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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).

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).

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.

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.

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.

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.

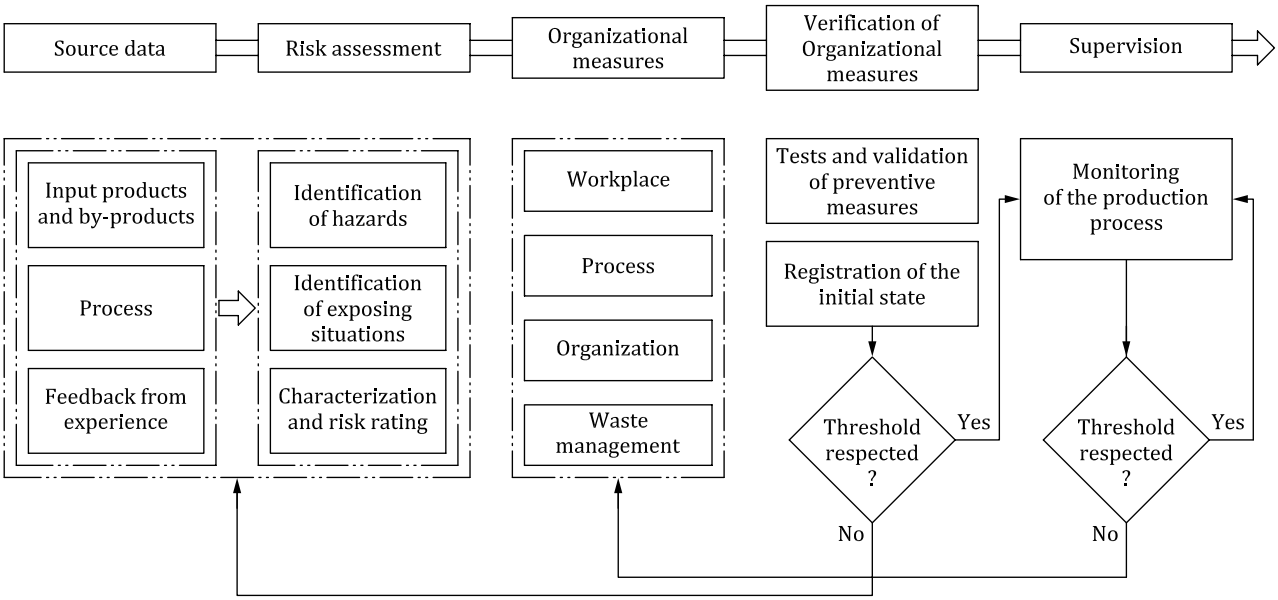

Figure 1 — Overall approach to risk assessment and implementation of prevention measures

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:

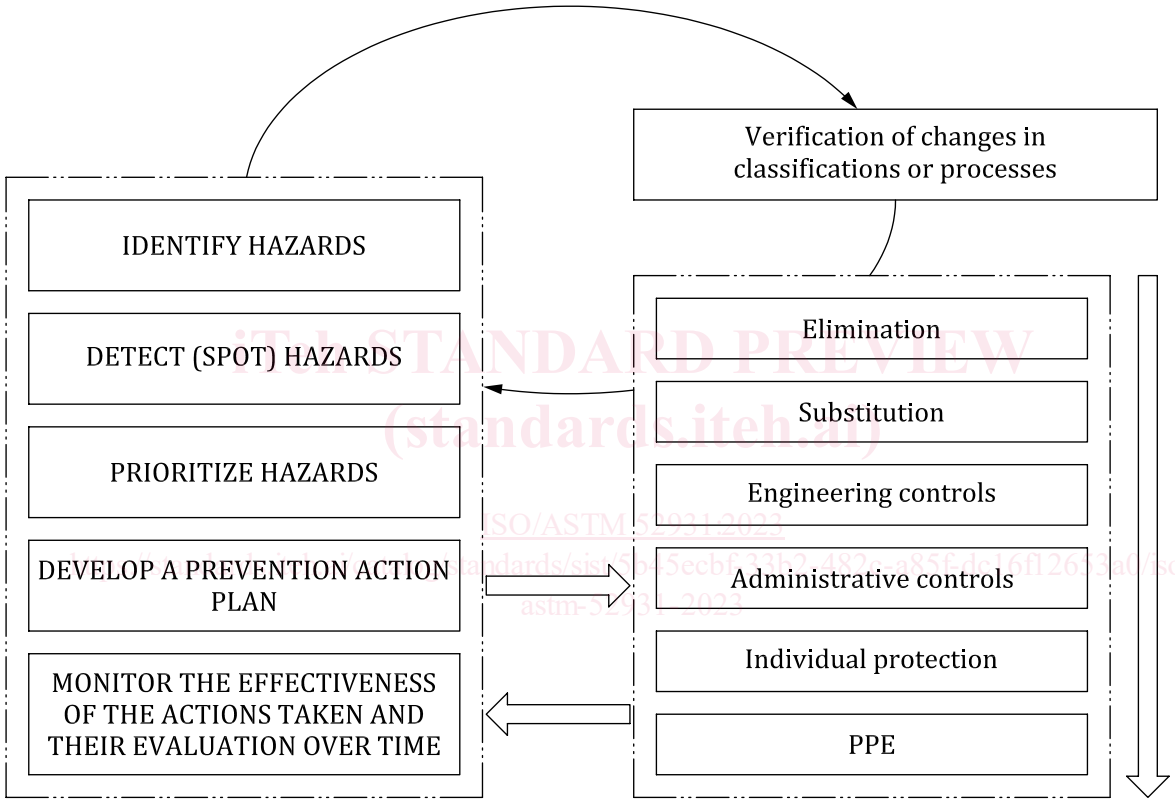

Figure 2 — Main steps of a chemical risks prevention process

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.