IAEG® Declaration Development Support Document

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*Version **2.1***

Version History

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12 July 2019	*1*	N/A	N/A
14 July 2021	*2*	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

Table of Contents

List of Tables

List of Figures

1.0 Introduction

Aerospace and Defense (AD) industry companies and their supply chains have an increasing need to obtain information about materials and substances contained within products due to the growing number of international chemical regulatory requirements. The International Aerospace Environmental Group (IAEG®) has developed resources to support the exchange of declarations containing material and substance data between members of the AD industry supply chain. This document was created by IAEG to support the identification and quantification of materials and substances within products consistent with the data elements contained in IPC-1754-AM2: *Materials and Substances Declaration for Aerospace and Defense and Other Industries* standard. The IPC-1754-AM2 standard establishes the requirements for exchanging material and substance data for products between suppliers and their customers for AD and other industries with deep supply chains and complex bills of materials (BOMs.)

2.0 Scope

This document is offered for suppliers' consideration when providing declarations for materials and substances contained within the products (e.g., articles, complex assemblies, hardware, etc.) that they supply to customers in the AD industry supply chain. The information in this document is intended to assist manufacturers or suppliers of products (including their supply chains) to estimate the substance content of materials in products, or of the products themselves. These estimates are based on the knowledge of properties of substances used to make, or modify those products and in some cases, an understanding of the physical characteristics of the products themselves. In some cases, the source data available to support the development of substance estimates is challenging to interpret (e.g., concentration ranges in Safety Data Sheets [SDS].) In meeting the objective of providing an acceptable estimate, this document's intent is to provide methods that can be used by suppliers to meet obligations that depend upon such estimates, including obligations imposed by direct regulatory requirements, or those used to satisfy other internal or customer needs.

3.0 Definitions and Acronyms

AD – Aerospace and Defense

AD-DSL – Aerospace and Defense Declarable Substances List

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 is any object that is not defined as a substance or mixture of substances (and usually represents the lowest-level part on a Bill of Materials.)

BOM – Bill of Materials (may also be referred to as a parts list.)

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

CAS Number – Chemical Abstracts Service (CAS) registry number is an identifier assigned to every chemical substance including organic and inorganic compounds, minerals, isotopes and alloys.

CAD – Computer Aided Design

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 the surface that is covered is turned into a protective layer by the chemical action between the coating solution and metal.

Declarable Substance List (DSL) – a list of substances and/or group(s) of substances that require declaration.

Declaration – reporting of product-related substance data in standardized format, using specific data elements and rules. Declaration may either be based on a customer request, in a “request/reply mode” declaration, or be developed by the supplier in anticipation of customer requests in a “distribute mode” declaration. The method used to report material and substance data is known as a “materials and substances declaration” and is referred to herein as a “declaration.”

Distribute mode – the supplier identifies which products are the subject of the declaration.

EC – European Commission

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

EU – European Union

EU REACH – the Registration, Evaluation, Authorisation and Restriction of Chemicals is a regulation of the European Union (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.)

Hotmelt – an adhesive that is applied in a liquid molten form but sets into a solid form as it cools.

IAEG Substance ID – a unique substance identifier assigned by IAEG.

Material – matter that is made up of one or more substances.

MIL-DTL – Military Detail (specification)

Mixture – a mix or solution of two or more substances.

PCB – Printed Circuit Board

Passivation – the process of treating or coating a metal to reduce the chemical reactivity of its surface. In stainless steel, passivation means removing the free iron from the surface of the metal using an acid solution to prevent rust.

Plating – a process whereby metal is deposited on a surface from a chemical bath.

Product – any substance, mixture, material, part, subassembly, or assembly up to a finished manufacturer's assembly that is the subject of a declaration.

Request/Reply mode – the requester determines which products are the subject of the declaration.

Requester – the company or other entity requesting a declaration from the supplier; the requester is the default recipient of the supplier's response.

RF – Radio Frequency

Safety Data Sheet (SDS) – a regulatory document that includes information about hazardous constituents and properties of a chemical product, including regulatory information, hazards and instructions for handling, management, disposal and transport and also first-aid, fire-fighting and exposure control measures.

Subassembly – a smaller, constituent unit assembled separately but designed to be incorporated (sometimes along with other subassemblies) into a larger, more complex manufactured product/assembly.

Substance – chemical elements and their compounds.

Substrate – the surface or base material on which a finish or coating may be applied.

Supplier – a company or other entity responsible for providing the finished goods and/or services required to produce a product supplied to a customer.

SVHC – a Substance of Very High Concern is a chemical substance (or part of a group of chemical substances) for which it has been proposed that the use within the European Union (EU) be subject to authorisation under the EU REACH regulation.

Threshold – the default content amount 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. The transformation takes place when the material is mixed or processed, and undergoes evaporation, drying, chemical reaction, or curing.

US – United States

Volatility – a measure of a substance's tendency to vaporize into the air, given a standard temperature and pressure.

Vapor pressure – a measure of the tendency of a substance to change into the gaseous or vapor state, and it increases with temperature.

4.0 General Information on Materials and Substances in Products

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

However, when transformational substances are present, the supplier must determine which substances actually remain on the final product to develop an accurate material declaration. This section provides guidance on typical AD processes that involve transformational materials and how to address them when developing 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 that do not remain as a part of the product after processing (e.g., acid used to deoxidize a metal surface;) and
- Substances that react to form new substances (e.g., isocyanates polymerize to form polyurethane.)

4.1 Volatile Substances

The *volatility* of a substance is a measure of its tendency to vaporize into the air. 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 properly 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, and their presence should not normally 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.

Volatility is a physical property of a pure substance and a function of the vapor pressure of that substance and is typically expressed in units of pressure (e.g., kilopascals or kPa, millimeters of mercury or mmHg, atmosphere or atm.) The vapor pressure for substances is readily available on safety data sheets or other sources of physical or chemical substance data. The higher the vapor pressure, the greater the tendency to vaporize. Elevated temperatures (e.g., present during thermal processing steps, such as curing) increase the vapor pressure, hence increasing the tendency to vaporize.

While all substances with a measurable vapor pressure evaporate, those with an elevated vapor pressure (or lower boiling point) evaporate more readily. A related physical property, the boiling point temperature is another indicator that is often used as a measure of the tendency of a substance to vaporize – the lower the boiling point temperature, the higher the volatility of a substance. In fact, the boiling point temperature of a substance is the temperature at which the vapor pressure of a liquid equals the (ambient) pressure surrounding the liquid – in the majority of cases, “normal” atmospheric pressure.

For the purposes of estimating the composition of products, mixtures with boiling points less than *approximately* 250^{o}C will usually vaporize at normal temperatures and pressures. Common examples include cleaners and solvents in coatings. 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 article.

4.2 Process Substances

Process substances are typically chemical products that are applied in one or more process steps during the manufacturing of an article. 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). Appendix B contains a list of some of the most common surface finish specifications.

4.2.1 Surface Cleaning Substances

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.

4.2.2 Surface Protective Treatments for Metal Alloys

Metals may have a surface treatment applied to enhance performance such as by 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 include:

Table I. 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)

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. For example, after chromic acid anodizing of aluminum, there should be little, if any, hexavalent chromium trioxide (CrO_3) remaining on the anodized surface. These trace amounts are likely less than 0.1%, *but should be confirmed* (e.g., the "ASD Sectoral Guidance for Substances in Articles under EU REACH"[2] states that less than 0.1% hexavalent chromium trioxide should remain on the surface after a chromic acid anodization process). 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 C.2.4 of Appendix C illustrates a calculation for a sodium dichromate sealing treatment on a chromic acid anodic coating.

[2] 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

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 conversion coating leaves residual hexavalent chromium compounds on the conversion coated surface. Type II conversion coating does not contain hexavalent chromium, and thus does not leave any residual hexavalent chromium. 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 removing the free iron from the surface using an acid solution 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)

4.3 Transformational / Reactive Substances

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. When determining the amount of a substance that is present in the final article, particularly in the case of paints, it is necessary to take into account that the concentration of the substance usually increases in the reaction product/mixture due to solvent evaporation (while the paint pigments/solids remain on the finished article). In contrast, substances in sealants normally do not change much in weight, while adhesives are so broad in possible behavior that a case-by-case approach must be applied. It is recommended (as good practice) 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 volatile or reactive substances on a declaration.

Coatings may be composed of multiple component materials that are mixed together prior to application. An example of this is a "base" and "activator" that are mixed together. Multi-component materials typically have 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.

When formulations are mixed and processed in accordance with the manufacturer's recommendations, no residual reactants should remain in the resulting material. 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.

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-delivered. Examples of these types of reactive materials include:

- Structural adhesive film
- Pre-impregnated composites (pre-pregs)
- Casting adhesives
- Filament winding materials
- Resinfusion materials (resin injection)
- Two-component systems (coatings, adhesives, sealants, etc.)
- 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 delivered. Materials such as hotmelts that are simply heated and then cooled should not undergo a change in composition.

5.0 Declaration Process

As indicated above, the method used to report material and substance data is known as a "materials and substances declaration" and is referred to simply as a "declaration" throughout this document. The process of developing declaration information is managed through an individual AD company's internal processes as well as data received from its suppliers, and is subject to the requirements of those business-to-business relationships and regulatory or contractual agreements. **Figure 1** is a high-level representation of the typical process a supplier might follow upon receiving a declaration request.

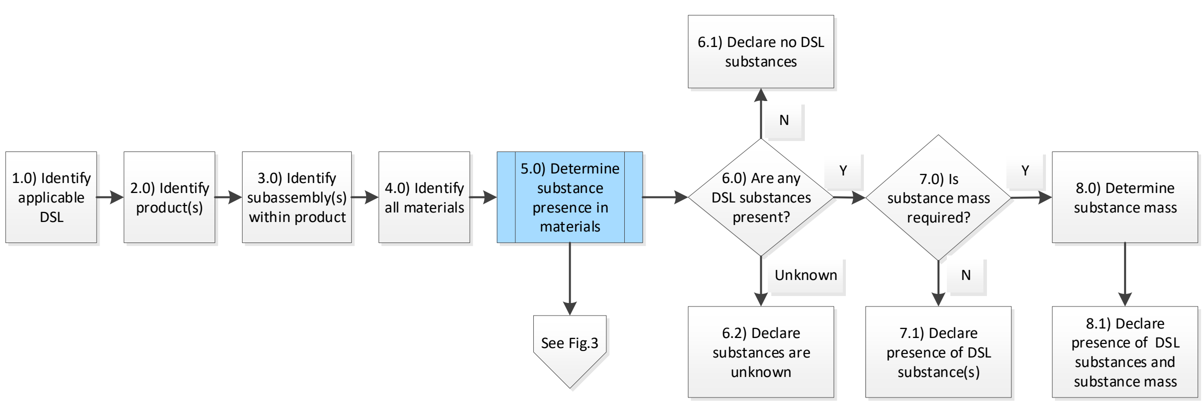


Figure 1. General declaration process flow diagram

Step 1: Identify applicable DSL: Determine the list of substances that must be declared when present. Typically, the requester identifies the DSL or the supplier determines the DSL when there is no requester (or one is not specified). Additional substances known to be present in the product but not listed on the DSL may be provided in a declaration in anticipation of requests from multiple requesters, or to minimize additional supplier declaration requests when new substances are added to the DSL. For the AD industry, the default DSL is the Aerospace and Defence Declarable Substances List (AD-DSL). (Note: Declarations may be developed as a full disclosure of article substance composition, known as a Full Material Declaration (FMD) or Full Substance Declaration (FSD)).

Step 2: Identify product(s): Identify the product(s) that require(s) a declaration. A supplier may provide a declaration without a request and identify the supplied products on the declaration.

Step 3: Identify subassembly(s) within 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. **Figure 2** is a graphical representation of such a complex product/assembly with multiple subassemblies. **Figure 3a** is a typical example of a complex product/assembly (an LED lamp), while **Figure 3b** is a graphical representation of the various subassemblies and articles that make up the LED lamp.

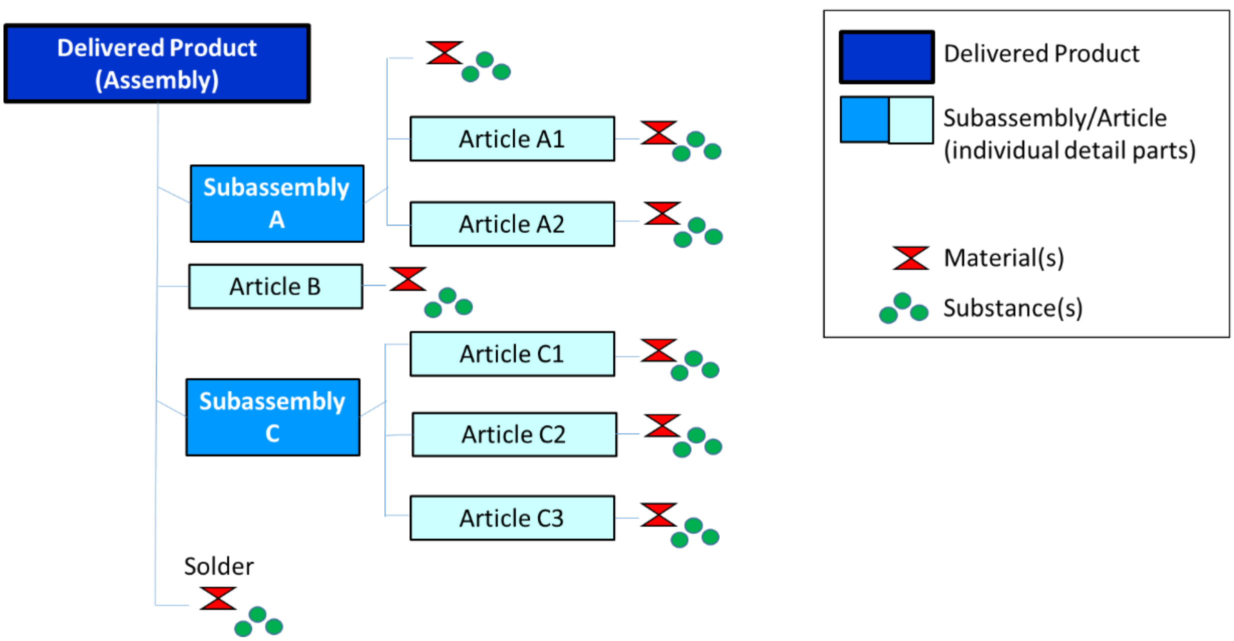


Figure 2. Graphical representation of a product with multiple subassemblies

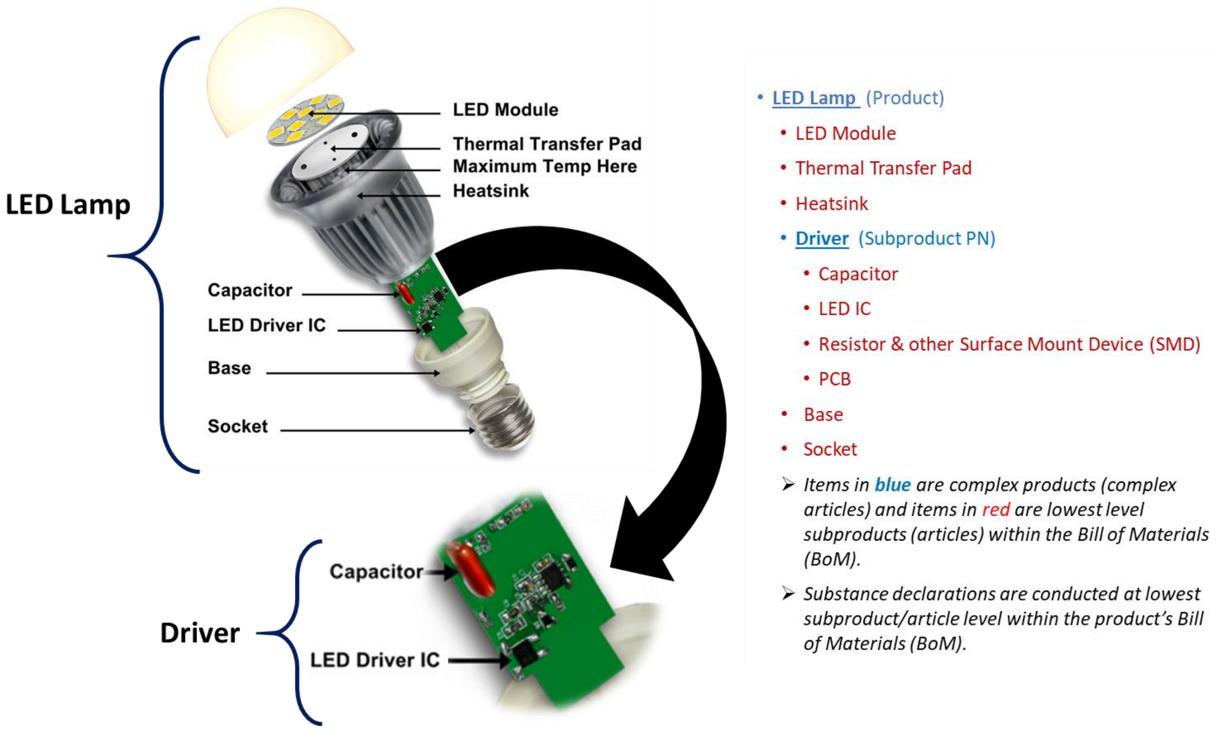


Figure 3a. Typical example of a complex product (LED lamp)

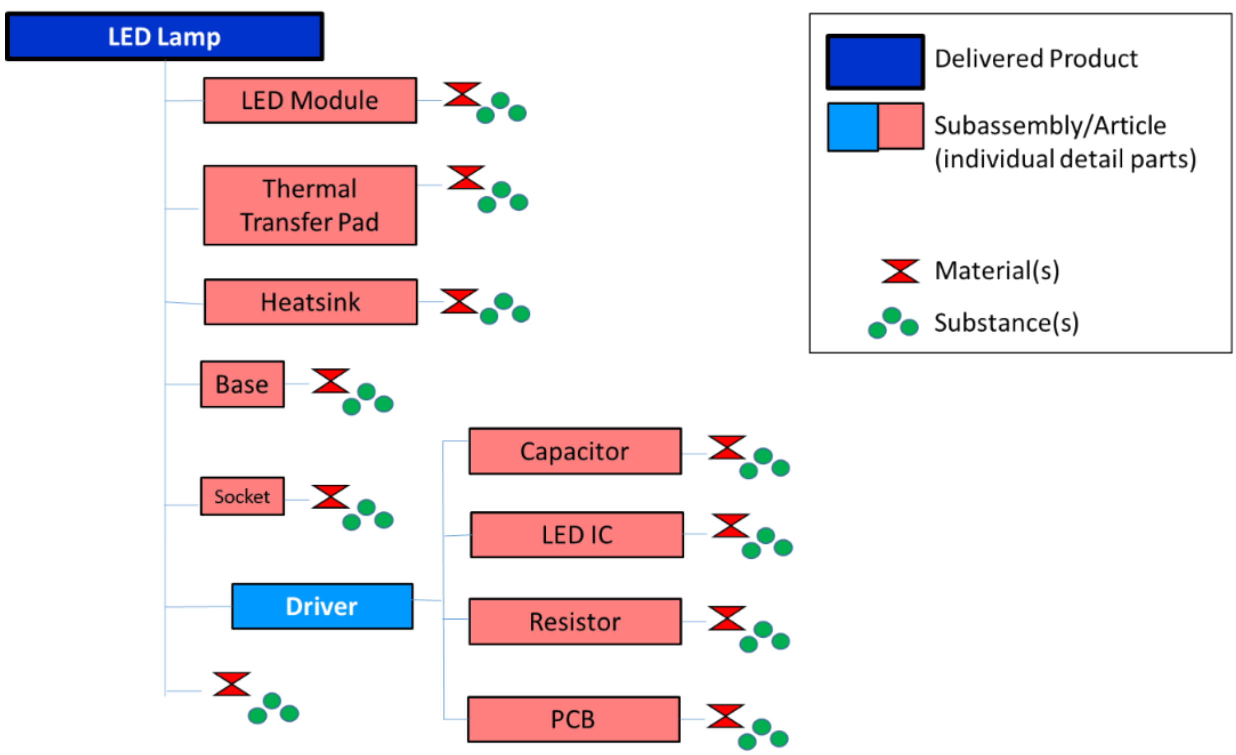


Figure 3b. Graphical representation of the LED lamp's subassemblies and articles (for Figure 3a)

<u>Step 4: Identify all materials</u>: Identify the unique materials (e.g., plastic, metal, ceramic, coatings, adhesives, etc.) in the product/assembly (within any subassemblies or articles that may make up the delivered product.)

<u>Step 5: Determine substance content of materials</u>: Identify the substance composition of each material. **Figure 4** displays the detailed steps for determining substances in materials.

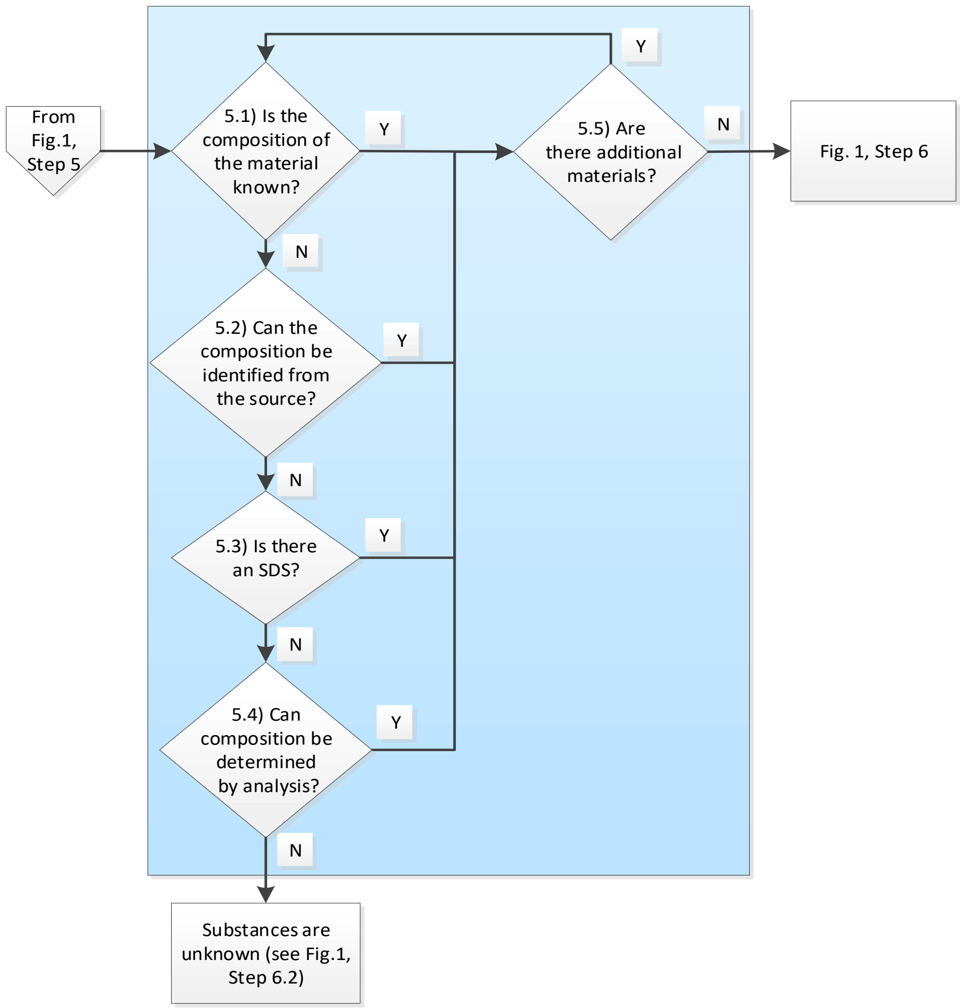


Figure 4. Identification of substances in materials

<u>Step 5.1: Is the composition of the material known</u>? Determine if the individual substances that compose the material can be identified from reviewing internal company resources (e.g., material database, specifications, test data, etc.) or leveraging materials subject matter experts.

<u>Step 5.2: Can the composition be identified from the source</u>? Determine if the individual substances that compose the material can be identified from appropriate sources such as:

- Formulator: The manufacturer of the material;
- Specification: Government, industry, supplier, etc.; and
- Literature: Supplier or industry information / data.

Step 5.3: Is there an SDS? Determine if an SDS is present for the material. If so, review the SDS and identify substances comprising the material. Caution should be used when referencing an SDS to determine the presence of substances in the product. For example, the SDS may ***not*** indicate:

- All substances contained in the material (e.g., some may be proprietary and are exempted from disclosure requirements). Further, it should be noted that SDSs created for certain jurisdictions (e.g., countries) 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)
- Substances may be referred to by different names or CAS numbers in different jurisdictions (e.g., countries)
- The substances formed from chemical reactions during processing (this is usually the case)
- 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)

Step 5.4: Can the composition be determined by analysis? Determine if the individual substances can be identified by engineering analysis or available chemical analysis (e.g., testing).

Step 5.5: Are there additional materials? Return to **Step 5.1** to review the next material.

Step 6: Are any DSL substances present? After identifying the materials and constituent substances, determine if any substances on the DSL were found.

Declare no DSL substances: No DSL substances were found during the product/material analysis. Document this information using the appropriate format.

Declare substances are unknown: If all options to determine the substances in a material have been exhausted, then the substance for that material is considered "unknown." If only a portion of the substances in the material is known, declare those known substances. It is anticipated that declaring an "unknown" substance may trigger a follow up from the requester to the supplier.

Common Assumptions and Tips for Substance Identification:

- SDS requirements and content vary by country or region, depending on governing regulations (e.g., EU safety data sheets are likely to contain more information on hazardous substances.)
- Metal alloys, such as corrosion resistant steel, often contain elemental chromium. Elemental chromium in metal alloys and plating form does not have the same environmental and health concerns as chromium present in hexavalent chromium compounds (i.e., metal alloys may contain elemental chromium, but do not contain regulated hexavalent chromium/compounds.)

- Metal plated finishes such as cadmium plating, chromium plating, and nickel plating 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 DSL substances (e.g., cadmium plating with a supplementary chromate coating.)
- Chromate conversion coatings (i.e., "chem film", Alodine®, or Iridite®) are often applied per MIL-DTL-5541 and can be either Type I or Type II. Type I conversion coating leaves residual hexavalent chromium compounds on the conversion coated surface; Type II conversion coating does not contain hexavalent chromium, and thus does not leave any residual hexavalent chromium. If the type is not specified, then MIL-DTL-5541 states to apply Type I conversion coating. Check with your source documentation to identify the materials used, if no type is specified.
- Anodized aluminum is composed of an aluminum oxide film, and chemicals used during the surface treatment do not remain on the metal surface after processing is completed. For example, after chromic acid anodizing, there is no hexavalent chromium trioxide (CrO_3) remaining on the anodized surface. However, anodized aluminum is often sealed and the anodize seal may contain declarable substances such as hexavalent chromium compounds (e.g., those meeting MIL-A-8625 Types I and IB requirements.)
- Painted aluminum parts typically have a conversion coating or anodize surface treatment applied first and should be checked for the presence of declarable substances. Bonded aluminum parts may omit the conversion coating or anodize but may also have chromate-containing bond primers that should also be investigated to for the presence of declarable substances.
- Solvents used for cleaning processes should not remain on the finished hardware/product as delivered.
- Substances in etchants, deoxidizers, and pickling chemical processes do not remain on the metal surface after chemical processing is completed.
- Substances used during the passivation of corrosion resistant steels per ASTM A967 or SAE AMS2700 do not remain on the metal surface after chemical processing is completed.
- Secondary passivation processes (e.g., post treatment, sealing, conversion coating, and surface treatment) typically leave substances on the hardware surface as delivered and should be checked for the presence of declarable substances.
- Solvents listed on the SDS that are present during 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.
- Multi-part materials composed of a base and activator (e.g., curing agent, catalyst, etc.) 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 safety data sheet(s). A consultation with the material manufacturer or supplier could be helpful in determining if declarable substances are present in the cured mixture.

- 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.
- Painted surfaces often have a primer which may contain hexavalent chromium.
- Polyvinyl chloride is fully polymerized and contains no vinyl chloride monomer.
- Phenolic resins do not contain free phenol monomer.
- Polymerized styrene (polystyrene) does not contain free styrene.
- Nitrile rubber contains no free cyanide compounds.

Step 7: Is substance mass required? Determine if specific substance quantity/mass data is required.

Declare presence of DSL substance: Provide the response to the requester using the agreed upon format for the presence of the DSL substances.

Step 8: Determine substance mass: 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 II** below illustrates examples of how substance mass data may be provided consistent with IPC-1754. Refer to Appendix C for examples of substance mass calculations.

Table II. 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 1-7%
	27.3		%	Mass is less than or equal to 27.3%
9.6			g	Mass is greater than or equal to 9.6g
12.1	15.6		kg	Mass is between or equals 12.1kg and 15.6kg
			unknown	Mass is unknown

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. (See example C.2.5 in Appendix C.)
- Densities of 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. (For examples of surface area calculations, refer to section C.2.1 in Appendix C.)
- When available, computer models provide more accurate physical data (e.g., surface area) to be used for substance mass calculations.
- When declaring a substance against a DSL that has a reporting threshold (e.g., the EU REACH regulation), if the presence of a substance is 0.1% or less in an article, then reporting of 0.1% maximum is sufficient. It may not be necessary to calculate very small trace amounts of substances unless required by the requester.
- For conversion coated aluminum greater than 9 mils (0.009 in) thick, the presence of hexavalent chromium compounds is less than 0.1% on the coated article. (See calculation C.2.3.1 in Appendix C.)
- For supplementary chromate film on cadmium plating, the presence of hexavalent chromium compounds is less than 0.1%. (See calculation C.3.1 in Appendix C.)

Step 8.1: Declare presence of DSL substances and substance mass: Provide the substance and associated mass information to the requester (using the agreed-upon format) on the presence of the DSL substances.

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 Aerospace and Defense industry.

CAS #	EC #	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	Di-(2-ethylhexyl) phthalate (DEHP)	Plasticizer in manufacture of polymer products (such as 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

CAS #	EC #	Substance Name	Synonyms	Typical Applications
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 (CrO3), trioxochromium	Surface treatment against corrosion (chromic acid anodizing, chromate conversion coating) for aluminum parts, wave guides, RF parts (adapters, filters, switches, etc.), 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

CAS #	EC #	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 FINISH 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: SUBSTANCE MASS CALCULATIONS

C.1 Mass (Weight) Calculations Overview

This Appendix contains an overview of mass calculation examples consistent with the declaration process overview steps in **Figure C1** (shown below). For the purposes of this document, the term "mass" is equivalent to "weight." The examples are provided for illustrative purposes only and are not intended to reflect the design of any specific vendor product/assembly. 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) unit of measures. Examples of calculating both, in the relative and absolute unit of measures, are provided in this Appendix. Typically, reporting of substance mass in mass percent is preferred.

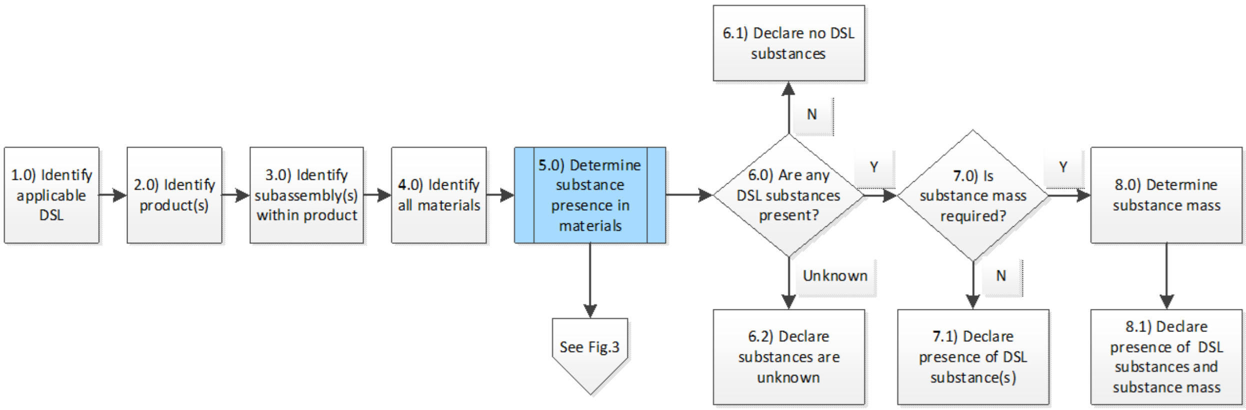


Figure C1. General declaration process flow diagram (for reference – from section 5.0)

C.1.1 Substance Mass and Mass % Calculation Formulas

Always ensure that consistent units (metric vs. imperial) are used during calculations. The substance mass percent on an individual article is calculated as follows:

Substance mass % $_{Article}$ **= (substance mass** $_{Article}$ **/ mass** $_{Article}$**)***100%

Where:

Substance mass $_{Article}$ is the measured or calculated weight (mass) of the substance in the article as delivered.

Mass $_{Article}$ is the weight (mass) of the article as delivered, including applied coatings and added materials (Note: All coatings are assumed to be dry/cured. The article mass should be known by the article manufacturer for shipping purposes or as article of a contract deliverable for overall mass calculations.)

C.1.1.1 Substance Mass Content in Bulk Materials

For substances that are integral constituents of the bulk material of the article, the substance mass percent is typically provided in the material or specification limits (e.g., 2.4 % beryllium in a copper beryllium alloy) and/or in the formulator's declaration or Safety Data Sheet (SDS) for the material as delivered (e.g., grease, battery, etc.) containing substance mass percent. Where the specification or the SDS has a range of values listed, the worst case value should be used as the mass percent of the substance. No calculations are required if the substance is not present in the article as delivered.

C.1.1.2 Substance Mass Content in Coatings

All coatings are assumed to be dry/cured. When the substance is in a coating (e.g., plating, paint, etc.) present on the article, then the mass of a substance in the coating is calculated as follows:

$$\textbf{Mass}_{\text{Substance in coating}} = \textbf{substance fraction}_{\text{Coating}} * \textbf{mass}_{\text{Coating}}$$

$$\textbf{Mass}_{\text{Coating}} = \textbf{thickness}_{\text{Coating}} * \textbf{density}_{\text{Coating}} * \textbf{surface area}_{\text{Coating}}$$

Where:

Mass $_{\text{Substance in coating}}$ is the mass of the substance in the coating as on the delivered article.

Substance fraction $_{\text{Coating}}$ is the fractional amount of substance in the coating as present on the delivered article.

Mass $_{\text{Coating}}$ is the mass of the coating as on the delivered article.

Thickness $_{\text{Coating}}$ is the actual or where there is a tolerance, the maximum thickness of the coating as on the delivered article.

Density $_{\text{Coating}}$ is mass per unit volume of the cured coating as on the delivered article.

Surface area $_{\text{Coating}}$ is the surface area of the coating on the delivered article. (A computer aided design, or CAD, model of the article that automatically determines the surface area is preferred. If CAD data is not available, an estimation of the surface area can be made. Refer to section C.2.1 for examples of how to estimate surface area.)

When the applied coating is a mixture of volatile and non-volatile substances, the substance fraction typically is not the mass percent listed on the SDS. The substance fraction is only that fraction that remains in the dried/cured coating. If the formulator cannot provide the substance fraction in the dry film, then the substance fraction can be calculated by determining the mass percent of each solid constituent from a SDS as follows:

$$\textbf{Substance fraction}_{\text{Solid substance in coating}} = \frac{\textbf{Mass \%}_{\text{Solid substance in coating}}}{\textbf{Mass \%}_{\text{Coating}}}$$

Where:

Mass % $_{\text{Solid substance in coating}}$ is the mass percent of the substance in the coating as on the delivered article.

Mass % $_{\text{Coating}}$ **(mass percent of coating)** is the sum of the dry film substance mass percents from the SDS, or Σ (solid substance mass %). (**Note**: an example calculation is provided in section C.2.5.) $\textbf{Mass \%}_{\text{Coating}} = \Sigma\ \textbf{Mass \%}_{\text{Solid substance mass \%}}$

The coating density can sometimes be found in the formulator's technical data sheets for the coating material or frequently can be obtained by contacting the formulator. If not readily available, the coating density can be estimated through calculation. This calculation will require some research into the densities of the solid compounds, but are usually available through internet search engines. An example including deriving the coating density is provided in section C.2.5.

C.2 Basic Calculations – Substrate Surface Areas and Volumes, Coating Substance Mass Thresholds, Sodium Dichromate Seal Calculations, and Safety Data Sheet Examples

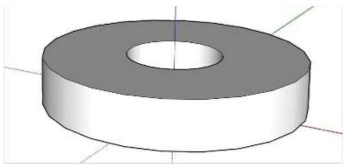
C.2.1 Calculating Substrate Surface Areas

A substrate is the material which provides the surface on which a coating is deposited or inscribed. Three options for determining article/substrate surface area include but are not limited to:

1. Obtain actual surface area from CAD drawing/model (preferred)
2. Calculate surface area based on similar basic shapes and applicable formulas (examples shown below;) and
3. "Eyeball it" to estimate surface area on the high side and provide as a maximum value.

<u>Example 1: Hexagonal nut</u>

For this example, a hexagonal nut is a ¾ inch (1.9cm) across flats with a ½ inch (1.2cm) bolt diameter and 7/16 inch (1.1cm) thickness. While calculation of a hexagonal cylinder area is possible using a specific formula, there is little accuracy lost by assuming that a nut can be represented as an annular ring. In this case, assuming an outside diameter (OD) of ¾ inch, an inside diameter (ID) of ½ inch and thickness (T) of 7/16 inch:

Surface area = Surface area $_{\text{top face}}$ + Surface area $_{\text{bottom face}}$ + Surface area $_{\text{outside circumference}}$ + Surface area $_{\text{inside circumference}}$

$= 2 (\pi (OD/2)^2 - \pi (ID/2)^2) + T * 2\pi(OD/2) + T * 2\pi(ID/2)$

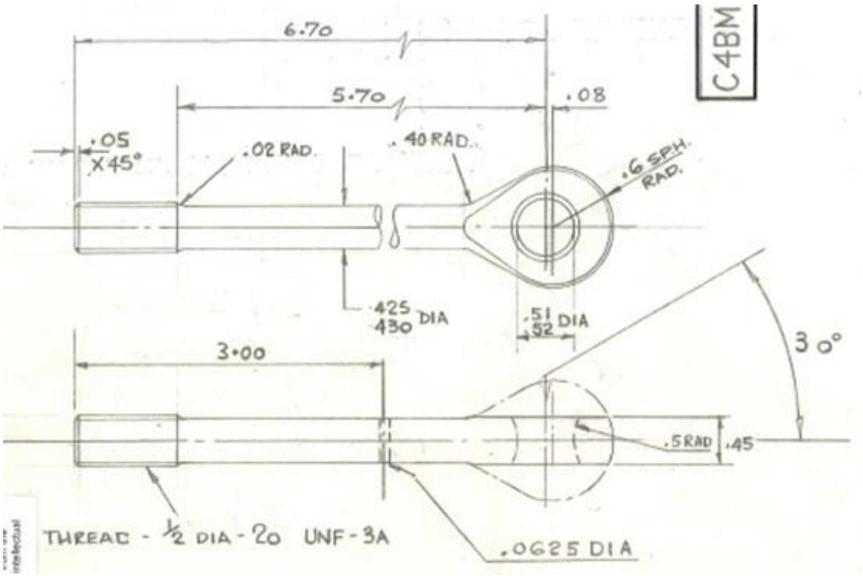
$= 2(3.14 * (0.375)^2 - 3.14 * (0.250)^2) + 0.438(2 * 3.14 * 0.375) + 0.438(2 * 3.14 * 0.250)$

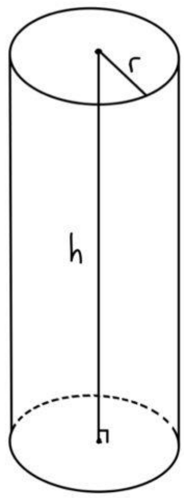
$= 2 (0.442 - 0.196) + 1.03 + 0.687$

$= 2.21$ in^2

Example 2: Cylindrical eye end

For this example, surface area will be calculated for a cylindrical shaped 4130 alloy steel (MIL-S-6758) Eye End[3].





By representing the eye end as a uniform solid cylinder, the surface area calculation can be easily estimated. Using a 1-inch straight length dimension ("h" in this example) for the article and a diameter of 0.425 inch (or a radius, "r", of 0.213 inch in this example) as representative for the cylindrical eye end, the surface area can be calculated using the equation for a solid cylinder.

Surface area $_{cylinder}$:

$= 2\pi rh + 2\pi r2$

$= 2 * (3.14) * (0.213) * (1) + 2 * (3.14) * (0.213)2$

= 1.62 in2

Example 3: Instrument Panel Frame[4]

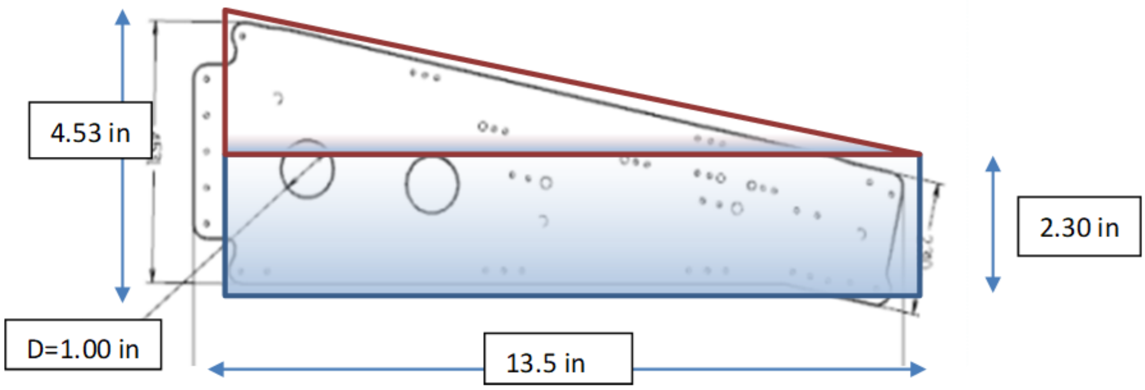
Surface area of the panel (top and bottom) is in the range of 83.5 to 89 inch^2 as determined by various methods listed below, all sufficiently precise:

1. By using CAD, analyze function on the flat article profile programmed for router:

   The surface area is 83.5 in^2 (0.58 ft^2) (This value will be used for subsequent calculations of chemical conversion coating and of strontium chromate in primer coating.)

[3] Figure shared with permission from Viking Air.
[4] Figures on this page shared with permission from Viking Air.

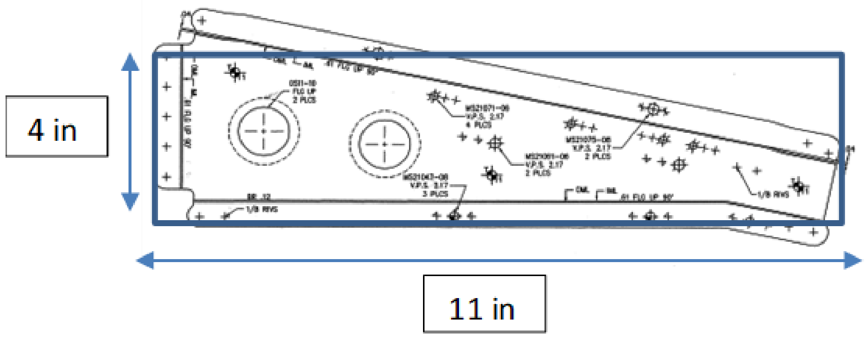
2. By using approximation of the flat profile of the panel; breaking down the shape into a rectangle and a triangle and subtracting holes:



$$
\begin{aligned}
13.5 * 2.30 \; + \; 13.5 * \frac{(4.53 - 2.30)}{2} \\
&= 46 \; in^2 of \; solid \; surface - \; 1 \; inch \; diameter \; holes \; (2 * 3.14 * 0.500^2) \\
&= 44.3 \; in^2 \; per \; side
\end{aligned}
$$

Surface Area = 88.6 in² (0.615 ft²) using basic shapes.

3. By "eyeballing" the surface area using a rectangle for the final article dimensions (holes not subtracted):



4 * 11 = 44 in² per side, therefore **88 in² per article (0.611 ft²)**

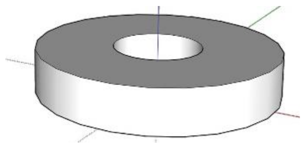
C.2.2 Calculating Substrate Volumes

Three options for determining article/substrate volume include (but are not limited to):

1. Obtain actual volume from CAD drawing/model (preferred)
2. Calculate volume based on similar basic shapes and applicable formulas; or
3. "Eyeball it" to estimate volume on the high side and provide as a maximum value.

Example 1: Hexagonal nut

For this example, a hexagonal nut is a ¾ inch (1.9 cm) across flats with a ½ inch (1.2 cm) bolt diameter and 7/16 inch (1.1 cm) thickness. While calculation of a hexagonal cylinder volume is possible using a specific formula, there is little accuracy lost by assuming that a nut can be represented as an annular ring. In this case, assuming an outside diameter (OD) of ¾ inch, an inside diameter (ID) of ½ inch and thickness (T) of 7/16 inch:

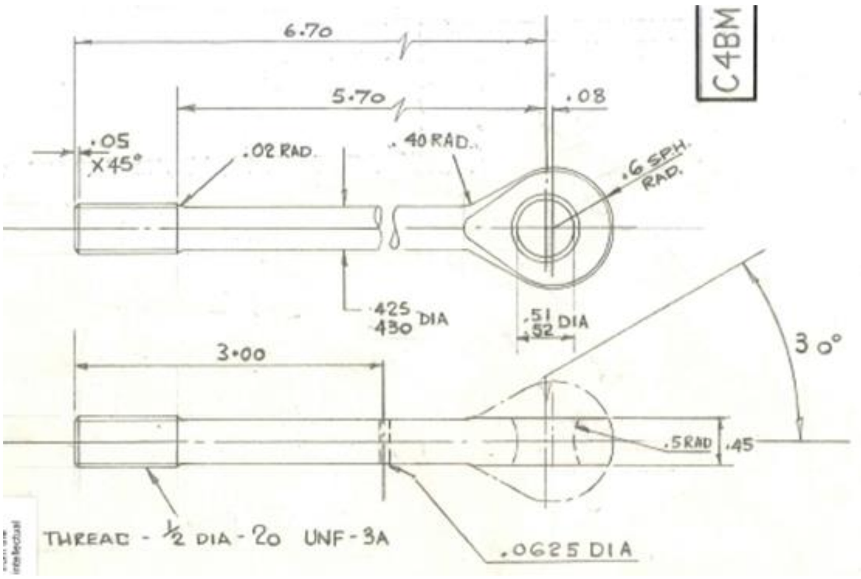


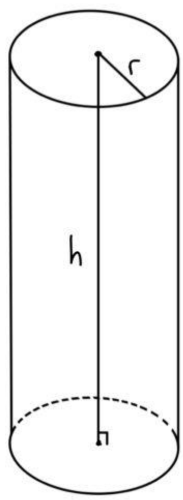
Volume $_{ring}$ = π * thickness $_{ring}$ * ((Diameter $_{outside}$/2)^2 – (Diameter $_{inside}$/2)^2)

$= \pi T\,((OD/2)^2 - (ID/2)^2)$
$= 3.14 * 0.438 * ((0.750/2)^2 - (0.500/2)^2)$
$= 3.14 * 0.438 * (0.0781)$
$= \mathbf{0.107\ in^3}$

Example 2: Cylindrical eye end

For this example, volume will be calculated for a cylindrical shaped 4130 alloy steel (MIL-S-6758) Eye End.





By representing the eye end as a uniform solid cylinder, the volume calculation can be easily estimated. Using a 1-inch straight length dimension ("h" in this example) for the article and a diameter of 0.425 inch (or a radius, "r", of 0.213 inch in this example) as representative for the cylindrical eye end, the volume can be calculated using the equation for a solid cylinder.

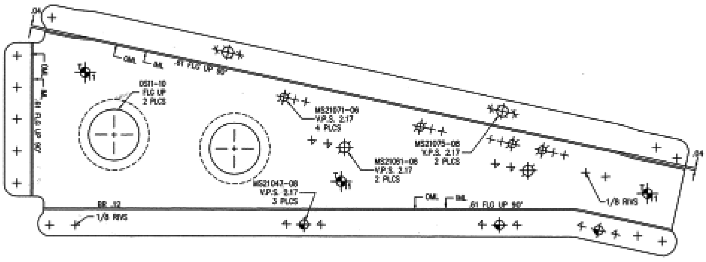
Volume cylinder = πr2h

= 3.14 * (0.213)2 * 1

= 0.142 in3

Example 3: Instrument Panel Frame[5]

For this example, volume will be calculated for an instrument panel frame using the surface area data in Sec C.2.1 Example 3. The thickness of the instrument panel frame is 0.0160 inch.



Volume $_{panel}$ **= thickness * surface area**

= 0.0160 * 83.5

= 1.34 in3

C.2.3 Minimum Substrate Thickness Needed to Fall Below Substance Mass Percent Threshold (EU REACH Regulation Examples)

A practical approach to estimating substance mass in a coating is to consider a single thin sheet of the substrate coated on both sides. This geometry provides the maximum surface area for the minimum mass.

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/mass for 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 or not there is risk of exceeding the mass % threshold of the substance.

The method for calculating the thickness of a 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)

[5] Figures on this page shared with permission from Viking Air.

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 $_{bottom\ face}$

Eq 1) Mass $_{Substrate}$ = thickness $_{Substrate}$ * 0.5 surface area $_{Substrate}$ * density $_{Substrate}$

Eq 2) Mass $_{Coating}$ = thickness $_{Coating}$ * density $_{Coating}$ * surface area $_{Substrate}$

Eq 3) Substance mass $_{Coating}$ = substance fraction $_{Coating}$ * Mass $_{Coating}$

Eq 4) Mass $_{Article}$= mass $_{Substrate}$ + mass $_{Coating}$

Eq 5) Substance fraction $_{article}$ = Substance mass $_{Coating}$ / Mass $_{article}$

Eq 6) Substance mass % $_{article}$ (mass percent of coating) = Substance fraction $_{article}$ * 100

Solving for the substrate thickness using Eq 1, Eq2, Eq 3, Eq 4 and Eq 5 results in:

Eq 7) $$F(Substance\ fraction\ in\ article) = \frac{f*t*d*S}{(T*0.5S*D + t*d*S)}$$

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

Eq 8) $$T(thickness\ of\ substrate) = \frac{2td}{D}\ [\frac{f}{F} - 1]$$

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.

C.2.3.1 Example: Chromate conversion coating (containing CAS # 1333-82-0) on Aluminum substrate

Equation 8 from section C.2.3 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 120 mg/ft^2 (2.64x10^{-4} lb/ft^2) and 55 mg/ft^2 (1.21x10^{-4} lb/ft^2) coating weight of the chromate conversion coating, respectively. The Case 1 calculation using a coating weight of 120 mg/ft^2 represents a maximum, or “worst case”, value while the Case 2 calculation with 55 mg/ft^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 and others within the document (i.e., mg/ft^2).

<u>Case 1 - Coating weight of 120 mg/ft^2 for Class 1A MIL-DTL-81706 chromate conversion coating ("worst case" weight)</u>

Basis:

Thickness $_{Coating}$ = t = 0.00003 inch maximum (equivalent to 120 mg/ft^2)

Density $_{Coating}$ = d = 0.054 lb/in^3 (specific gravity of chromate conversion coating)

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

Density $_{Substrate}$ = D = 0.098 lb/in^3 (specific gravity of aluminum)

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

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

T $_{Aluminum\ Substrate}$ = $[(2 * 0\ .00003\ *\ 0.054)/0.098]\ *\ [(0.6/.001)\ -1]$ = **0.020 inch**

Thus, if using 120 mg/ft^2 (2.64x10^{-4} lb/ft^2) chemical conversion coating weight, any sheet of aluminum exceeding 0.020 inch 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.

<u>Case 2 – Coating weight of 55 mg/ft^2 for Class 1A MIL-DTL-81706 chromate conversion coating ("typical" weight)</u>

Basis:

Thickness $_{Coating}$ = t = 0.000013 inch maximum (equivalent to 55 mg/ft^2)

Density $_{Coating}$ = d = 0.054 lb/in^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 = 0.098 lb/in^3 (specific gravity of aluminum)

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

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

T $_{Aluminum\ Substrate}$ = $[(2 * 0\ .000013\ *\ 0.054)/0.098]\ *\ [(0.6/.001)\ -1]$ = **0.0087 inch**

Thus, if using 55 mg/ft^2 (1.21x10^{-4} lb/ft^2) chemical conversion coating weight, any thin sheet of aluminum exceeding 0.0087 inch 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.

Conclusions for chromate conversion coatings:

- Chromate conversion coatings applied under a primer fall below 0.1% mass of CAS # 1333-82-0 chromium (VI) oxide on the article.
- For articles that have chemical conversion coating weights of 120 mg/ft2 (2.64x10-4 lb/ft2) or greater, calculations shall need to be done for substrates less than 0.02 inch in thickness.

C.2.3.2 Example: Cadmium (CAS # 7440-43-9) plating on steel substrate

Cadmium plating thickness is 0.0005 – 0.0008 inch per QQ-P-416 Class 1 on a 4130 alloy steel plate.

Basis:

Thickness $_{Coating}$ = t =0.0008 inch maximum

Density $_{Coating}$ = d = 0.312 lb/in^3 (specific gravity of cadmium)

Substance fraction $_{Coating}$ = f = 1 (dimensionless) as worst case for cadmium

Density $_{Substrate}$ = D = 0.284 lb/in^3 (specific gravity of 4130 alloy steel)

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

Again, using Equation 8 from section C.2.3, the simplified correlation is:

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

T $_{4130\ Substrate}$ = $[(2 * 0.0008 * \ 0.312)/0.284] \ * \ [(1/.001) \ - 1]$ = **1.76 inch**

Therefore, for articles having a Class I cadmium plating, any sheet of 4130 alloy steel greater than 1.76 inches in thickness would have a mass % of cadmium below 0.1%.

Conversely, articles having 4130 alloy steel substrate thicknesses below 1.76 inches would need to be specifically evaluated for the mass% of cadmium substances on the article, as it is likely to be greater than 0.1%.

C.2.3.3 Example: Epoxy primer coating containing strontium chromate (CAS # 7789-06-2) on aluminum substrate

<u>Case 1 - Epoxy primer dry film coating thickness per MIL-PRF-23377 is 0.0006 – 0.0009 inch on an aluminum alloy plate. (Note: this is the thickness range required by this specification for 1 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.</u>

Basis:

Thickness $_{Coating}$ = t =0.0009 inch maximum

Density $_{Coating}$ = d = 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 = 0.0976 lb/in^3 (specific gravity of aluminum alloy)

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

Again, using Equation 8 from section C.2.3, the simplified correlation is:

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

T $_{\text{Aluminum Substrate}}$ = $[(2 * 0.0009 * 0.0840)/0.0976] * [(0.21/.001) - 1]$ = **0.324 inch**

Therefore, for articles having a strontium chromate based primer containing 21% of substance mass $_{\text{Coating}}$, any sheet of aluminum greater than 0.324 inch in thickness would have a mass % of strontium chromate below 0.1%.

Conversely, articles having aluminum substrate thicknesses below 0.324 inch 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%.

Case 2 - Epoxy primer dry film coating thickness per MIL-PRF-23377 is 0.0006 – 0.0009 inch on an aluminum alloy plate. (Note: this is the thickness range required by this specification for 1 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.) This primer is a Low Chrome (LC) primer with strontium chromate content of 9% by mass in the dry primer.

Basis:

Thickness $_{\text{Coating}}$ = t = 0.0009 inch maximum

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

Substance fraction $_{\text{Coating}}$ = f = 0.09 (dimensionless) as worst case of strontium chromate

Density $_{\text{Substrate}}$ = D = 0.0976 lb/in^3 (specific gravity of aluminum)

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

Again, using Equation 8 from section C.2.3, the simplified correlation is:

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

T $_{\text{Aluminum Substrate}}$ = $[(2 * 0.0009 * 0.0840)/0.0976] * [(0.09/.001) - 1]$ = **0.138 inch**

Therefore, articles having a strontium chromate based primer containing 9% of substance mass $_{\text{Coating}}$, any sheet of aluminum greater than 0.138 inch in thickness would have a mass % of strontium chromate below 0.1%.

Conversely articles having aluminum substrate thicknesses below 0.138 inch 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%.

C.2.5 Safety Data Sheets and Volatile Substances

The following is an example of information available on an actual primer SDS and an assumption on the final condition of each substance:

Table III. Example Safety Data Sheet (SDS)

CAS #	Substance Name	Mass % $_{\text{Substance in primer}}$	Assumed Condition (Solid, Volatile, Reacted)
100-41-4	Ethylbenzene	0.2	*Volatile*
108-10-1	Methyl isobutyl ketone	17.8	*Volatile*
123-86-4	Butyl acetate	2	*Volatile*
13463-67-7	Titanium dioxide	2.5 - 3	*Solid*
14807-96-6	Talc	15	*Solid*
67-64-1	Acetone	7	*Volatile*
68855-54-9	Calcined amorphous silica	8	*Solid*
7789-06-2	Strontium chromate	12.2 - 12.8	*Solid*
	Total reported	***65.8***	

SDS often do not state the full composition of a formulation because they are only required to cite the hazardous materials, or because the formulation contains proprietary or trade secret chemicals. In this case, at a minimum, the epoxy base is not listed on the SDS and could potentially include reacted or solid ingredients. For the purposes of this example, assume that the epoxy contains 5% reactants and 29.2% solids by mass.

Using the equations from section C.1.1.2 for only the *solid* substances on the SDS, we can determine the substance fractions for each of the substances (shown in the third column of the table below):

$$\textbf{Mass \%}_{\text{Primer}} = \Sigma\ \textbf{Mass \%}_{\text{Solid substance mass \%}} = 3 + 15 + 8 + 12.8 + 29.2 = 68\%$$

$$\textbf{Substance fraction}_{\text{Solid substance in primer}} = \frac{\textbf{Mass \%}_{\text{Solid substance in primer}}}{\textbf{Mass \%}_{\text{Primer}}}$$

Table IV. Determination of substance fractions for solids on example SDS

Substance	Density $_{\text{Substance}}$ (lb/ in^3)	Substance fraction $_{\text{Solid substance in primer}}$
Strontium chromate	0.139	0.188
Epoxy	0.0470	0.429
Talc	0.0980	0.221
Calcined amorphous silica	0.0960	0.118
Titanium dioxide	0.153	0.044

$$\textbf{Density}_{\text{Solid substances in primer}} = \Sigma(\ \textbf{Density}_{\text{Substance}} * \textbf{Substance fraction}_{\text{Solid substance in primer}})$$

$$= (0.139*0.188) + (0.0470*0.429) + (0.098*0.221) + (0.0960*0.118) + (0.153*0.044)$$

$$\mathbf{= 0.086\ lb/in^3}$$

C.3 Examples of Substance Mass Calculations

C.3.1 Example: Cadmium plated nut (imperial units)

Step 1: *Identify applicable DSL:* **The AD-DSL is the DSL being used.**

Step 2: *Identify product (s):* **Hexagonal nut.**

Step 3: *Identify subassembly(s) within product:* **None in this case.**

Step 4: *Identify all materials:*

- **Substrate is low carbon steel grade 2H per the ASTM A194 specification.**
- **Surface is plated with cadmium per AMS-QQ-P-416, Type II, Class 2.**

Step 5: *Determine substance(s) present in material(s):* The following substances are present in the product as delivered:

- **ASTM A194 steel alloy 2H grade; contains carbon, phosphorus, sulfur, silicon, and iron. (Note that alloys are mixtures of metals and other materials. The constituents of an alloy are mixed, but not chemically joined.)**
- **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 and supplemental surface treatment of hexavalent chromium compounds.**

Step 6: *Are any DSL substances present?* **Yes.**

Compare the substances identified in Step 5 to the substances listed in the AD-DSL to identify substances subject to declaration.

The following substances require declaration:

- **Cadmium** (CAS # 7440-43-9)
- **Hexavalent chromium** (Chromium (VI) CAS # 18540-29-9)

Note: CAS # 18540-29-9 is for the hexavalent chromium ion, and may be used when the exact hexavalent chromium compound is unknown.

Step 7: *Is substance mass required?* **Yes** (assume that the substance mass is required by the declaration request for this example.)

Step 8: *Determine substance mass:*

Both the cadmium and hexavalent chromium are applied to the surface of the nut as a coating. The mass of the substances on the nut can be determined as follows.

The surface area and volume of this nut are calculated in C.2.1 (Example 1) as:

Surface area $_{\text{Article}}$ (surface area of the nut as delivered) = 2.21 in^2

Volume $_{\text{Article}}$ (volume of nut as delivered) = 0.107 in^3

Density $_{\text{Substrate}}$ (density of 4130 alloy steel) = 0.284 lb/in^3

Mass $_{\text{Article}}$ (weight of the nut as delivered) **= volume** $_{\text{Article}}$ *** density** $_{\text{Substrate}}$

= $0.107\ in^3 * 0.284\ lb/in^3$

= 0.0304 lb

Cadmium plating:

Substance fraction $_{\text{Coating}}$ = 1 (assume plating is 100% cadmium)

Thickness $_{\text{Coating}}$ (AMS-QQ-P-416 Class 2 max cadmium thickness) = 0.0005 in

Density $_{\text{Coating}}$ (density of cadmium) = $0.312\ lb/in^3$

Surface area $_{\text{Coating}}$ = $2.21\ in^2$

Mass $_{\text{Cadmium in article}}$ = **mass** $_{\text{Cadmium in coating}}$ (because the cadmium is only present in the coating)

From C.1.1.2,

Mass $_{\text{Cadmium in coating}}$ **= substance fraction** $_{\text{Coating}}$ *** mass** $_{\text{Coating}}$

Where:

Mass $_{\text{Coating}}$ **= thickness** $_{\text{Coating}}$ *** density** $_{\text{Coating}}$ *** surface area** $_{\text{Coating}}$

Or,

Mass $_{\text{Cadmium in coating}}$ **= substance fraction** $_{\text{Coating}}$ *** thickness** $_{\text{Coating}}$ *** density** $_{\text{Coating}}$ *** surface area** $_{\text{Coating}}$

= $1 * 0.0005\ in * 0.312\ lb/in^3 * 2.21\ in^2 = 0.000345\ lb$

Mass % $_{\text{Cadmium in article}}$ = **mass %** $_{\text{Cadmium in coating}}$ = **(mass** $_{\text{Cadmium in coating}}$ **/ mass** $_{\text{article}}$**)** *100

= (0.000345/0.0304) * 100 = 1.13%

Mass % $_{\text{Cadmium in article}}$ **= 1.13%**

Supplementary Chromate Treatment on Cd plating:

Supplementary chromate treatments on plating materials such as cadmium are not measured or controlled. However, these coatings are somewhat similar to chromate passivation of steels, so based on the thickness of passivation coatings (0.00005 inch maximum) and an assumption that 100% of the converted surface remains hexavalent chromium (chromium (VI) oxide), the calculation would be as follows:

Surface area $_{\text{Coating}}$ = $2.21\ in^2$

Density $_{\text{Coating}}$ (density of chromium VI oxide) = $0.0980\ lb/in^3$

Mass $_{\text{Chromium (VI) oxide in coating}}$ **= surface area** $_{\text{Coating}}$ *** thickness** $_{\text{Coating}}$ *** density** $_{\text{Coating}}$

= $2.21\ in^2 * 0.00005\ in * 0.0980\ lb/in^3$

= 0.0000108 lb

Mass % $_{\text{Chromium (VI) oxide in article}}$ = **mass %** $_{\text{Chromium (VI) oxide in coating}}$ = **(mass** $_{\text{Chromium (VI) oxide in coating}}$ **/ mass** $_{\text{article}}$**)** *100

= (0.0000108 /0.0304) * 100 = 0.0355%

Mass % $_{\text{Chromium (VI) oxide in article}}$ **= 0.0355%**

C.3.2 Example: Cadmium plated end eye component (imperial units)

Step 1: *Identify applicable DSL:* **The EU REACH Candidate List is the DSL being used.**

Step 2: *Identify product (s):* **End eye component.**

Step 3: *Identify subassembly(s) within product:* **None in this case.**

Step 4: *Identify all materials:*

- **Substrate is 4130 (MIL-S-6758) alloy steel.**
- **Surface is plated with cadmium per AMS-QQ-P-416, Type II, Class 2.**

Step 5: *Determine substance(s) present in material(s):* The following substances are present in the product as delivered:

- **MIL-S-6758 steel alloy; contains carbon, manganese, phosphorus, sulfur, silicon, chromium, molybdenum, nickel, copper, and iron. (Note that alloys are mixtures of metals and other materials. The constituents of an alloy are mixed, but not chemically joined; therefore, the 4130 alloy steel contains chromium but does not contain chromium compounds.)**
- **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 and supplemental surface treatment of hexavalent chromium compound(s). There is no nickel strike below the cadmium layer.**

Step 6: *Are any DSL substances present?* **Yes.**

Compare the substances identified in Step 5 to the substances listed in the DSL (EU REACH Candidate List) to identify substances subject to declaration.

The following substances require declaration:

- **Cadmium** (CAS # 7440-43-9)
- **Hexavalent chromium** (Chromium (VI) CAS # 18540-29-9)

Note: CAS # 18540-29-9 is for the hexavalent chromium ion and may be used when the exact hexavalent chromium compound is unknown.

Step 7: *Is substance mass required?* **Yes** (assume that the substance mass is required by the declaration request for this example.)

Step 8: *Determine substance mass:*

Basis:

Density $_{\text{Coating}}$ (density of cadmium) = 0.312 lb/in^3

Thickness $_{\text{Coating}}$ (maximum cadmium thickness) = 0.0005 in

Both the cadmium and hexavalent chromium are applied to the surface of the eye component as a coating. The mass of the substances on the component can be determined as follows.

The surface area and volume of this end eye component are calculated in C.2.1 (example 2) as:

Surface area $_{Article}$ (surface area of the end eye as delivered) = 1.62 in^2

Volume $_{Article}$ (volume of end eye as delivered) = 0.142 in^3

Density $_{Substrate}$ (density of 4130 alloy steel) = 0.284 lb/in^3

Mass $_{Article}$ (weight of the component as delivered) = **volume** $_{Article}$ *** density** $_{Substrate}$

= 0.142 in^3 * 0.284 lb/in^3

= 0.0403 lb

Cadmium plating:

Substance fraction $_{Coating}$ = 1 (assume plating is 100% cadmium)

Thickness $_{Coating}$ (AMS-QQ-P-416 Class 2 max cadmium thickness) = 0.0005 in

Density $_{Coating}$ (density of cadmium) = 0.312 lb/in^3

Surface area $_{Coating}$ = **Surface area** $_{Article}$ = 1.62 in^2

Mass $_{Cadmium\ in\ article}$ = **mass** $_{Cadmium\ in\ coating}$ (because the substance is only present in the coating)

From C.1.1.2,

Mass $_{Cadmium\ in\ coating}$ **= substance fraction** $_{Coating}$ *** mass** $_{Coating}$

Where:

Mass $_{Coating}$ **= thickness** $_{Coating}$ *** density** $_{Coating}$ *** surface area** $_{Coating}$

Or,

Mass $_{Cadmium\ in\ coating}$ **= substance fraction** $_{Coating}$ *** thickness** $_{Coating}$ *** density** $_{Coating}$ *** surface area** $_{Coating}$

= 1 * 0.0005 in * 0.312 lb/in^3 * 1.62 in^2 = 0.000253 lb

Mass % $_{Cadmium\ in\ article}$ = **mass %** $_{Cadmium\ in\ coating}$ = **(mass** $_{Cadmium\ in\ coating}$ **/ mass** $_{Article}$**)** *100

= (0.000253/0.0403) * 100 = 0.628%

Mass % $_{Cadmium\ in\ article}$ **= 0.628%**

Supplementary Chromate Treatment on Cd plating:

Supplementary chromate treatments on plating materials such as cadmium are not measured or controlled. However, these coatings are somewhat similar to chromate passivation of steels, so based on the thickness of passivation coatings (0.00005 inch maximum) and an assumption that 100% of the converted surface remains hexavalent chromium (chromium (VI) oxide), the calculation would be as follows:

Surface area $_{Coating}$ = 1.62 in^2

Density $_{Coating}$ (density of chromium VI oxide) = 0.0980 lb/in^3

Mass $_{\text{Chromium (VI) oxide in coating}}$ **= surface area** $_{\text{Coating}}$ *** thickness** $_{\text{Coating}}$ *** density** $_{\text{Coating}}$

= 1.62 in^2 * 0.00005 in * 0.0980 lb/in^3

= 0.00000794 lb

Mass % $_{\text{Chromium (VI) oxide in article}}$ **= mass %** $_{\text{Chromium (VI) oxide in coating}}$ **= (mass** $_{\text{Chromium (VI) oxide in coating}}$ **/ mass** $_{\text{article}}$**)** *100

= (0.00000794/0.0403) * 100 = 0.0197%

Mass % $_{\text{Chromium (VI) oxide in article}}$ **= 0.0197%**

C.3.3 Example: Primer-coated aluminum cover (SI units)

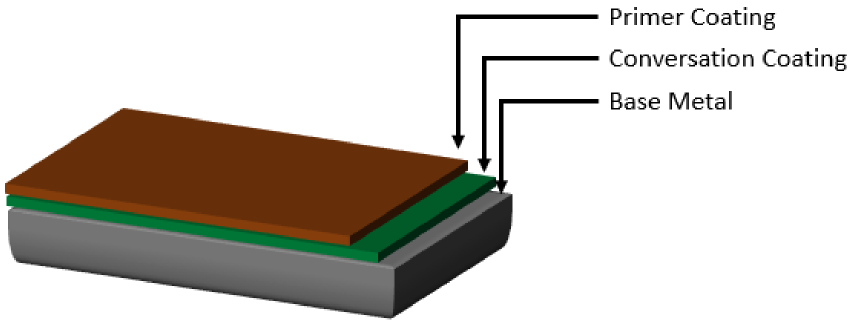
Step 1: *Identify applicable DSL:* **The AD-DSL is the DSL being used.**

Step 2: *Identify product (s):* **Cover (painted on one side.)**

Step 3: *Identify subassembly(s) within product:* **None in this case.**

Step 4: *Identify all materials*:

- **Substrate is A357 aluminum alloy.**
- **First coating/surface treatment is MIL-DTL-5541 Type I, Class 1A conversion coating.**
- **Second coating is MIL-PRF-23377, Type I (standard pigments), Class C2 (strontium chromate-based corrosion inhibitor) primer.**



Step 5: *Determine substance(s) present in material(s):* The following substances are present as the finished product as delivered (Note: all solvents in the primer are assumed to have evaporated and are no longer present):

- **A357 aluminum alloy contains aluminum, silicon, beryllium, iron, copper, magnesium, titanium, zinc, and manganese. (Note that alloys are mixtures of metals and other materials. The constituents of an alloy are mixed, but not chemically joined.)**
- **MIL-DTL-5541, Type I conversion coating contains hexavalent chromium compounds.**
- **MIL-PRF-23377, Type I, Class C2 primer contains strontium chromate and an epoxy polymer that is not listed on the DSL.**

Step 6: *Are any DSL substances present?* **Yes.**

Compare the substances identified in Step 5 to the substances listed in the AD-DSL to identify substances subject to declaration.

The following substances require declaration:

- **Beryllium** (CAS # 7440-41-7)
- **Hexavalent chromium** (Chromium (VI) CAS # 18540-29-9)
- **Strontium chromate** (CAS # 7789-06-2)

Step 7: *Is substance mass required?* **Yes** (assume that the substance mass is required by the declaration request for this example.)

Step 8: *Determine substance mass:*

In this example, there is a reportable substance in the substrate, the conversion coating and the primer (each involves a separate calculation).

For the sake of this example, assume that the conversion coating is applied all over the article but the primer is applied on an outside surface only. As above, an article can be broken down into simple geometric shapes but doing so for a complex shape like a casting will involve a lot of effort but rough calculations are often sufficient as long as they err on the side of overestimating the amount of the substance. Note that properties and calculations below are shown in metric units (as opposed to imperial units used throughout the rest of this document), simply as an illustration for readers who prefer the metric system.

Basis (from CAD data):

Volume $_{\text{Article}}$ = 482×10^3 mm^3

Mass $_{\text{Article}}$ = 1.3 kg

Surface area $_{\text{Article}}$ = 108.9×10^3 mm^2

Surface area $_{\text{Primer}}$ = 58.3×10^3 mm^2

Calculations:

Beryllium in Substrate

A357 alloy contains 0.07% by mass beryllium maximum. When additional coatings are applied to an A357 alloy article, it would decrease the beryllium mass percent (as the total article weight increases).

Mass % $_{\text{Beryllium in article}}$ = 0.07% maximum

Hexavalent Chromium in Conversion Coating

Substance fraction $_{\text{Coating}}$ = 0.6 (60% maximum or "worst case" from chromate conversion coating manufacturer)

Thickness $_{\text{Coating}}$ = 0.254 - 1.016 µm (use maximum or "worst case" value)

Density $_{\text{Coating}}$ (density of chromium VI oxide) = 2.71 g/cm^3

Surface area $_{\text{Coating}}$ = **Surface area** $_{\text{Article}}$ **=** 108.9x10^3 mm^2

Mass $_{\text{Chromium (VI) oxide on article}}$ = **mass** $_{\text{Chromium (VI) oxide in coating}}$ (because the substance is only present in the coating)

Mass $_{\text{Chromium (VI) oxide in coating}}$ **= substance fraction** $_{\text{Coating}}$ *** thickness** $_{\text{Coating}}$ *** density** $_{\text{Coating}}$ *** surface area** $_{\text{Coating}}$

= 0.6 * 1.016x10^{-3} mm * 2.71x10^{-3} g/mm^3 * 108.9x10^3 mm^2 = 0.18 g (0.00018 kg)

Mass % $_{\text{Chromium (VI) oxide in article}}$ **= mass %** $_{\text{Chromium (VI) oxide in coating}}$ = **(mass** $_{\text{Chromium (VI) oxide in coating}}$ **/ mass** $_{\text{Article}}$**)** *100

= (0.00018/1.3) * 100 = 0.0138%

Mass % $_{\text{Chromium (VI) oxide in article}}$ **= 0.0138%**

Strontium Chromate in Primer

The amount of strontium chromate ($SrCrO_4$) in the primer that remains on the article as delivered is not likely to be available in published safety data sheets or technical data sheets. This information will need to be sought from the formulator or calculated based on knowledge of what other substances evaporate or react during the process (the latter being much less precise). For this example, assume the only information available is from the SDS information illustrated in section C.2.5.

From section C.2.5:

Substance fraction $_{\text{Strontium chromate}}$ = 0.18

Thickness $_{\text{Primer}}$ = 50.8 µm

Density $_{\text{Solid substances in primer}}$ = 2.46 g/cm^3

Surface area $_{\text{Primed surface}}$ = 58.3x10^3 mm

Mass $_{\text{Strontium chromate in primer}}$ **= substance fraction** $_{\text{Strontium chromate}}$ *** thickness** $_{\text{primer}}$ *** density** $_{\text{Solid substances in primer}}$ *** surface area** $_{\text{Primed surface}}$

= 0.18 * 50.8x10^{-3} mm * 2.46x10^{-3} g/mm^3 * 58.3x10^3 mm^2

= 1.3 g (0.0013 kg)

Mass % $_{\text{Strontium chromate in article}}$= **mass %** $_{\text{Strontium chromate in primer}}$ = (**mass** $_{\text{Strontium chromate in primer}}$ / **mass** $_{\text{article}}$) *100

= (0.0013 / 1.3) * 100 = 0.10%

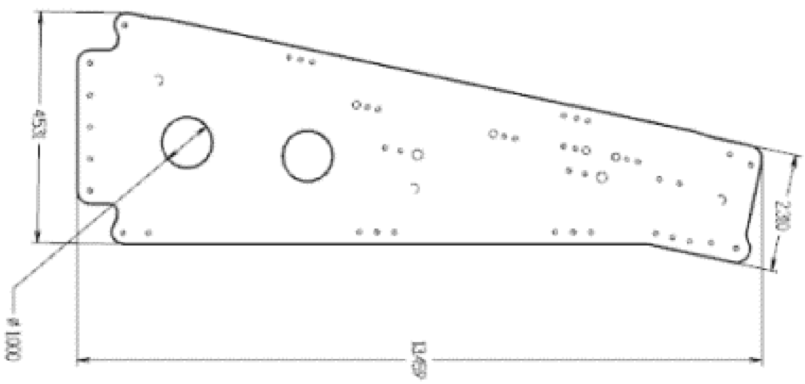
Mass % $_{\text{Strontium chromate in article}}$ **= 0.10%**

C.3.4 Example: Chromate conversion coating and strontium chromate-based primer on an instrument panel frame[6] (imperial units)

Step 1: *Identify applicable DSL:* **The EU REACH Candidate List is the DSL being used.**

Step 2: *Identify product (s):* **Instrument panel frame.**

Step 3: *Identify subassembly(s) within product:* **None in this case.**



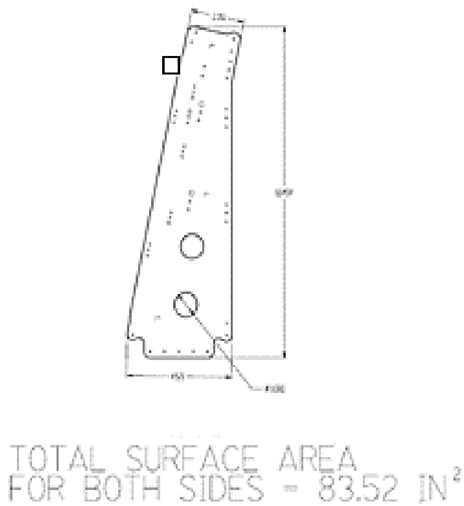
Step 4: *Identify all materials*:

- **Substrate is 0.032" 2024 aluminum alloy (spec QQ-A-250/5).**
- **First coating / surface treatment is MIL-DTL-5541 Type I, Class 1A conversion coating.**
- **Second coating is MIL-PRF-23377, Type I (standard pigments), Class C2 (strontium chromate-based corrosion inhibitor) primer.**

Step 5: *Determine substance(s) present in material(s):* The following substances are present in the article as delivered:

- **2024 aluminum alloy contains silicon, iron, copper, manganese, magnesium, chromium, nickel, zinc, titanium, and aluminum.**
- **MIL-DTL-5541, Type I conversion coating contains hexavalent chromium compounds.**
- **MIL-PRF-23377, Type I, Class C2 primer contains strontium chromate and an epoxy polymer (epoxy polymer is not listed on the DSL.)**

(**Note:** all solvents in the primer are assumed to have evaporated and are no longer present.)



[6] Figures in this example shared with permission from Viking Air.

<u>Step 6</u>: *Are any DSL substances present?* **Yes.**

Compare the substances identified in Step 5 to the substances listed in the DSL (EU REACH Candidate List) to identify substances subject to declaration.

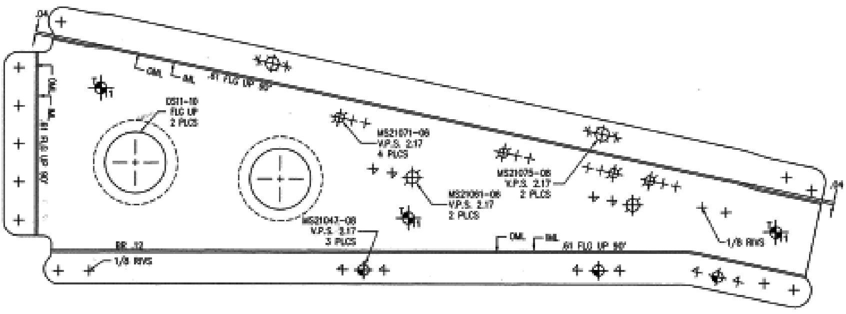
The following substances require declaration:

- **Chromium (VI) oxide** (CAS # 1333-82-0)
- **Strontium chromate** (CAS # 7789-06-2)

<u>Step 7</u>: *Is substance mass required?* **Yes** (assume that the substance mass is required by the declaration request for this example.)

<u>Step 8</u>: *Determine substance mass:*

1. Calculate mass % of chromium (VI) oxide on the instrument panel frame (article) using known coating mass (mg/ft²) information.
2. Calculate mass% of strontium chromate on the same article using a known % content of strontium chromate in the dry film primer.



Basis:

Mass $_{\text{Substrate}}$ (aluminum substrate mass prior to chromate conversion coating, weighed using a scale) = 0.132 lb

Mass $_{\text{Chromium (VI) oxide}}$ = 40 – 55 mg/ft^2 (use 55 mg/ft^2, or 1.21x10^{-4} lb/ft^2, as the worst case value)

Mass % $_{\text{Chromium (VI) oxide}}$ (mass % of chromium (VI) oxide CAS # 1333-82-0 in dry chemical conversion coating) = 60% max per information from chromate conversion coating manufacturer

Mass $_{\text{Chromated substrate}}$ (aluminum substrate mass after chromate conversion coating, weighed using a scale) = 0.132 lb

Thickness $_{\text{Primer}}$ = 0.0006 in to 0.0009 in (use maximum thickness of 0.0009 in)

Mass % $_{\text{Primer}}$ (mass % of strontium chromate CAS # 7789-06-2 in dry primer) =18% per information from primer manufacturer (see section C.2.5)

Mass $_{\text{Article}}$ (instrument panel mass after applying primer, weighed using a scale) = 0.137 lb

Density $_{\text{Primer}}$ = 0.0890 lb/inch^3 (per SDS calculation example shown in section C.2.5)

Surface area $_{\text{Primed surface}}$ (surface area of instrument panel that is coated with primer) = 83.5 in^2 (0.58 ft^2; as calculated in section C.2.1 using CAD data)

(i) Calculate mass % of chromium (VI) oxide (CAS # 1333-82-0) on the instrument panel frame

The article's aluminum substrate is 0.032 inch thick and the maximum coating weight of chemical conversion coating is 55 mg/ft^2 (1.21×10^{-4} lb/ft^2). According to the tip/calculation in section C.2.3.1, aluminum substrates/articles thicker than 0.02 inch are not anticipated to contain chromium (VI) oxide in excess of 0.1% by mass in their surface finishes. Consequently, the mass % of chromium (VI) oxide (CAS # 1333-82-0) is below the EU REACH reporting threshold of 0.1% and does not need to be calculated or declared.

(ii) Calculate mass % of strontium chromate (CAS # 7789-06-2) in primer coating

A simple method for substance mass determination is to weigh the article before and after primer coating application (Method 1). When a part is not available for weighing, an alternative method to calculate substance mass is described in Method 2.

<u>Method 1 - Based on weight of the article before and after coating:</u>

This method provides a factual value of the coating mass present on the substrate and there is no need to perform calculations of surface areas, thicknesses or density. The concentration of the substance in the dry coating however must still be (a) obtained from the manufacturer, (b) estimated based on available information or (c) verified by a chemical test method.

$\textbf{Mass}_{\text{Primer}} = \textbf{mass}_{\text{Article with primer}} - \textbf{mass}_{\text{Article without primer}} = 0.137 - 0.132 = 0.00500$ lb

$\textbf{Substance fraction}_{\text{Strontium chromate}} = 0.18$ (from section C.2.5)

$\textbf{Mass}_{\text{Strontium chromate in primer}} = \textbf{mass}_{\text{primer}} * \textbf{substance fraction}_{\text{Strontium chromate}}$

$= 0.00500 * 0.18 = 0.0009$ lb

$\textbf{Mass \%}_{\text{Strontium chromate in article}} = \textbf{mass \%}_{\text{Strontium chromate in primer}} = (\textbf{mass}_{\text{Strontium chromate in primer}} / \textbf{mass}_{\text{article}}) * 100$

$= (0.0009 / 0.137 \text{ lb}) * 100 = 0.657\%$

$\textbf{Mass \%}_{\text{Strontium chromate in article}} = \mathbf{0.657\%}$

According to method 1, the strontium chromate (CAS # 7789-06-2) mass % on the article is calculated to be 0.657%.

<u>Method 2 - Based on maximum primer thickness, density and surface area (from CAD data):</u>

$\textbf{Mass}_{\text{Strontium chromate in primer}} = \textbf{substance fraction}_{\text{Strontium chromate}} * \textbf{thickness}_{\text{primer}} * \textbf{density}_{\text{Solid substances in primer}} * \textbf{surface area}_{\text{Primed surface}}$

$= 0.18 * 0.0009 \text{ in} * 0.0890 \text{ lb/in}^3 * 83.5 \text{ in}^2 = 0.0012$ lb

$\textbf{Mass \%}_{\text{Strontium chromate in article}} = \textbf{mass \%}_{\text{Strontium chromate in primer}} = (\textbf{mass}_{\text{Strontium chromate in primer}} / \textbf{mass}_{\text{article}}) * 100$

$= (0.0012 / 0.137) * 100 = 0.876\%$

$\textbf{Mass \%}_{\text{Strontium chromate in article}} = \mathbf{0.876\%}$

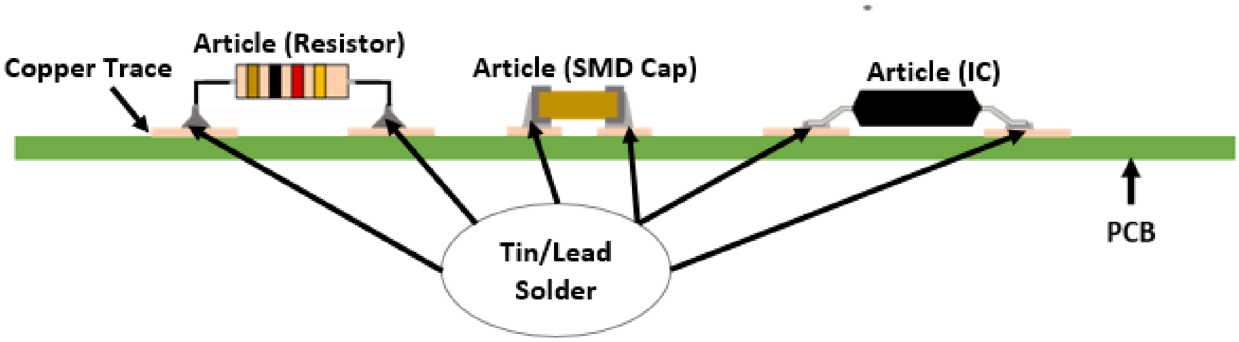
According to method 2, the strontium chromate (CAS # 7789-06-2) mass % on the article is calculated to be 0.876%, which is on the same order of magnitude as the result using Method 1 (0.657%).

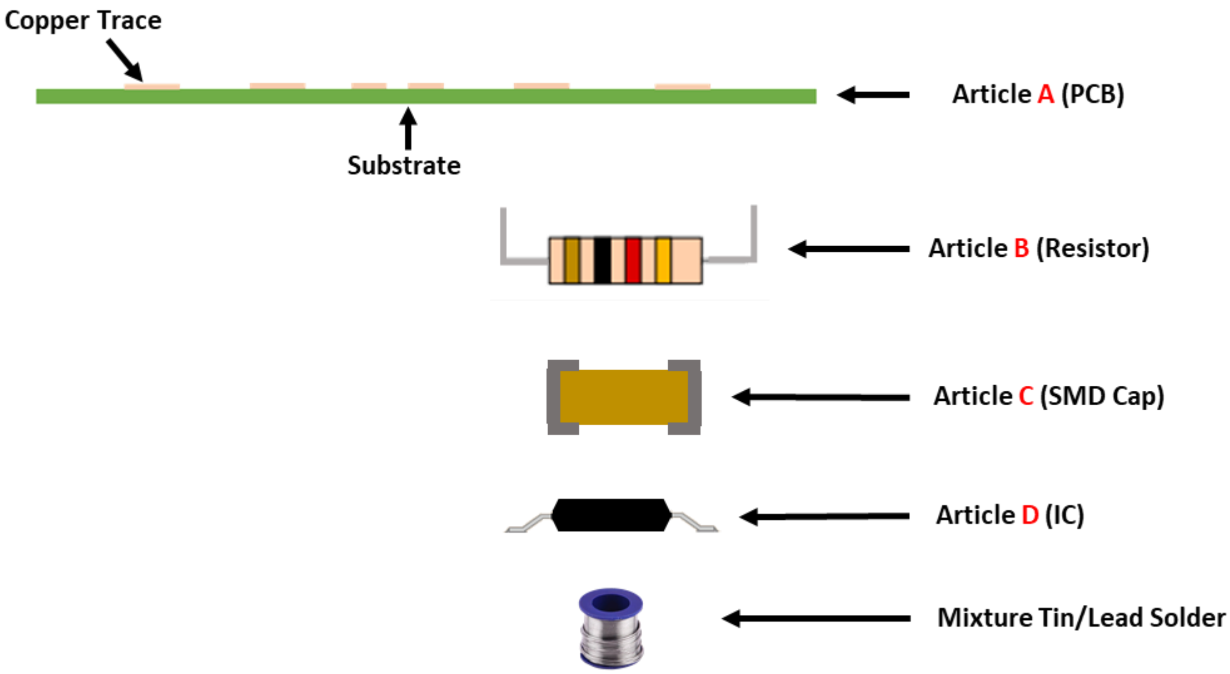
C.3.5 Example: Lead in solder (imperial units)

<u>Step 1</u>: *Identify applicable DSL:* **The EU REACH Candidate List is the DSL being used.**

<u>Step 2</u>: *Identify product (s):* **Complex article.**

<u>Step 3</u>: *Identify subassembly(s) within product:* **In this example below, a complex article (product) is produced by soldering three articles (B, C and D) to a circuit board (A) with a solder (mixture.)**





<u>Step 4</u>: *Identify all materials*:

- **Articles A, B, C and D 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.**

<u>Step 5</u>: *Determine substance(s) present in material(s):*

- **Lead (Pb) is a DSL substance and it is part of the solder (mixture) composition.**

<u>Step 6</u>: *Are any DSL substances present?* **Yes.** (Lead in solder.)

Step 7: *Is substance mass required?* **Yes.** (Assume that the substance mass is required by the declaration request for this example.)

Step 8: *Determine substance mass:*

Mass $_{\text{Article A}}$ = 0.123 oz

Mass $_{\text{Article B}}$ = 0.00123 oz

Mass $_{\text{Article C}}$ = 0.000989 oz

Mass $_{\text{Article D}}$ = 0.0010 oz

Mass $_{\text{Complex article}}$ = 0.153 oz (determined by weighing product after soldering)

Mass $_{\text{Solder}}$ = **mass** $_{\text{Complex article}}$ **– (mass** $_{\text{Article A}}$ + **mass** $_{\text{Article B}}$ + **mass** $_{\text{Article C}}$ **+ mass** $_{\text{Article D}}$)

= 0.153 – (0.123 + 0.00123 + 0.000989 + 0.0010) = 0.0268 oz

Substance mass % $_{\text{Solder}}$ (percent lead in solder) = 40%

Substance mass $_{\text{Solder}}$ (mass of lead in solder) = (**mass** $_{\text{Solder}}$ * **substance mass %** $_{\text{Solder}}$)/100

= (0.0268 oz * 40)/100 = 0.0107 oz

Substance mass $_{\text{Solder}}$ = **substance mass** $_{\text{Complex article}}$ (because substance is only present in solder)

Mass % $_{\text{Lead in complex article}}$ **= (substance mass** $_{\text{Complex article}}$ **/ mass** $_{\text{Complex article}}$) * 100

= (0.0107 / 0.153 oz) * 100

= 6.99%

Mass % $_{\text{Lead in complex article}}$ **= 6.99%**

C.3.6 Example: Sodium dichromate sealing treatment on a chromic acid anodic coating (imperial units)

Step 1: *Identify applicable DSL:* **The AD-DSL is the DSL being used.**

Step 2: *Identify product (s):* **1 inch^2 surface area of a flat surface.**

Step 3: *Identify subassembly(s) within product:* **None in this case.**

Step 4: *Identify all materials:*

- **Substrate is** aluminum 2024 alloy per AMS QQ-A-250/4.
- **Surface is anodized per MIL-PRF-8625**, Type IB in chromic acid.
- **Sodium dichromate (CAS # 10588-01-9)** as supplemental sealing solution.

Step 5: *Determine substance(s) present in material(s):* The following substances are present in the product as delivered:

- **Aluminum AMS QQ-A-250/4 alloy contains aluminum, copper (3.8-4.9%), magnesium (1.2-1.8%), manganese (0.3-0.9%), silicon (< 0.5%), iron (<0.5%), zinc (<0.25%), and chromium (<0.1%.)**
- **Chromic Acid Anodic Coating MIL-PRF-8625, Type IB (typically ~300 mg/ft2) is a porous aluminium oxide layer.**
- **Sodium dichromate residue from supplemental sealing solution used to seal the porous Anodic Coating. A typical concentration of Sodium dichromate (CAS # 10588-01-9) used in sealing solution is 65 g/L (0.14 lb/L.)**

Step 6: *Are any DSL substances present?* **Yes.**

Compare the substances identified in Step 5 to the substances listed in the AD-DSL to identify substances subject to declaration.

The following substances require declaration:

- **Sodium dichromate** (CAS # 10588-01-9)

Note: CAS # 18540-29-9 is for the hexavalent chromium ion, and may be used when the exact hexavalent chromium compound is unknown, however in this case the substance is known.

Step 7: *Is substance mass required?* **Yes** (assume that the substance mass is required by the declaration request for this example)

Step 8: *Determine substance mass:*

Using a 1 in^2 surface area of any part as a basis. Using 0.016-inch-thick aluminium (the thinnest aluminium used to manufacture AD in articles) as a worst case scenario for resulting in the greatest mass% of substance in an article:

Surface area $_{\text{Article}}$ (surface area) = 1 in^2

Volume $_{\text{Base material}}$ (volume a 0.016 in thick aluminium) = 0.0160 in^3

Density $_{\text{Substrate}}$ (density of aluminum) = 0.1 lb/in^3

Mass $_{\text{Base material}}$ (weight of the 1 in^2 0.0016-inch-thick part as delivered)

= volume $_{\text{Article}}$ *** density** $_{\text{Substrate}}$

= 0.0160 in^3 * 0.1 lb/in^3

= 0.00160 lb

Calculations:

Anodic coating

Anodization creates a porous complex aluminum oxide layer on the surface of the base material. Depending on process parameters, chromic acid anodize may add a *trace* amount of Cr^{+6} to the oxide layer and therefore need not be included in the Cr^{+6} mass calculation.

The maximum thickness of the anodic coating to be sealed is 0.0007 inch. Reference for coating thickness of anodic coatings on aluminum alloys is in Section 6.10.5 and Table IV of MIL-PRF-8625.

While MIL-PRF-8525 is the most widely used anodizing specification, the process is also described in AMS 2470 and Defence Standard (DEF-STAN) 03-24/3. MIL-PRF-8625, Type IB requires a minimum coating weight of 200 mg/ft^2, but a more typical weight is 300 mg/ft^2 (0.0000046 lb/in^2).

Mass $_{\text{Anodic coating}}$ = 1 in^2 * 0.0000046 lb/in^2 = 0.0000046 lb

Mass $_{\text{Article}}$ **= Mass** $_{\text{Base material}}$ **+ Mass** $_{\text{Anodic coating}}$

= 0.00160 lb + 0.0000046 lb

= 0.0016046 lb

<u>Sodium dichromate (CAS # 10588-01-9) sealant residue in anodic coating layer</u>

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 10-20% in the coating, but due to the reactions described above, a more conservative porosity value of 40% will be used for this calculation.

Substance fraction $_{\text{Coating}}$ = 0.4 (all pores are filled with sodium dichromate solution)

Thickness $_{\text{Coating}}$ (max anodic coating thickness) = 0.0007 in

Concentration $_{\text{Sodium dichromate}}$ (max concentration of **Sodium dichromate** in sealant solution)

= 65 g/L = 0.00235 lb/in^3

Surface area $_{\text{Coating}}$ = 1 in^2

Mass $_{\text{Sodium dichromate in article}}$ = **mass** $_{\text{Sodium dichromate in Anodic coating}}$ (because the substance is only present in the Anodized porous protective layer)

Mass $_{\text{Sodium dichromate in coating}}$ **= surface area** $_{\text{Coating}}$ *** thickness** $_{\text{Coating}}$ *** density** $_{\text{Sodium dichromate}}$ *** Substance fraction** $_{\text{Coating}}$

= 1 in^2 * 0.0007 in * 0.00235 lb/in^3 * 0.4

= 6.58x10^{-7} lb

Mass % $_{\text{Sodium dichromate in article}}$ = **(mass** $_{\text{Sodium Dichromate in Anodic coating}}$ **/ mass** $_{\text{article}}$**)** *100

= (6.58x10^{-7} lb /0.00160046 lb) * 100 = 0.041%

Mass % $_{\text{Sodium dichromate in article}}$ **= 0.041%**

The worst case value for a MIL-PRF-8625 Type IB chromic acid anodic coating would be 0.041% sodium dichromate (CAS # 10588-01-9).

APPENDIX D: HELPFUL WEBSITES AND REFERENCES

D.1 Substrate and Material Content Information

D.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

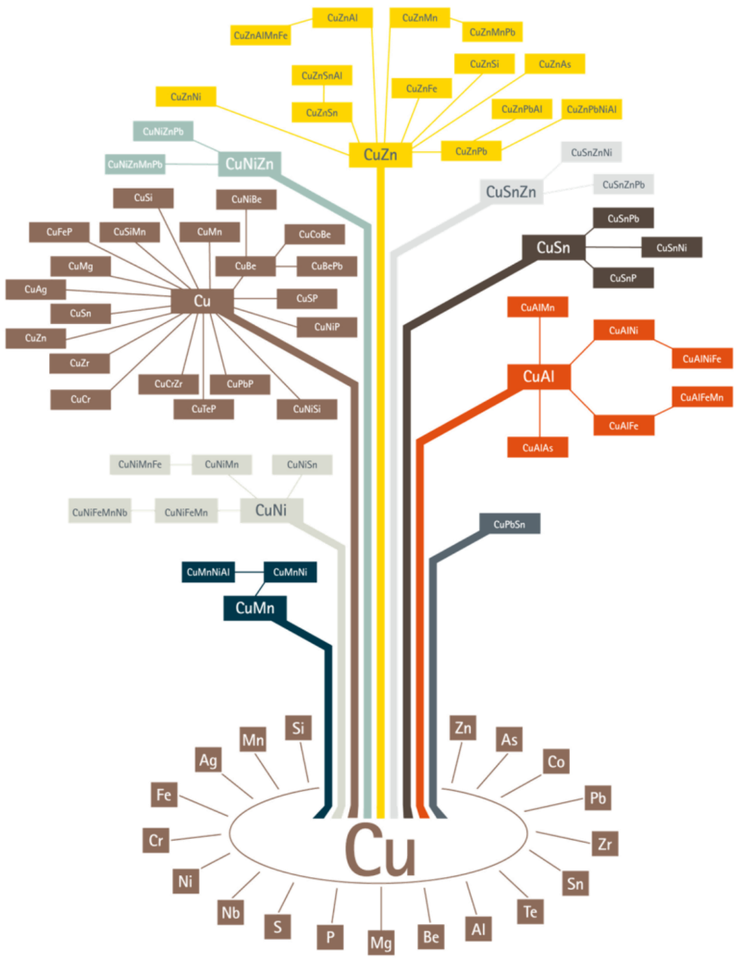


Figure D1. Copper alloy tree[7]

D.1.1.1 Copper Reference Websites

1. http://copperalliance.eu/about-copper/alloys
2. http://www.conductivity-app.org/
3. https://www.elecmat.com/alloys/

D.1.2 Aluminum in Aerospace Applications

Several aluminum alloys were specifically engineered for use in the aerospace industry. The following alloys were specially designed to meet the requirements of aircraft specifications:

- Aluminum Alloy 2014 — this alloy ranks among the strongest heat treatable products available. It combines excellent strength with good machinability. Aluminum 2014 is one of the easiest aluminum alloys to weld and it performs well with arc and resistance welding methods. However, its corrosion resistance is limited. When exposure to the elements is

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

anticipated, alloy 2014 should be clad with pure aluminum or painted for protection. Alloy 2014 is an excellent forging alloy for aircraft parts such as landing gears and hydraulic cylinders.

Aluminum Alloy 2219 — another high-strength option, Aluminum Alloy 2219 is heavily relied upon for applications that require maximum toughness at elevated temperatures. Alloy 2219 is frequently utilized for structural aerospace components — this alloy was used to produce the external tank for the original space shuttle — as it maintains excellent mechanical properties and machinability in the annealed condition. It is also weldable but it should be heat treated after welding to maintain its corrosion resistance.

Aluminum Alloy 7475 — developed by the Alcoa, Aluminum Alloy 7475 is most often used in high performance aerospace applications that require high resistance to fracture. Providing uncompromising strength and crack fatigue resistance, Alloy 7475 offers the industry's best fracture toughness. It can also be readily formed and machined in the annealed condition, with improved forming available by heating the alloy to 250°F. It has been frequently used for components such as wing spars, wing skins, and fuselage bulkheads.

Aluminum Alloy 7178 — the primary alloying elements in Aluminum Alloy 7178 are magnesium and copper, making this alloy another solid choice for high-strength applications. Its toughness has made it a sought-after material for aircraft skins, particularly for protecting components that must undergo compressive stress. This alloy is easier to machine when used with oil lubricants, offering significant improvement in mechanical properties seen with precipitation hardening. Precipitation heat treatment is achieved at temperatures of 250°F for 24 hours to produce tempers of T6 and T651.

D.1.2.1 Aluminum Reference Websites

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

D.1.3 Plastics in Aerospace Applications

The plastics family includes the following:

- Bio-based plastics
- Biodegradable plastics
- Engineering plastics
- Epoxy resins
- Expanded polystyrene
- Fluoropolymers
- Polyolefins
- Polystyrene
- Polyurethanes
- Polyvinyl chloride
- Thermoplastics

The “Plastic additives initiative” is a joint project by the European Chemicals Agency (ECHA) and industry that has resulted in a list of over 400 functional additives and pigments used in plastics, including information on the polymers they are most commonly found in and the typical concentration ranges. A link to this site as well as others is shown below.

D.1.3.1 Plastics Reference Websites

1. https://echa.europa.eu/mapping-exercise-plastic-additives-initiative#table
2. https://www.plasticsindustry.org/
3. https://www.plasticseurope.org/en
4. https://www.plasticisers.org/regulation/reach/

D.2 General Websites and Resources

D.2.1 Websites

1. International Aerospace Environmental Group (IAEG) – http://www.iaeg.com/
2. European Chemicals Agency (ECHA) – https://echa.europa.eu/home
3. Metals Gateway – https://metals-gateway.com/
4. AeroSpace and Defence Industries Association of Europe – https://www.asd-europe.org/aerospace-and-defence-industries-association-of-europe
5. Chemical Watch - https://home.chemicalwatch.com/
6. GlobalSpec - https://www.globalspec.com/
7. SAE International - https://www.sae.org/

D.2.2 Publications

1. 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
2. European Chemicals Agency (ECHA) – “Guidance on Requirements for Substances in Articles;” https://echa.europa.eu/-/guidance-on-requirements-for-substances-in-articles
3. IPC-1065 – “Material Declaration Handbook (For Users and Manufacturers of Printed Circuit Boards)”