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**Additive manufacturing of metals —  
Environment, health and safety —  
General principles for use of metallic  
materials**

*Fabrication additive de métaux — Environnement, santé et sécurité  
— Principes généraux pour l'utilisation de matériaux métalliques*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is ISO/TC 261, *Additive manufacturing*, in cooperation with ASTM Committee F42, *Additive manufacturing technologies*, on the basis of a partnership agreement between ISO and ASTM International with the aim to create a common set of ISO/ASTM standards on additive manufacturing, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 438, *Additive manufacturing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

The use of additive manufacturing (AM) processes with metallic feedstock entails a number of hazards. It is therefore important, as a first step, to implement a high level of protection during manufacturing and installation of the additive manufacturing machine or system. For this purpose, ISO/ASTM 52938-1 dealing with safety of PBF-LB machines is under preparation.

In addition, the users of additive manufacturing plants have the duty to reduce the risks for the operators remaining after installation so that they fulfil the nationally or regionally pertinent regulations for health and safety at work. The latter are very different worldwide and the requirements of a standard cannot fully reflect them. For users of additive manufacturing plants, the guidelines and requirements of this document are, therefore, particularly relevant with regard to aspects not sufficiently covered by pertinent national or regional regulations for safety and health at work.

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# Additive manufacturing of metals — Environment, health and safety — General principles for use of metallic materials

## 1 Scope

This document provides guidance and requirements for risk assessment and implementation of prevention and protection measures relating to additive manufacturing with metallic powders.

The risks covered by this document concern all sub-processes composing the manufacturing process, including the management of waste.

This document does not specify requirements for the design of machinery and equipment used for additive manufacturing.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11611, *Protective clothing for use in welding and allied processes*

ISO 16321-1, *Eye and face protection for occupational use — Part 1: General requirements*

ISO 16321-3, *Eye and face protection for occupational use — Part 3: Additional requirements for mesh protectors*

ISO/ASTM 52900, *Additive manufacturing — General principles — Fundamentals and vocabulary*

ISO/ASTM 52907:2019, *Additive manufacturing — Feedstock materials — Methods to characterize metal powders*

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

IEC 60079-10-2, *Explosive atmospheres — Part 10-2: classification of areas — Combustible dust atmospheres*

ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/ASTM 52900 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

## 4 Abbreviations

The abbreviations and acronyms used in this document are listed in [Table 1](#).

**Table 1 — Abbreviations and acronyms**

Abbreviation	Signification
ACGIH	American Conference of Governmental Industrial Hygienists
AHU	air handling unit
ATEX	atmospheres explosives
CLP	classification, labelling, packaging
CMR	carcinogenic, mutagenic or reprotoxic
EChA	European Chemicals Agency
EHS	environmental health and safety
GHS	globally harmonized system
MSD	musculo skeletal disorder
NIOSH	National Institute for Occupational Safety and Health
OEL	occupational exposure limit
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
REACH	registration, evaluation and authorisation of chemicals
SDS	safety data sheet
UNECE	United Nations Economic Commission for Europe

## 5 Methodology

### 5.1 General

The method described in this document allows the user to assess the EHS risk considering the following:

- metallic powders used;
- AM process;
- AM system installation conditions;
- applicable good practices;
- feedback from experience.

The methodology is based on a characterization of physical hazards (e.g. fire and explosion), hazards to the health of the operator or the potentially exposed third parties and to the environment. The overall approach to risk assessment and implementation of prevention measures is illustrated in [Figure 1](#) and detailed in [Table 2](#).

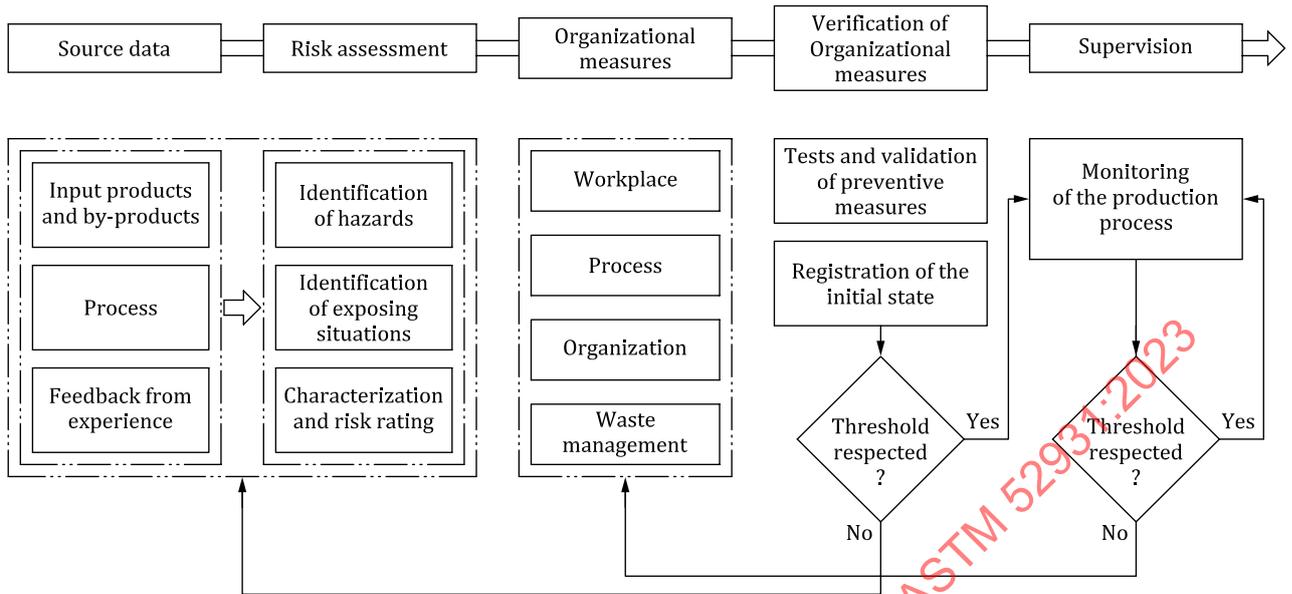


Figure 1 — Overall approach to risk assessment and implementation of prevention measures

Table 2 — Content of the steps toward the evaluation and prevention of risks

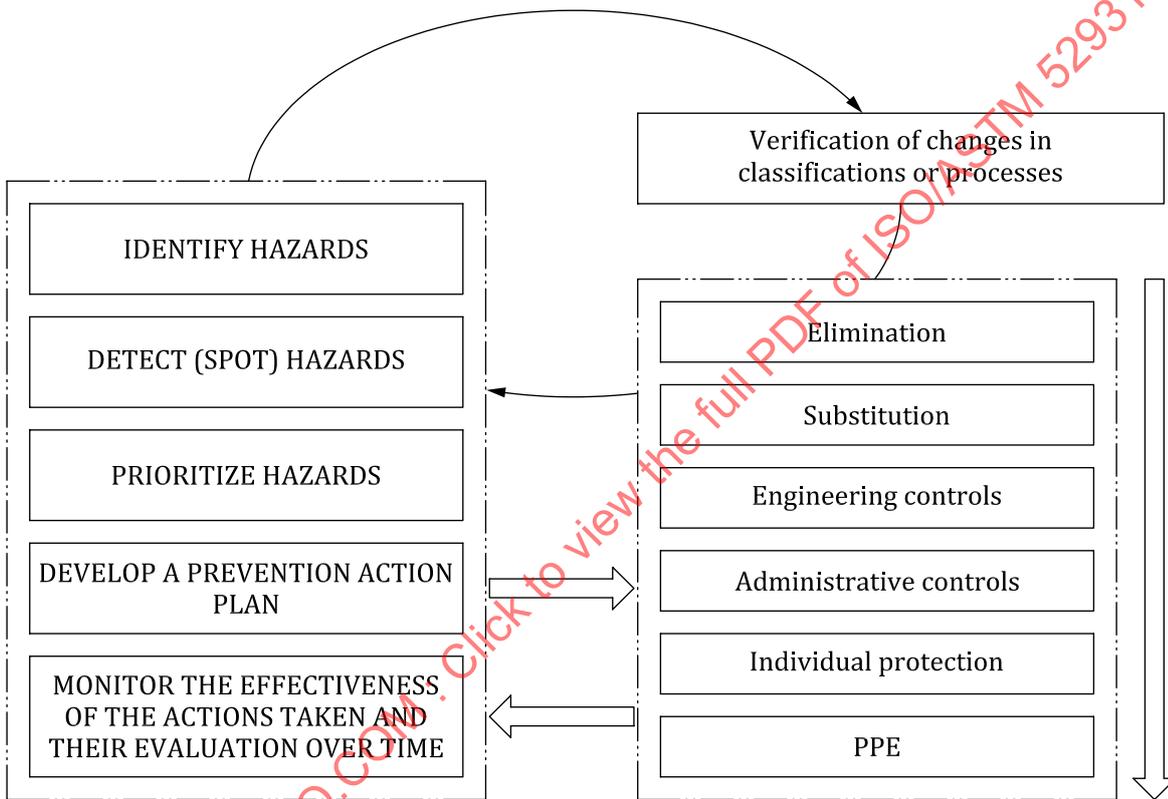
Main steps	Aspects taken into account	Factors/measures
Source data	Input products and by-products	Safety data sheets, products implemented with classification, toxicity and granulometry, Instruction handbooks, Current regulations
	Process	Means (premises and work equipment) implemented for the storage, transport and processing of inputs
	Feedback from experience	Measurement, analysis, medical follow-up, incident reports, supervision of technology and regulation
Risk assessment	Identification of hazards	Identification of the inherent hazards of the inputs and by-products generated at the different stages of the process and the exposing situations
	Identification of exposing situations	Identification of tasks and activities with potential for exposures at the different stages of the process including accidental exposure
	Characterization and risk rating	Characterization and rating of the risks to health, safety and environment
Verification of organizational measures	Workplace	Layout, performance of containment, airflow/ventilation, air monitoring function
	Process	Feedstock, work equipment, capture performance, sealing, filtration cleanliness, level of reliability of detection functions, controls, category of risks related to explosion.
	Organization	Procedures, process flow, level of training, PPE, medical follow-up, monitoring of premises and equipment
	Waste management	Waste collection, storage and disposal. Spill prevention and containment
Verification of prevention and protection measures	Tests and validation of preventive measures	Sampling, atmospheric dosimetry, surface measurements, adequacy audit
	Registration of initial state	Ambient measurement

**Table 2 (continued)**

Main steps	Aspects taken into account	Factors/measures
Supervision	Monitoring of the production process	Monitoring and management of workplace/process/organization modification, regulatory and technological monitoring, Sampling, atmospheric dosimetry, area of surface contamination

**5.2 Chemical hazard methodology**

The steps for assessing and controlling the risk of exposure to hazardous chemical agents are described in [Figure 2](#):



**Figure 2 — Main steps of a chemical risks prevention process**

**6 Source data**

**6.1 General**

Applicable local regulations should be considered (see Directive 89/391/EEC in Europe and OSHA in USA).

**6.2 Input products and by-products**

**6.2.1 Safety data sheet**

See information given in [Annex A](#).

## 6.2.2 Product technical datasheet

The product technical datasheet should also contain information about particle size distribution.

Technical specification of metal powders shall be provided in accordance with ISO/ASTM 52907:2019, Annex A.

## 6.3 Process

### 6.3.1 General

The instructions for proper installation, use and maintenance of the AM equipment and post processing equipment shall be followed. The user should ensure that the combination of feedstock and AM equipment and post processing equipment has been taken into account. The user shall perform a specific risk assessment, preferably with the support of the AM equipment and post processing equipment manufacturer and of the supplier of the feedstock(s).

### 6.3.2 Means of storage and implementation

For the regular use of metallic powders, national regulations and organisational policies related to hazardous substances should be observed. This would include registering of the material in the organization and risk assessments for the individual processes performed with the material based on information from the safety data sheets. This would provide hierarchical control for the following, as a minimum:

- powder identification;
- storage location;
- storage requirements (legal aspects, safety aspects and powder quality aspects);
- manual handling requirements;
- maximum volume/s of powder for each process;
- use of ancillary equipment (wet separators, sieving units, etc.);
- housekeeping requirements;
- PPE requirements.

## 6.4 Feedback from experience

### 6.4.1 Incident reports

When an incident occurs for an operator of a facility, the company should provide a report analysing the causes of the incident, its effects and consequences on people and the environment. The description useful for in the incident report is:

- description of the process and its equipment: implementation, products involved, operating conditions in normal operation, procedures, rules, control operations, maintenance, cleaning, etc.;
- safety measures (prevention, protection), procedures, qualifications, training;
- circumstances, context and chronology of the incident:
  - operating context before and during the incident, product condition, identification of deviations from normal, testimonials, latest interventions (maintenance, control, inspections, interviews, work, other incidents...);

- chronology of events and incident management (interveners present, actions carried out, date/time,...);
- miscellaneous findings;
- characterization of the consequences:
  - experimental characterization to remove doubts (measurement, incident reproduction, product characterization);
  - characterization by modelling (e.g. fire in an AM workplace);
- recommendations: prevention, detection, protection, management of activities.

#### 6.4.2 Technical and normative watch

Technical and/or normative documents should be available, reviewed and the AM process updated as needed as soon as practicable after publication.

#### 6.4.3 Measurement reports and analyses

All emission measurements, either on receipt of the equipment or in normal operation, as well as the history of exposure measurements are useful feedback for risk assessment or re-assessment.

If the risk assessment shows that there is at least one exposure situation subject to a regulatory OEL, exposure levels shall be controlled in accordance with the regulations.

NOTE Currently, there are no known common cases in the field of AM with metallic materials requiring the intervention of an accredited body, but this cannot be excluded.

## 7 Risk assessment

### 7.1 Identification of hazards

All dangerous chemicals and materials shall be identified. The prevention approach consists in systematically identifying the presence of such products and any working situation in which operators and other personnel could be exposed.

NOTE Reactive and non-reactive powders have different handling and storage requirements. Refer to safety data sheet (SDS) for these requirements.

### 7.2 Documentation on hazards

#### 7.2.1 General

For AM workspaces and feedstock storage locations the use of chemical safety cards (CSC) is strongly recommended, and depending on local regulations, mandatory. Chemical safety cards provide the essential health and safety information of chemicals in a clear and concise manner. This includes information on hazards, required PPE and actions to be taken in the event of an accident or spill.

Chemical safety cards are available for pure substances only in the database mentioned in the note below. For alloys and mixtures, it is recommended that the employer composes a similar document based on the information provided in the safety data sheet (SDS) and structured in a similar way as a chemical safety card.

NOTE An extensive database of ready to use cards has been composed in the International Chemical Safety Cards (ICSC) project. This project is a collaboration between International Labour Organization (ILO) and the World Health Organization (WHO), with the cooperation of the European Commission. For more information see the following references:

<https://www.ilo.org/dyn/icsc/showcard.home>

<https://www.who.int/publications/m/item/international-chemical-safety-cards-leaflet>

<https://www.cdc.gov/niosh/ipcs/default.html>

## 7.2.2 Identification of hazards related to inputs

### 7.2.2.1 General

The following requirements shall be satisfied, in order to identify the hazards related to handling metal alloys in powder:

- consider the regulatory requirements that are relevant to the production and use site;
- identify the hazards related to each metallic element in the alloy and by alloy family.

A guidance for understanding safety data sheets (SDSs) is given in [Annex A](#).

Users should regularly check for the latest available updates of the SDS.

### 7.2.2.2 Identification of dangerous products

The classification information included in the safety data sheets sent by the supplier shall be taken into account. The safety data sheets shall be written in the language of the recipient country and accompany each product.

NOTE 1 In European countries, classification information is available in the classification, labelling and packaging regulation. For the other countries, it is suitable to refer to the national regulations or by default to the GHS regulation.

Within the European Union, the CLP regulation gives the classification applicable to chemicals. They are classified into the following 3 families:

- substances (unitary chemical elements: aluminium, iron, titanium, etc.);
- mixtures (in the form of raw materials: free powder, alloys, etc.);
- articles (semi-finished products and finished products: bars, sheets, manufactured products, etc.).
- For alloys, only in lack of specific data, the hazard shall be rated as the sum of the hazards of the substances, using the classification rules.

NOTE 2 Classification, labelling and packaging regulation of substances that are accessible and up to date on the website of ECHA make it possible to check whether Section 2 of the manufacturer's safety data sheet conforms, see the following:

<https://echa.europa.eu/fr/information-on-chemicals/cl-inventory-database>

NOTE 3 Two sources exist for establishing the classification:

- EU member countries; this classification is said to be “harmonized”;
- manufacturers who generally come together into consortiums; this classification is said to be “joint submission”;
- REACH files has increased the numbers coming under this second classification.

NOTE 4 The GHS system of classification and labelling of chemicals is an international initiative under the guidance of UNECE. Parallel to GHS UNECE is also involved in the composition of guidelines concerning the safe transport of chemicals.

NOTE 5 While UNECE does not compose legislation, it is the intention to translate the suggested guidelines by UNECE into the local regulatory and legal framework of the governments involved. A list of participating countries and the status of the implementation in those countries can be found on the UNECE website. This includes links to the local governmental bodies and ratified texts.

[https://www.unece.org/trans/danger/publi/ghs/implementation\\_e.html](https://www.unece.org/trans/danger/publi/ghs/implementation_e.html)

NOTE 6 While in this document the term GHS is used freely understanding that the GHS guidelines are, or are to be, implemented worldwide, it is up to the reader to check the status of the local implementation.

### 7.2.2.3 Hazards related to the nature of products

Hazards are identified in Section 2 of the safety data sheet. The user shall take this into account.

The chemical risk depends on the hazard (see [Table 4](#)) and on the exposure. The exposure to chemical substances can occur mainly via three modes of penetration which are inhalation, skin contact, and ingestion.

Generally, the main routes for occupational exposure to metals are inhalation (especially in powder form) as well as skin contact (for powders as well as for wires).

NOTE 1 OELs for dermal exposure are lacking and it is the responsibility of the user to decide on skin contamination criteria. Resources exist such as:

- NIOSH skin notations: [https://www.cdc.gov/niosh/topics/skin/skin-notation\\_profiles.html](https://www.cdc.gov/niosh/topics/skin/skin-notation_profiles.html);
- ACGIH provides skin and sens notations if applicable for metals.

NOTE 2 For Europe, some information can be found in REACH and EChA.

Alloys shall in general be considered as substances. Only in lack of sufficient data for an alloy, for each metal element of an alloy, an exposure assessment shall be conducted in order to establish a reference for the chemical risk related to exposure by inhalation.

NOTE 3 These data are indicated in Section 8 of the safety data sheet (See [Annex A](#)).

The relevant national regulations take precedence over any other reference. However, when there is no OEL in the applicable regulations, or when a significant difference exists related to more recent limit values, it is recommended to choose a reference that is more stringent than the applicable regulations. For all particles or dust not having any specific effect, the OEL is as follows:

- 10 mg/m<sup>3</sup> for the total fraction;
- 5 mg/m<sup>3</sup> for the breathable, respirable fraction or alveolar fraction.

A substance that is not classified in the classification, labelling and packaging regulation and that has an occupational exposure limit value identical to one of those references is not a substance with a specific chemical risk. Those references are therefore not indicators or drivers of the toxicity of an alloy powder.

NOTE 4 The “breathable fraction”, “alveolar fraction” or “respirable fraction” is the effective inhaled fraction that reaches the pulmonary alveoli, where the majority of it can penetrate into the person's system.

NOTE 5 There is a European database, GESTIS, which gives the OEL values for various countries available at:

<https://www.dguv.de/ifa/gestis/gestis-internationale-grenzwerte-fuer-chemische-substanzen-limit-values-for-chemical-agents/index-2.jsp>.

The European regulations are being drafted and certain new stringent occupational exposure limit values can be set.

#### 7.2.2.4 Hazards related to particle size distribution

The particle size distribution is an important parameter to consider in prevention. A high concentration of fine particles generates health risks due to the physical nature of the particles (see [Table 3](#)).

**Table 3 — Effects of particles on health depending on particle size distribution**

Particle diameter <sup>a</sup>	Effects <sup>b</sup>
less than 100 µm	All particles less than 100 µm can easily enter the nasal cavities
between 5 µm and 100 µm	Trapped by impact in the nasal cavity, the pharynx, and the larynx Cannot keep up with the sudden changes of direction and collide with the walls or hairs
between 1 µm and 5 µm	Most of them are deposited by sedimentation in the trachea, the bronchi, and the bronchioles
less than 1 µm	Reach the alveoli
<sup>a</sup> In some context particle aerodynamic diameter as defined in ISO 18158 could be of concern.	
<sup>b</sup> Can cause immunological and inflammatory reactions.	

NOTE See EN 481 for details of the respective definition of size fractions.

**CAUTION — The size of the particles is not indicated in the SDS and It is nevertheless essential to take it into account. The size of unused feedstock powder particles stated by a manufacturer on a technical specification sheet or other document may not be indicative of the size of particles that can be released during handling, printing, or other tasks. Any risk related to powder particle size shall be taken into account.**

#### 7.2.2.5 Hazards identified per substance

A non-exhaustive list of OELs identified according to the substances (compound and oxidized forms) is given in [Annex D](#).

#### 7.2.2.6 Hazards identified per family of alloys

The hazards identified per family of alloys are listed in [Table 4](#).

Table 4 — Hazards per family of alloys

Base	Alloys	Family substances	Flammability and/or explosion risk	Alloy containing 1 or more CMR substance <sup>a</sup>	Alloy not containing CMR substance <sup>bc</sup>
Al	AlSi and derivatives	Al, Si, Mg, Ti	Yes	Ti	others
	superalloy: H188, Inconel 783, ...	Co, Al, B, C, Cr, Fe, La, Nb, Ni, Si, Ti, W	SDS to be checked	Cr, Co, Ni, Ti	others
Co	stellite 6, 12, 21, ...	Co, C, Cr, Mo, Ni, W	SDS to be checked	Co, Cr, Ni	others
	CoCr and derivatives	Co, Cr, Mo, V	SDS to be checked	Cr, Co, V	others
Cu	CuCr1Zr	Cu, Cr, Zr	SDS to be checked	Cr	others
	CuNi2CrSi (CuNi2)	Cu, Ni, Cr, Si	SDS to be checked	Ni, Cr	others
Fe	Stainless steel: 316L, 420, ...	Fe, Cr, Mo, Mn, Nb, Ni,	SDS to be checked	Cr, Ni	others
	Precipitation Hardening Stainless Steels: 15-5PH, 17-4PH, ...	Fe, Ni, Cr, Mo, Cu, C	SDS to be checked	Cr, Ni	others
	Maraging steel: 1,270 9, ...	Fe, Ni, Co, Mo, Ti, Al, C	SDS to be checked	Co, Ni, Ti	others
Ni	Structural hardening: Hastelloy, Inconel 625, ...	Ni, C, Co, Cr, Fe, Mo, Nb, W	SDS to be checked	Cr, Co, Ni	others
	Precipitation hardening	Ni, Al, B, Co, Cr, Fe, Mo, Nb, Ta, Ti, W	SDS to be checked	Cr, Co, Ni, Ti	others
	Inconel 718, waspaloy, ...				
Ti	Pure Nickel: Ni200, Ni201, ...	Ni	SDS to be checked	Ni	
	Ti alloys	Al, Mo, Sn, Si, V, Zr	Yes	Ti, V	others
	TiAl and derivatives	B, Al, Nb, Mo	Yes	Ti	others

<sup>a</sup> Substances presenting CMR-risk or suspect to present CMR risk.

<sup>b</sup> Substances not presenting CMR risk.

<sup>c</sup> The bio accessibility of the substances do not linearly correspond to the content in the alloy.

NOTE: This table is not complete. e.g. non-metallic substances as parts of the alloys are not contained. In these cases, the safety data sheet contains relevant information.

### 7.2.3 Hazards related to substances generated during additive manufacturing

Substances generated during the process shall be taken into account. The feedstock materials can interact with compounds in the environment to form other substances having different states.

During the additive manufacturing process, the input substance may be a non-classified metal whose use induces a chemical transformation (e.g. oxidation) and forms species that can potentially be classified as hazardous or indeed as carcinogenic, mutagenic, or toxic for reproduction substances (CMR substances).

Some examples are provided below:

- vanadium pentoxide  $V_2O_5$  is significantly more hazardous than elemental vanadium;
- chromium is toxic in its chromium(VI) oxide form, but its chromium(III) oxide form presents a different set of hazard. Speciation is thus very significant for this element.

### 7.2.4 Hazards related to fire and explosion

The use of any type of metal powder can incur a fire or explosion hazard. The user shall be aware about the powder combustibility. If this information about the powder combustibility is not provided by the powder supplier, see [Annex C](#) for guidance. An additional dust explosion hazard is incurred when flammable material in powder form is suspended in the air, generating a dust cloud. Furthermore, during additive manufacturing processes based on the melting of metal powders fine particles can form by condensation of evaporated metals. The processed alloy can contain condensates or fumes that can often be flammable and/or, due to their typical small size, pyrophoric.

For water reactive materials, such as some aluminium and titanium alloys, the formation of flammable gasses can pose an additional fire and explosion hazard. These gasses can be generated upon contact with water, such as in an explosion proof vacuum cleaner using a water immersion filter. This gas can be ignited when present in sufficient concentration by the ignition sources mentioned below.

When using such flammable materials all ignition sources in the vicinity shall be avoided. These ignition sources include, but are not limited to, static discharge or static electricity, hot surfaces, open flames and live circuitry. It is the users' responsibility to apply the safety precautions as described in the system manufacturers manuals. Furthermore, sufficient measures shall to be taken to limit static discharge, including the use of grounded antistatic equipment, antistatic work surfaces and floors and antistatic garments and grounding of personnel.

### 7.3 Identification of exposing situations

To perform the risk assessment, each step of the process shall be defined including the exposure in routine situations (production, cleaning, etc.) and during occasional activities (maintenance, accident, etc.). See [Table 5](#).

Table 5 — Guidance list for the identification of exposing situations

Step of the global process	Operation in the step	Main risks identified
Prior to use	Taking delivery of and re-packaging of feedstock	Health risk (powder): size or chemistry – Exposure by inhalation or skin contact for containers that are poorly sealed, soiled, or damaged, or during transfer from the containers to other containers Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places Manual handling risk, MSD
	Storage of feedstock	Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places
	Transfer of feedstock to the process	Health risk (powder): size or chemistry – Exposure by inhalation or skin contact for containers that are poorly sealed, soiled, or damaged Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places Manual handling risk, MSD
Use	Preparing the feedstock	Health risk (powder): size or chemistry – Exposure by inhalation or skin contact during powder transfer Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places Manual handling risk, MSD
	Loading feedstock (raw material) into the machine	Health risk (powder): size or chemistry – Exposure by inhalation or skin contact while filling the containers of the machine when transferring the powder Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places Manual handling risk, MSD
	In situ manufacturing in the machine	Health risk (powder) – Exposure to degradation products by inhalation or skin contact: CO, metal oxides, and aldehydes if the machine is poorly sealed. Anoxia due to the use of inert gas Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places if the working atmosphere is not inert Mechanical risk associated with moving parts of the machine, if such parts are accessible Non-ionising radiation risk – exposure to laser rays if there is no screen

Table 5 (continued)

Step of the global process	Operation in the step	Main risks identified
End of use	Recovering unused feedstock Recovering the part Cleaning the part Cleaning the machine Transferring the parts to post-processing Mixing / separating waste streams	<p>Health risk (powder): size or chemistry – Exposure by inhalation or skin contact during powder transfer</p> <p>Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places</p> <p>Manual handling risk, MSD</p> <p>However, there is an additional risk with the residue (fumes) deposited on the walls of the machine. Such residue is often constituted by extremely fine particles that can ignite instantly on coming into contact with the air when the machine is opened. This applies particularly with Ti alloy powders in PBF processes.</p> <p>In addition, it is necessary to take into account the extraction of the gas or the air that is inside the machine: before opening the machine in the work area there may be some remaining particles or residue if it is not emptied by removing the filtered gases or air to the outside</p> <p>When handling or mixing unpassivated waste products from different material streams / processes a thermite reaction can occur when mixtures of light metals, such as aluminum and titanium, with oxidized iron based products are ignited.</p> <p>NOTE 1 Mixing waste streams can also complicate processing by waste management providers, as danger classes can be compounded.</p>

Table 5 (continued)

Step of the global process	Operation in the step	Main risks identified
Post-processing	Finishing the parts	Health risk (powder): size or chemistry – Exposure by inhalation or skin contact during cutting, drilling, sanding, etc Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places Manual handling risk, MSD
	Cleaning of filters	Health risk – Exposure to cutting fluids (if such fluids are used for cooling the tools) Health risk (powder): size or chemistry – Exposure by inhalation or skin contact during manual handling of filters Flash fire risk when handling filters containing condensate particulates, even if the feedstock powder is not combustible. Some condensate particulate can be pyrophoric. Portable vacuum cleaners used for combustible dust cleaning could pose additional risks when handling water sensitive or pyrophoric dust or condensate particulates. Manual handling risk, MSD
	Manual handling of the machine	Health risk (powder) – Exposure to residual powders or to degradation products by inhalation or skin contact: Co, metal oxides, aldehydes. Anoxia due to the use of inert gas Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places if the working atmosphere is not inert Mechanical risk associated with moving parts of the machine, if such parts are accessible Non-ionising radiation risk – exposure to laser rays
Maintenance of the machine	Any operation on the machine and requiring direct access to the parts of the machine that have been in contact with the powders or residues/degradation products: Conventional maintenance Deep internal cleaning when there is a change of powder composition Altering the machine when that requires having access to the described parts Replacing the filter(s) Manual handling of the machine (e.g. for moving it to another place)	Health risk (powder): size or chemistry – Exposure to residual powders or to degradation products by inhalation or skin contact: Co, metal oxides, aldehydes. Anoxia due to the use of inert gas Fire/explosion risk for combustible powders with low Minimum Ignition Energies (e.g. Ti, Al, Mg). occurs several places Manual handling risk, MSD Mechanical risk associated with moving parts of the machine, if such parts are accessible Radiation risk – exposure to laser rays NOTE 2 The steps described are not exhaustive

## 7.4 Characterization and risk rating

### 7.4.1 General

The job description for operators working in the additive manufacturing area, and possibly on the parts produced by AM shall take into account the specific risks listed in [6.2](#). For the risk rating, all significant applicable risks shall be considered.

**WARNING — The high risk category should be evaluated by the operating company through a very detailed risk analysis.**

### 7.4.2 Rating of risks related to contamination, inhalation or skin contact

For the risk rating, the hazard severity shall be classified in 3 levels according to [Table 6](#).

**Table 6 — Hazards for the operator depending on the level of severity**

Level of severity	Possible impacts on the operator
High	Accident or occupational disease that can cause irreversible or fatal effects
Medium	Accident or occupational disease that can cause reversible effects but requires care by health professionals
Low	Accidents or occupational diseases or diseases that can be treated on site

Exposure to CMR substances always leads to high level of severity. Low level of severity is only applicable for completely closed processes where no exposure to dangerous substances under normal working conditions occur.

For the risk rating, the exposure frequency shall be classified in 3 levels: high, medium and low levels. Example for an exposure frequencies characterization is shown in [Table 7](#), for a manufacturing process conducted many times a day.

**Table 7 — Characterization of the exposure frequencies**

Level of frequency	Frequency
High	At least once a day
Medium	Exposure more often than once a week but less than daily
Low	Exposure less than weekly

The level of risk is the product of severity by the exposure frequency. Based on appropriated and established criteria for the obtained product values, the risk shall be classified in 3 levels: high, medium and low levels. Example for a levels of risk characterization is shown in [Table 8](#).

**Table 8 — Level of risk as a function of frequency by severity**

Frequency	Severity		
	Low	Medium	High
High	Medium	High	High
Medium	Medium	Medium	High
Low	Low	Medium	Medium

The prevention and protection measures to be implemented depend on the rating (see [Table 9](#)).

**Table 9 — Preventive and/or protective measures according to the level of risk**

Level of risk	Impacts on prevention and/or protection measures
High	Additional technical preventive and/or protective measures are necessary. The risk assessment shall then be repeated for the concerned tasks.
Medium	At least additional organisational preventive and/or protective measures are necessary. The risk assessment shall then be repeated for the concerned tasks.
Low	No additional preventive and/or protective measures are necessary.

NOTE The code of practice on Workplace Safety and Health Risk Management, 6.4.7 Action for risk levels (see [Table 7](#)) gives guidance. see the following website:

<https://www.tal.sg/wshc>

**7.4.3 Rating the risks related to explosion**

It should be appropriate to use a rating by 3 levels of risk (1, 2, and 3).

The user should be aware that a feedstock which is not combustible can produce combustible particles and gases (e.g hydrogen) during the process. The user should recognize the electrostatic discharge contribution to fire and explosion risks.

NOTE NFPA 484 give guidance for methodology to determine potential dust explosion scenarios.

As a part of the risk analysis, the explosion hazard shall be carried out. Zones for potentially explosive atmospheres shall be defined in accordance with IEC 60079-10-1 and IEC 60079-10-2. See [Table 10](#).

**Table 10 — Simplified definitions of Zones resulting from the application of IEC 60079-10-1 and IEC 60079-10-2**

Explosive atmosphere	Gas/vapour area	Dust area
Continuously, in normal operation	0	20
Occasionally, in normal operation	1	21
Accidentally, in the event of a malfunction	2	22

The characteristics for zones are the following:

- Zone 0: A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.
- Zone 1: A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.
- Zone 2: A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.
- Zone 20: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.
- Zone 21: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.
- Zone 22: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

## 8 Prevention and protective measures

### 8.1 General

The assessment of residual risks is carried out by the user of the system through the application of the criteria of severity and frequency of the hazardous situation according to [7.3](#). Residual risks are those remaining after protective measures have been implemented.

**NOTE** The protective measures implemented by the responsible manufacturer/supplier of the AM system to achieve this objective are applied in the following sequence according to ISO 12100:2010, 6.1:

- inherently safe design measures to eliminate hazards or reduce the associated risks by a suitable choice of design features of the machine itself and/or interaction between the exposed persons and the machine. They mainly affect the process (see [Figure 1](#)).
- appropriately selected safeguarding and/or complementary protective measures taking into account the intended use and the reasonably foreseeable misuse to reduce risk when it is not practicable to eliminate a hazard, or reduce its associated risk sufficiently, using inherently safe design measures

Where risks remain despite inherently safe design measures, safeguarding and the adoption of complementary protective measures, the responsible manufacturer/supplier identifies the residual risks in the information for use (instruction manual, warnings, etc.). Other preventive measures shall be taken into account by suppliers of by-products through the obligation of substitution of hazardous products.

If required by the assessment of the residual risks the user of the system shall apply additional preventive measures. They can be technical (concerning e.g. process, input products and by-products, working rooms), organizational (e.g. adequate training) and/or personal (e.g. the wearing of personal protective equipment).

These additional protection measures are implemented by the user taking into account the information for use including in particular:

- the information provided by the manufacturer of the AM system through the instruction manual defining the limits of use in the different phases of life of the AM system;
- the safety data sheets (SDS) of the products implemented.

The implementation of the additional protection and/or prevention measures and the information required by the operator shall take into account the work environment and the results of the assessment of the residual risks established for all the operating phases of the AM system.

### 8.2 Workplaces

#### 8.2.1 Floors and walls

Protection and prevention measures are integrated according to the results of the risk assessment complying with [Clause 7](#).

Sticky floor mats shall be provided for dust collecting at the access points to the production area in order to prevent powder from spreading.

The AM workplace shall be considered as place with specific EHS control requirements. Controls shall be in place to keep powder used in the AM system from escaping the room. The wall coating should be such that it does not retain the powder and is easy to clean.

**NOTE** Coating can be e.g. polyurethane type.

In case of combustible powders and with the risk of fire/explosion in the free state, the floor shall be static dissipative. In addition, and depending of the risk analysis, the walls should be also static dissipative.

### 8.2.2 Air flow rate

The extracted air flow rate and the compensation air flow rate shall be defined to reduce the specific metallic dust.

The diffusion flow shall capture the powder on the floor as much as possible and minimize the atmospheric exposure and temperature at the head level. The flow rate shall be calculated according to the expected target level of 50 % of the relevant OEL.

The air flow rate should exchange the air from top to bottom with laminar flow entry at ceiling height and extraction by grids at the floor. The Air Handling Unit (AHU) should provide 100 % of fresh air. If allowed by the legislation, energy reduction with the possibility of recycling and enslaved to the proper functioning of the absolute filtering shall be taken into account. Otherwise, an efficiency calculation shall size a heat exchanger.

A risk assessment towards collection of dangerous materials should be performed on the AHU. This risk assessment is to be used to determine the type of filtration system, if any, to be used in the AHU with the risk of fire and towards the general environment in mind.

Wherever possible, the AHU and filters should be located indoors, weather resistant and with an easy maintenance as a priority.

An oxygen monitoring system coupled to a workplace audio and visual alarm shall be used to detect build-up or accidental release of inert gasses used in the process. This sensor shall be placed near floor level (at 0,5 m) to detect heavier than air gasses or above head level to detect lighter than air gases prior to the creation of a hazardous situation.

In all rooms where metal powders are stored, handled or processed no exposed water mains shall be present.

A underpressure between 2 Pa to 5 Pa between each autonomously managed area, with the air flow rate through the ventilation system shall be provided. The source gases removed from the source during the process should be exhausted outside after filtration and not being reused in the AM workplace.

### 8.2.3 Fire

Fire protection shall be determined in detail according to local and operational conditions. Fire prevention measures for combustible powder weighing, sieving, transport, processing and post-processing operations shall be based on a combustible dust hazard analysis.

These measures shall include the provision of an emergency shutdown system with local and remote actuation devices, smoke and heat ventilation systems, as well as escape and rescue routes in compliance with national and regional standards.

NOTE 1 For detailed national fire protection requirements see e.g. NFPA 484 (US), TRGS 800 and DGUV Information 205-001 (Germany).

Neither automatic water sprinklers nor gaseous fire suppression systems shall be installed in rooms where metal powders are stored, handled or processed. An exception may be permitted where a documented and reviewed hazard analysis, accounting for the deleterious interactions of metal with these suppression agents, determines that other fire hazards creating a more severe fire hazard warrant protection using one of these systems.

Agents for extinguishing class D fires (according to NFPA 10 and EN 2) shown to be effective for controlling pertinent combustible-metal fires shall be provided in areas where combustible metal powders are present. The alloy powder safety data sheet and pertinent national regulations and standards shall be reviewed in selecting specific agents.

NOTE 2 Some countries have national standards containing requirements for extinguishing powder of fire class D,

The supply of portable and mobile extinguishers shall be made in accordance with the local body responsible for fire protection.

NOTE 3 NFPA 484 has a table showing whether or not specific Class D agents are effective in extinguishing particular metal fires. The table indicates that dry sodium chloride and certain specific commercial Class D agents are effective for aluminium, magnesium, and titanium fires, but not on steel alloy fires. Dry sand is listed as effected on all the metals shown in the table. Methods of applying Class D extinguishing agents to combustible metal fires are also described in NFPA 484.

Arrangements shall be made in advance with the local body responsible for fire protection to develop a comprehensive emergency preparedness plan accounting for any special reactivity hazards of the metal alloys being used at the facility.

NOTE 4 For additional planning details see e.g. NFPA 484 (US), DGUV-Information 205-001 (Germany).

#### 8.2.4 Electric

Low voltage distribution (LV) wiring supports shall be minimized in length and dust surface. They shall be easy to clean. Holes in partition walls for pipes or cables shall be airtight.

The lighting and power outlets shall be at minimum consumption, for a required lighting level of 500 lx minimum. They shall be easy to clean.

Cable distribution in the confined area shall be sealed.

Powder sealing and short circuit protection of all electric equipment shall be at least IP54 or better if dictated by local legislation or if the risk assessment for the process and workplace dictates as such.

#### 8.2.5 Powder storage

Limitations on the amount of metal powder stored and required separations as well as powder storage restrictions for specific metals, should be as specified in national, regional, and local building and fire codes and regulations.

The storage area shall be free of leakage and condensation and free from overhead water and steam lines. The storage instruction contained in the safety data sheet shall be applied. Additionally, the following items shall be considered:

- store in a closed container to prevent accidental dust generation and to prevent possible contamination (because of dampness, dust, etc.);
- protect containers from physical damage;
- welding, grinding, or other processing that can generate heat and sparks shall not be performed close to storage areas. Smoking shall not be permitted in storage areas;
- storage containers of metal powders shall be kept separate from other chemicals in a storage area. Those chemicals can be, but are not limited to oxidizers, organics, fuels, etc.;
- for reactive powders (e.g. titanium), water-based sprinkler systems SHALL NOT BE USED AS THEY CAN LEAD TO EXPLOSION OF HYDROGEN GAS. Extinguishing systems specified for reactive powders should be used instead;
- review with local building authority for restrictions on building, storage piles, and total allowable quantities (e.g.: use of cabinet storage);
- external surfaces of containers should be kept visibly clean to minimize the potential for skin exposure and spread of contamination.

NOTE Local regulations can be more specific.

## 8.2.6 Best practices for workplaces for personnel

### 8.2.6.1 Changing rooms

Unless the risk assessment indicates otherwise, the PPE equipment room should be designed with two successive premises for clean PPE and for dirty PPE, separated by a door always closed (with alarm), obligatory passage in both directions of entry and exit:

- a) Changing room for clean PPE and storage of personal effects not kept under the suit. People come in work clothes (they changed themselves before in a previous room). As a result, there is no male/female differentiation necessary for the changing room for clean PPE;
- b) Changing room for dirty PPE to remove and discard all dirty PPE. This is also where the hoods should be cleaned and stored before removing the suit, and where the hands should be washed before going out. A sticky floor mat should be placed in front of the intermediate door between the two changing rooms. A shower in case of accident is preferably there or it shall be fitted in the production site.

Used PPE should be properly removed and stored to avoid contamination.

### 8.2.6.2 First aid

Wherever metal powder is stored, handled or processed, adequate access to eye showers should be provided for immediate relief after contact with powder. Location of eye showers shall also take into account the risk related to reactive powders. Workers handling powders shall be trained in the use of these devices.

An adapted first aid kit shall be present in the immediate vicinity of all rooms where powder is handled. At least two responsible workers trained in the use of first aid media shall be present at all times in the production site.

## 8.3 Process

Depending on the process in use and the operating phase considered, the prevention and protection measures against the risks associated with the use of powder shall be adapted.

They can be:

- integrated into the machine during its design (capture at source, glove box, etc.);
- provided by machine peripherals (installation of general and/or workplace exhaust systems, etc.);
- located in the premises (fire suppression equipment, etc.).

## 8.4 Organization

### 8.4.1 General

The organizational measures of prevention and protection against the risks related to the use of powder can be grouped as following:

- staff training;
- personnel information on operating procedures (including during maintenance operations);
- limitation of the number of people exposed;
- wearing personal protective equipment.

### 8.4.2 Training of personnel

Staff shall be trained in the general risks and specific risks associated with the use of the products and by-products used.

This training shall include a presentation of the following elements:

- pictograms for chemical hazard;
- reading and understanding of labels and material safety data sheets (SDS);
- proper use of necessary PPE;
- good practices related to the use, storage and disposal of the feedstocks handled;
- first aid actions in emergency situations.

### 8.4.3 Information for personnel

In addition to training, staff shall have access to the following information:

- instructions provided by the manufacturers of the equipment involved in the process;
- position notices, informing about the risks to which staff can be exposed and the measures taken to avoid them;
- safety data sheets (SDS);
- operational mode or other procedures and work instructions.

### 8.4.4 Limitation of exposed personnel

The number of people exposed should be the minimum required.

If required by the risk analysis, intrusion control shall consist of emergency exit doors secured by a closed door control with feedback to the operation control station and fitted with an audio alarm signal, or similar solutions having the same effect.

Unless the risk assessment indicates otherwise:

- access to the confined area shall be restricted to the strict need of operating, both in terms of personnel and equipment.
- access to the changing room for clean PPE from the outside shall be controlled by a safety device. The door between clean and dirty PPE changing rooms should be self-closing (e.g. with an hydraulic opener) and with an audio alarm signalling when opening is maintained.

### 8.4.5 Reduction of exposure

After a due risk assessment carried out by the user, protective measures for reducing the exposure shall be applied according to a hierarchy that reflects the STOP principle:

- substitution (avoid the risk as far as possible, and keep remaining risks as low as possible);
- technical measures against risks, which cannot be sufficiently reduced by substitution;
- organisational measures, which cannot be sufficiently reduced by technical measures (keep people out of the hazardous area e.g. when changing filters or recovering part from bed, train and instruct those who cannot be kept out);
- personal protective measures/equipment against remaining risks.

#### 8.4.6 Personal protective equipment

Personal protective equipment shall be adapted to the relevant risks according to [Clause 6](#).

##### 8.4.6.1 Protective glasses

If the protective glasses are to be used for operation they shall be in accordance with ISO 16321-1 and ISO 16321-3, or ANSI Z87.1.

NOTE CEN/TR 13464 or ISO 19734 gives guidance for the choice of glasses.

The use of contact lenses is not recommended due to the possibility of powder getting stuck behind the contact lens.

##### 8.4.6.2 Protective shoes

Safety footwear should either be conductive (ESD) or dissipative.

NOTE ISO/TR 18690 gives guidance for the selection, use and maintenance of safety and occupational footwear and other personal protective equipment offering foot and leg protection.

##### 8.4.6.3 Protective gloves

Skin contact with metallic powders, can cause some reaction or irritation (e.g. dermatitis). Furthermore, in the case of small powder particles, the particles can penetrate the skin and become absorbed into cells in various parts of the body, including the brain. Gloves in material suitable to avoid small powder particle skin contamination should be worn in case of small particle powders processes.

Use different gloves and glove material depending on the different operations:

- Check recommendations for the glove materials in the relevant safety data sheets.
- Use gloves while working with powder materials (e.g. nitrile rubber with aluminium powder); make sure that the material is sufficiently thick in order to resist to the mechanical loads.
- Wear suitable chemical protection gloves when cleaning with solvents. When using isopropanol provide for nitrile rubber gloves with a thickness of at least 0,4 mm for a maximum wearing time of 8 h.
- When handling hot objects (e.g. when expanding a building plate, especially when using a pre-heating system during the construction process), provide for heat-insulating gloves.
- If support structures are removed manually, provide protective gloves with sufficient cut protection.
- Provide vibration protection gloves when using hand-held radial grinders.

##### 8.4.6.4 Respiratory mask

Measurements of hazardous substances enable the hazardous substance load to be determined during the operations in the users' premises. Provide breathing protection unless it is ensured that concentration is below the occupational exposure limit (OEL) in all the work steps within the process chain. Select the breathing protection quality in accordance with the safety data sheet of the processed materials. Breathing protection masks may only be worn for a limited time as a rule.

Use of PPE is the least preferred control and should only be implemented if substitution, elimination, engineering, and/or administrative controls cannot sufficiently reduce exposures" in [8.4.5](#).

NOTE Guidance for selection, use and maintenance of respiratory protective devices are contained in ISO/TS 16975-1, ISO/TS 16975-2 and ISO 16975-3.

#### 8.4.6.5 Protective clothes

The use of flame-retardant work clothing, e.g. a pocket-less overall cat. III type 5/6 (anti-static, flame-retardant according to ISO 14116) or a lab coat with corresponding properties, is recommended. Use overalls for activities with CMR substances.

Operators shall use a different garment for each material to avoid cross contamination.

NOTE 1 NFPA 2112 and ISO 14116 give guidance on qualifying fire clothes for flash fire resistance. The applicability of those standards can be subject to local regulation.

Unless single-use products are used, clean protective and working clothes professionally according to a specific cleaning plan.

NOTE 2 Guidelines on the selection, use, care and maintenance of protective clothing are available in CEN/TR 15321:2006.

NOTE 3 Guidelines for selection, use, care and maintenance of chemical protective clothing are available in CEN/TR 15419:2017.

Clothes including overalls shall comply with ISO 11611.

#### 8.4.6.6 Extinguishers

The extinguishing agents shall be selected according to the feedstock used and its applicable safety data sheet.

NOTE NFPA 484:2019, Table A.8.3.3 gives guidance in selecting specific agents.

### 8.5 Waste management

#### 8.5.1 General

Three distinct waste streams are present when working with metal powders:

- a) contaminated filters;
- b) waste from immersion vacuums and cleaning systems;
- c) general dry powder scrap.

Each of these waste streams has its own hazards and is treated in a different manner, though general rules apply. In general, all hazardous material, including waste, shall be stored in an appropriately rated container. The type of container depends on the ADR or DOT classification of the waste.

Local regulation can add additional stipulations, such as neutralization of waste before collection by a recycling service provider. It is highly advised to contact the local waste management provider and/or government agency for the correct regulations to be applied.

Waste material containers shall be stored in a closed off, preferably roofed, area to prevent the impact of incidents. The risk of release to the environment shall be mitigated by spill and leak containment measures, such as spill trays. The risks associated with the waste shall be marked clearly visible on the outside of the containers using standardized ADR/DOT pictograms.

If an AM machine is used with several powders, cross contamination of the filters, or collecting dissimilar metals/alloys in a single vacuum cleaner (for example), could cause a reaction, via combining two or more reactive materials, which are inert when considered in isolation. Therefore, dedicated filters and/or vacuum cleaners shall be assigned to specific feedstock.

The specific waste streams are addressed in [8.5.2](#), [8.5.3](#) and [8.5.4](#).

### 8.5.2 Contaminated filters

Metal powder based additive manufacturing machines are equipped with filters to catch fine particles and fumes/condensate. These materials can pose a fire hazard even when the bulk feedstock is not a flammable combustible. This is due to the small particle size and often elemental oxide-free composition of individual particles. The safe removal of the filters from the equipment shall be performed according to the machine instruction handbook and a combustible dust hazard analysis for filter removal. Flash fire resistant garments and a face shield shall be used.

In most cases these filters are best stored in a sealed off appropriately rated metal barrel. If a bag-in bag-out system is used, store the filter still sealed in its bag in the barrel. For bagged filters it is recommended not to needlessly agitate the containers housing them. Air can seep in bags when a less than ideal seal is obtained, or the bag can be damaged.

NOTE In some cases, the filter housing is designed to function as a rated waste container, and the filter can be removed and disposed of through the proper channels.

### 8.5.3 Waste from immersion vacuums and cleaning systems

When using wet cleaning systems or immersion vacuums a liquid–powder sludge waste mixture is generated. This waste is typically contained in a separate compartment with a provision for waste removal. The sludge waste should be removed daily and transported in a vented covered metal container to an outdoor or dedicated ventilated disposal area.

Eventually this waste separates into 2 phases:

- contaminated liquid;
- sludge or sediment consisting mostly of powder.

This liquid shall not be released to the environment and shall be collected in appropriate leak-proof containers stored on a spill containment surface. This includes all liquid obtained through other cleaning operations.

For most materials the sludge can be collected in a barrel and stored as such. This does not apply for water reactive material in an aqueous sludge. For all intents and purposes under water reactive materials are all materials which release gas and heat upon contact with water. This includes both water reactive materials as specified in the GHS and UN guidelines and materials with a reaction rate below the threshold to be classified as such. Most, if not all, aluminium alloys fall under this category.

Due to reaction with water, pressure and heat can build up when sludge is stored in a closed vessel. In this case the water shall be removed as much as possible, through sedimentation or the use of an adsorbent before sealing the barrel. If not all water can be removed, it is better to allow the sludge to dry out before closing off the vessel.

### 8.5.4 General dry powder waste

Dry powder waste is collected as scrap from sieving operations, powder removal from parts and small spill swept up with a broom and dust pan. This waste often consists of a mixture of different powders. In most countries this waste can be collected in a sealed barrel, similar to the contaminated filters (see [8.5.2](#)).

## Annex A (informative)

### Safety data sheet

The safety data sheet (SDS) is the essential tool for chemical risk management. This 16-section document gives:

- explanations of the health risks related to the exposure or use of dangerous products;
- all information on handling, use or storage of products.

The SDS shall be provided in the language of the country of use of the product, updated with each new information and sent to each update.

NOTE 1 For more details on the safety data sheet, the reader can consult the “How to read an SDS” thematic sheet at: <https://vividlearningsystems.com/safety-toolbox/how-to-read-an-sds-sheet>.

The safety data sheet shall be provided free of charge in paper form or in electronic form no later than the date on which the substance or mixture is first supplied (REACH Regulation, Clause 31).

All the 16 items (or sections) present in the SDS shall be read and particular attention should be paid to the following topics:

- Section 2 contains the hazard identification (toxic, CMR, ...), the hazard statements are input data for the analysis of chemical risks to health. Combustible powders can also be so identified in this section.

NOTE See 8th edition of the UN Globally Harmonized System of Classification and Labelling of Chemicals, Annex 11: Guidance on Other Hazards not Resulting in Classification

- Section 8 contains the recommended exposure limit values (OELs) and personal protective equipment (PPE). Exposure values are important data for the selection of PPE.
- Section 12 contains information useful for conducting an environmental risk analysis.

NOTE 2 Values can change with the regulations update.

The understanding of the OEL is not easy, each country may have a different value. In addition, OELs are based on scientific results, the validity of which can change over time. (see [Table D.1](#))

NOTE 3 The REACH process has created reference values that are almost similar to OELs, but established by industry. At the current stage of regulation, only OELs are to be taken into account.

For each metal alloy a dosage of each of the compounds thereof shall be performed.

Hazardous substances (including CMR) are listed in Annex VI of the CLP Regulation, mixtures containing these substances are considered hazardous (mandatory labelling) if the content of these substances exceeds the threshold set by the regulation.

GESTIS Substance Database can be found in:

<https://www.dguv.de/ifa/gestis/gestis-stoffdatenbank/index-2.jsp>

Information on Occupational exposure limit values (OELs) can be found in:

<https://www.dguv.de/ifa/fachinfos/occupational-exposure-limit-values/index.jsp>

## ISO/ASTM 52931:2023(E)

In addition to these national information, very useful could be this site with an international character: GESTIS - International limit values for chemical agents (Occupational exposure limits, OELs):

<https://www.dguv.de/ifa/gestis/gestis-internationale-grenzwerte-fuer-chemische-substanzen-limit-values-for-chemical-agents/index-2.jsp>

There is a great heterogeneity within these SDSs which leads to disparities in the categories or terms used, which sometimes makes it difficult to compare one supplier to another.

Another factor to take into account is the particle size of the powders. Different particle size ranges apply to different types of processes, typically:

PBF-LB: 5  $\mu\text{m}$  to 45  $\mu\text{m}$

PBF-EB: 45  $\mu\text{m}$  to 105  $\mu\text{m}$

DED-LB: 45  $\mu\text{m}$  to 105  $\mu\text{m}$

Powders within these different size range intervals have very different indices in terms of explosiveness.

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## Annex B (informative)

### Definition of limit values

#### B.1 General

The choice of reference shall be made after taking into account the regulations:

- regulatory values of the country of use,
- OEL values present in the REACH file and communicated by the SDS.

Then, considering references values proposed by agencies of recognized expertise, with an international impact (transcription in several countries).

#### B.2 Relevant agencies worldwide

ACGIH: expert association in toxicology and industrial hygiene in the USA. The ACGIH OELs have US recommendation values, and regulatory bond values in other countries, including Belgium, Spain ...

SCOEL: Expert from the European Union, in charge of recommending, on a purely scientific basis, the reference values for monitoring the exposure to chemicals in the workplace. Their recommendations, to be applied by regulation, shall be taken up by European bodies that will study the socio-economic applicability. This process is often very lengthy, which causes a lack of readability on the concrete application of the recommendation.

Reference values proposed by national agencies of experts, countries recognized for the quality and the number of their works:

- a) ANSES, France.
- b) BAuA, Germany,
- c) STAMI, Norway.

WHO has priority public health objectives. The protection of public health implies the consideration of different parameters of worker protection, so WHO's recommendations are most often to be placed in this context in order to be interpretable and usable. For example, WHO considers night work as carcinogen. This classification is based on studies showing a link between breast cancer and low daylight exposure for night shift nurses.

In this hierarchy of sources, it is necessary to add the consideration when it is communicated, transparency on the calculation of the development of the OEL.

The statement of a reference value has two phases: the choice of the starting point, which gives a dose compared to an observed effect. The security factor application to this "starting point". Most often, there is unanimity or clear discussion about the choice of "starting point", and differences arise from the calculation and application of safety factors.