.2. General Websites and Resources

C.2.1. Websites

International Aerospace Environmental Group (IAEG) http://www.iaeg.com/

Additional supporting resources for declaration development
https://www.iaeg.com/workgroups/wg1/chemicalrpt

European Chemicals Agency (ECHA) https://echa.europa.eu/home

Metals Gateway - https://metals-gateway.com/

AeroSpace and Defence Industries Association of Europe https://www.asd-europe.org/

C.2.2. Publications

AeroSpace and Defence Industries Association of Europe (ASD) – "Sectoral Guidance for Substances in Articles under REACH"
https://www.asd-europe.org/asd-sectoral-guidance-for-substances-in-articles-under-reach

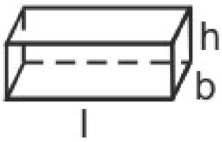
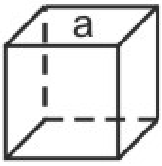
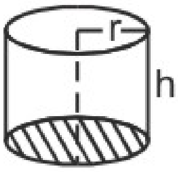
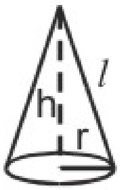
European Chemicals Agency (ECHA) – "Guidance on Requirements for Substances in Articles"
https://echa.europa.eu/-/guidance-on-requirements-for-substances-in-articles

IPC-1065 – "Material Declaration Handbook (For Users and Manufacturers of Printed Circuit Boards)"

Appendix D Helpful Geometric Formulas

Below in Table D-1 are a few examples of helpful mathematical formulas for area and volume.[25] This is not an exhaustive list and there may be others not listed.

Table D-1. Volume and Surface Area Equations for Common Solid Shapes

Name	Figure	Curved Surface area	Total surface area	Volume
Cuboid		$2h(l+b)$	$2(lb+bh+lh)$	lbh
Cube		$4a^2$	$6a^2$	a^3
Right circular cylinder		$2\pi rh$	$2\pi r(r+h)$	πr^2h
Right circular cone		πrl	$\pi r(l+r)$	$\frac{1}{3}\pi r^2h$
Sphere		–	$4\pi r^2$	$\left(\frac{4}{3}\right)\pi r^3$
Hemi-sphere		$2\pi r^2$	$3\pi r^2$	$\left(\frac{2}{3}\right)\pi r^3$

[25] https://www.campusgate.in/2015/03/volumes-and-surface-areas.html