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**Solid recovered fuels — Safe handling  
and storage of solid recovered fuels**

*Combustibles solides de récupération — Sécurité de la mise en oeuvre  
et dus stockage de combustibles solides de récupération*

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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).

This document was prepared by Technical Committee ISO/TC 300, *Solid recovered fuels*.

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

Modern society is based on production and consumption of an enormous variety of products, both for industrial and private use. After its intended use, the product will be disposed as waste by the user and will then enter the chain of waste management which includes a variety of handling, storage and processing/recycling methods.

With production, handling, transportation and storage of SRF (Solid Recovered Fuels) there is always a significant risk of fire and dust explosion. A fire or an explosion provides risks both for human health and the environment and cause large economical losses. It is therefore important that operators throughout the supply chain ensure that there is a developed strategy to prevent fires and to prevent dust explosions, and if a fire should occur, a readiness to handle the fire effectively to reduce the consequences.

Fires will, in addition to economic losses and effects on health and the environment, also have a negative impact on the confidence in the SRF industry and difficulty to obtain insurance coverage might also increase.

In facilities where dry combustible materials are handled such as in SRF facilities, there are several risks present for fires and dust explosions. A typical cause for an ignition of the material is friction heat or impact ignition sources generated within the processing chain. Such ignition sources can be generated due to mechanical wear or break-down, metal pieces and stones, material overfeeding, etc. Most mechanical machines contain moving parts that potentially could generate friction heat high enough to ignite the material. Examples are shredders, conveyors, screening/separation machinery and fans. Other sources causing ignitions are for example hot surfaces, electrical discharges, hot works and self-ignition inside storages.

An ignition source can ignite the material being processed or dust accumulations inside and around the machinery. It is important to take necessary measures for reducing the risk for ignitions. Accumulations of combustible dust are intended to be avoided. However, dust can quickly accumulate to a stage where it can become a significant fire load.

This document provides support, advice and guidance to facility owners, logistics providers, equipment suppliers/manufacturers, consultants, authorities and insurance providers to assess and mitigate different risks when producing, handling and storing SRF.

# Solid recovered fuels — Safe handling and storage of solid recovered fuels

## 1 Scope

This document provides principles and requirements for safe handling, treatment and storage of solid recovered fuels (SRF), prepared from non-hazardous waste, to be used for energy purposes. This document covers process stages from point of acceptance of material to point of delivery of SRF.

This document excludes fuels that are included in the scope of ISO/TC 238 *Solid biofuels* and ISO/TC 28 *Petroleum products and related products of synthetic or biological origin*.

It uses a risk-based approach to determine what safety measures are to be considered.

Although unloading and loading of e.g. vessels, trains or trucks are included, the safety issues following the loading and transport itself are not.

## 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 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 21637:2020, *Solid recovered fuels — Terminology, definitions and descriptions*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21637:2020 and the following apply.

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

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

### 3.1 Parts of the SRF process

#### 3.1.1 baling

process of producing a compressed material bundle or package secured by wires, hoops, cords or similar

#### 3.1.2 belt conveyor

conveyor with an endless belt acting as a carrying and traction element

Note 1 to entry: There are several belt conveyor types, such as; troughed belt conveyor, deep troughed belt conveyor, pipe belt conveyor, walled belt conveyor, flat belt conveyor and radial conveyor.

### 3.1.3

#### **belt feeder**

shortened form of *belt conveyor* (3.1.2), normally running at slow speed, designed to extract or control the rate of flow of bulk materials from hoppers

[SOURCE: EN 620:2002+A1:2010, 3.2.4]

### 3.1.4

#### **box**

storage with two or three walls

### 3.1.5

#### **bucket elevator**

elevator for loose bulk materials with buckets as the carrying medium attached to a belt or chains as the driving medium

Note 1 to entry: The bucket elevator consists of a strap forming belt, stretched vertically between a driving head pulley and a pulley of foot. Buckets are attached to the strap and the whole is enclosed in a metal frame.

Note 2 to entry: The foot of the elevator is equipped with a chute in which the buckets are filled by shovelling and a head shape suitable for evacuating grain by projection centrifugal.

[SOURCE: EN 618:2002+A1:2010, 3.1.3 – modified: notes to entry were added]

### 3.1.6

#### **bunker**

storage which is closed on four sides and reachable from the top

### 3.1.7

#### **chain conveyor**

conveyor for loose bulk materials with a chain as the driving medium having attached flights or scraper flights moving the material "en masse" in an enclosing trough

### 3.1.8

#### **chain reclaimer**

machine for loose bulk materials with a chain as driving medium having attached flights or scraper flights moving the material in an open drop-in pit or drive over pit

### 3.1.9

#### **conveyor system**

number of linked conveyors with their ancillary equipment and control system

[SOURCE: EN 620:2002+A1:2010, 3.1 – modified: "control system" was added]

### 3.1.10

#### **crushing**

mechanical reduction of *particle size* (3.3.4) by exerting mainly blunt deforming forces to a material

[SOURCE: ISO 21637:2020, 3.15]

### 3.1.11

#### **density separation**

separation of mixed materials by using density differences of the different fractions for classification

Note 1 to entry: With respect to SRF-production, most common application of density separation is wind shifting applying airflow as conveying/transport medium. A process of separation by different densities of particles and fluids.

### 3.1.12

#### **dust collection system**

system that collects free dust from the air in process systems

**3.1.13****electromagnetic separation of non-ferrous metals**

separation of non-ferrous metals by inducing temporary magnetic forces

Note 1 to entry: This term is also known as eddy current separators.

[SOURCE: ISO 21637:2020, 3.26]

**3.1.14****enclosed conveyor**

conveyor which is enclosed to avoid contamination between the interior and the exterior environment

**3.1.15****enclosed storage**

storage that is enclosed to avoid contamination between the interior and the exterior environment

**3.1.16****feeder**

mechanical device for delivering material at a controlled rate

[SOURCE: ISO 1213-1:1993, 10.1.02]

**3.1.17****ferrous metal separation**

separation of ferrous metals by use of permanent magnetic forces

**3.1.18****fine shredding**

*shredding* (3.1.28) of materials to an average particle size of 20 mm - 50 mm

**3.1.19****idler**

mechanical element rotating on internal bearing and fitted to support the belt

Note 1 to entry: On *belt conveyors* (3.1.2), several idlers can be used. These are called e.g. troughing idler (which supports the belt and maintains it in a troughed form), carrying idler, return idler.

**3.1.20****main shredding**

mechanical reduction of particle size of material via *shredding* (3.1.28) it to average *particle size* (3.3.4) of 50 mm - 100 mm

**3.1.21****manual separation**

separation of material particles individually by hand or mechanical solution

**3.1.22****optical recognition**

recognition of material particles individually by optical sensors

[SOURCE: ISO 21637:2020, 3.50]

**3.1.23****pneumatic conveying**

method of transporting bulk materials by means of air through pipes or ducts

**3.1.24****pre-shredding**

mechanically reducing particle size of material by *shredding* (3.1.28) it to average *particle size* (3.3.4) of 100 mm – 300 mm

**3.1.25**

**screening**

separation of larger particles from material flow, typically >150 mm

**3.1.26**

**screw conveyor**

conveyor for loose bulk materials with a trough or tube as the carrying medium, the material being moved by the action of a rotating screw

**3.1.27**

**screw reclaimer**

mobile equipment located below a stockpile for continuously reclaiming bulk materials using a screw as the carrying or conveying medium

[SOURCE: EN 618:2002+A1:2010, 3.3.8]

**3.1.28**

**shredding**

mechanical reduction of *particle size* ([3.3.4](#)) by tearing, cutting or other means

[SOURCE: ISO 21637:2020, 3.73]

**3.1.29**

**sil**

part of a continuous handling system used to contain intended kind(s) of bulk material(s) during a certain period of time

Note 1 to entry: The sil is usually charged from the top and discharged from one or more outlets at the bottom or side.

[SOURCE: EN 617:2001+A1:2010, 3.1 – modified: part of definition was added as a note to entry]

**3.1.30**

**step feeder**

feeder which uses friction to transfer material

Note 1 to entry: Walking floor is an example of a step feeder.

**3.1.31**

**under-screen fraction**

material fraction that goes through a screen

[SOURCE: ISO 21637:2020, 3.87]

**3.2 Risk management**

**3.2.1**

**residual risk**

*risk* ([3.2.2](#)) remaining after risk reduction measures have been implemented

[SOURCE: ISO/IEC Guide 51:2014, 3.8]

**3.2.2**

**risk**

combination of the probability of occurrence of harm and the severity of that harm

Note 1 to entry: The probability of occurrence includes the exposure to a hazardous situation, the occurrence of a hazardous event and the possibility to avoid or limit the harm.

[SOURCE: ISO/IEC Guide 51:2014, 3.9]

**3.2.3****risk analysis**

systematic use of available information to identify hazards and to estimate the *risk* (3.2.2)

[SOURCE: ISO/IEC Guide 51:2014, 3.10]

**3.2.4****risk assessment**

overall process comprising a *risk analysis* (3.2.3) and a *risk evaluation* (3.2.8)

[SOURCE: ISO/IEC Guide 51:2014, 3.11]

**3.2.5****risk control**

process of decision-making for managing and/or reducing *risk* (3.2.2); its implementation, enforcement and re-evaluation from time to time, using the results of risk assessment as one input

**3.2.6****risk criteria**

terms of reference against which the significance of a *risk* (3.2.2) is evaluated

Note 1 to entry: Risk criteria are based on organizational objectives, and external and internal context.

Note 2 to entry: Risk criteria can be derived from standards, laws, policies and other requirements.

[SOURCE: ISO/IEC Guide 73:2009, 3.3.1.3]

**3.2.7****risk estimation**

process of assigning values to the probability of occurrence of events and their consequences

[SOURCE: ISO 13824:2020, 3.15]

**3.2.8****risk evaluation**

procedure based on the *risk analysis* (3.2.3) to determine whether *tolerable risk* (3.2.11) has been exceeded

[SOURCE: ISO/IEC Guide 51:2014, 3.12]

**3.2.9****risk management**

coordinated activities to direct and control an organization with regard to *risk* (3.2.2)

[SOURCE: ISO/IEC Guide 73:2009, 2.1]

**3.2.10****risk reduction measure****protective measure**

action or means to eliminate hazards or reduce risks

[SOURCE: ISO/IEC Guide 51:2014, 3.13 – modified: example has been removed.]

**3.2.11****tolerable risk**

level of *risk* (3.2.2) that is accepted in a given context based on the current values of society

Note 1 to entry: For the purposes of this document, the terms "acceptable risk" and "tolerable risk" are considered to be synonymous.

[SOURCE: ISO/IEC Guide 51:2014, 3.15]

### 3.3 Operation and safety

#### 3.3.1

##### **hot particles**

solid particles whose temperature that can be above minimum ignition temperature of flammable gases or vapours and combustible dusts.

#### 3.3.2

##### **intended use**

use of a machine in accordance with information for use provided in the instructions

[SOURCE: ISO 12100:2010, 3.23]

#### 3.3.3

##### **oversize particle**

particle exceeding a specific particle size

Note 1 to entry: The definition of oversize particle is dependent on the application and determined between the producer and user.

[SOURCE: ISO 21637:2020, 3.51]

#### 3.3.4

##### **particle size**

size of the fuel particles as determined in a solid fuel

Note 1 to entry: Different methods of determination can give different results.

Note 2 to entry: See also *particle size distribution* (3.3.5) and *over size particle* (3.3.3).

#### 3.3.5

##### **particle size distribution**

proportions of various *particle sizes* (3.3.4) in a solid fuel

[SOURCE: ISO 21637:2020, 3.53]

#### 3.3.6

##### **personal protective equipment**

##### **PPE**

equipment that can include, but is not limited to, clothing, gloves, helmets, footwear and face protection

[SOURCE: ISO/TR 21808:2009, 2.1]

#### 3.3.7

##### **reasonably foreseeable misuse**

use of a machine in a way not intended by the designer, but which can result from readily predictable human behaviour

[SOURCE: ISO 12100:2010, 3.24]

#### 3.3.8

##### **reduced explosion pressure**

resulting overpressure generated by an explosion in an enclosure after effective explosion venting or explosion suppression

## 4 Introduction to the use of this document

Although risks in connection with the production, handling, transportation and storage of SRF are recognized, factors affecting each risk are different depending on the material type, climate, processing equipment, etc. This document does not intend to focus specifically on the separated risks for individual components, but rather on how the components constitute parts in a system and for example, how

hazards can be transferred. Therefore, broad and detailed instructions and recommendations on requirements for design and construction of facility and processes and for operation and maintenance of equipment are given in this document. This document is structured based on different parts in the SRF production and handling process. Stakeholders such as regulators, producers, and consumers of SRF are encouraged to develop regulations or guidelines, considering the local properties and situation as well as this document. Users of this document are responsible for identifying local regulations.

## 5 Risk management

### 5.1 General

To improve the safety during production, handling and storage of SRF, both design and operation shall be considered. Safety concerns anyone who is responsible or exposed to the hazards arising from the activities within the premises, here limited to the scope of this document.

For identified hazards the following hierarchy shall be followed as a minimum:

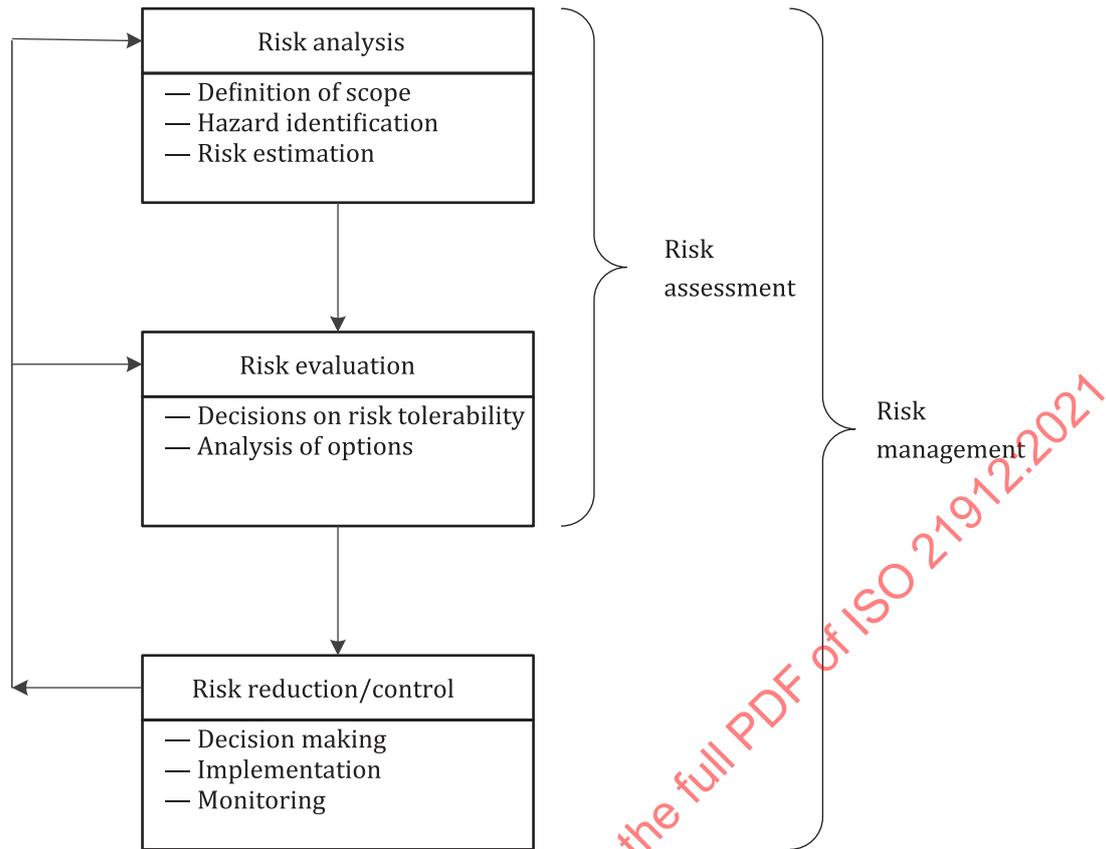
- 1) Elimination
- 2) Substitution
- 3) Engineering controls
- 4) Administrative controls
- 5) Personal protective equipment (PPE)

The items above shall be addressed as early as during the design stage, as well as during operation and maintenance.

For the operational management of occupational health and safety, the Plan-Do-Check-Act (PDCA) model according to ISO 45001 should be used.

An important part of these processes, both during design and operation, is management of risk, which includes several steps and sub-steps.

For this document the detailed steps which shall be followed and documented for the general risk management are shown in [Figure 1](#).



**Figure 1 — Risk management**

The risk management process includes a risk analysis and a risk evaluation, which form the basis for the risk assessment and what risk reduction/control measures are required for each specific plant.

The objects, issues and aspects to be considered and documented in the risk management process are related to general design and construction and general operation and maintenance procedures including preplanning of emergency operations.

For fire prevention and fire protection of machinery, ISO 19353 should be used, when applicable.

Further specific issues to consider are also provided for receiving and feeding (8.1.1); crushing, milling and shredding (8.2); conveying (8.3); storage solutions (8.4); separation and screening (8.5); and other systems (8.6).

The documentation shall describe and justify the measures taken, as well as include aspects not considered applicable or relevant.

The person responsible for the risk management process shall have the necessary levels of competence to undertake a fire and explosion risk assessment; the level of competency required should be commensurate with the complexity of the facility to be assessed, i.e.:

- a) A good understanding of SRF and the equipment and processes used for the production and along the supply chain of SRF
- b) A good understanding of fire related aspects of building control and function
- c) Appropriate knowledge of national fire/explosion and safety legislation and the requirements of other enforcing bodies and stakeholders (i.e. insurers)
- d) Appropriately trained and/or experienced in fire/explosion safety and fire protection issues

- e) Knowledge of relevant national and local codes and experience of application

## 5.2 Introduction to the risk management process

Management of risks include several steps and sub-steps as shown in [Figure 2](#). In [5.2.1](#) to [5.2.5](#), the different parts of risk management are defined and described.

### 5.2.1 Definition of scope

When performing a risk analysis, the scope shall be defined, i.e. the system that is to be included in the analysis. This includes definition of the boundary of the system and to identify user, intended use and reasonably foreseeable misuse. Assumptions and limitations for the analysis should also be defined. Technical, environmental, organisational and other aspects relevant for the problem/system should be included.

### 5.2.2 Hazard identification

Hazard identification involves systematic review of the system under study to identify the type of inherent hazards that are present together with the ways in which they could be realized. Different hazards and sources of risks shall be identified and the type of hazard they pose analysed. Hazard identification methods fall mainly into three categories:

- 1) Comparative methods (e.g. checklists, hazard indices and reviews of historical data)
- 2) Fundamental methods, that are structured to stimulate a group of people to apply foresight in conjunction with their knowledge to the task of identifying hazards (e.g. HAZOP studies, ISO 12100 and FMEA)
- 3) Inductive reasoning techniques (e.g. event tree logic diagrams)

The significance of the sources of risks shall be analysed by an initial evaluation, based on a consequence analysis. The aim of this analysis is to decide whether:

- a) Actions should be taken to eliminate or reduce the hazard
- b) The analysis can be terminated due to the insignificance of hazard
- c) The analysis should be continued with a risk estimation

There are many factors influencing the risk management, e.g. the storage capacity, annual SRF turnover and complexity of on-site handling and to consider all the variables that might be valid for a facility.

### 5.2.3 Risk estimation

Risk estimation should examine the initiating events or circumstances, the sequence of events that are of concern, any mitigating features and the nature and frequency of the possible deleterious consequences of the individual hazards to produce a measure of the level of the risk being analysed. The measures could address human, property or environmental risks and should include an indication of the uncertainty associated with the estimates. The risk estimation process can be described by the following steps:

- a) Frequency analysis used to estimate the likelihood of each undesired event identified during the hazard identification stage. To estimate event frequencies three different approaches are commonly used: relevant historical data, analytical or simulation techniques and expert judgement
- b) Consequence analysis is used to estimate the likely impacts should the undesired event occur
- c) Risk calculations where risk should be expressed in the most suitable term, e.g.: individual risk, predicted frequency of mortality, frequency versus consequence plots (F-N curves), the statistically

expected loss rate in terms of casualties, economic loss or environmental damage, the distribution of the risk of a specific damage level

#### 5.2.4 Risk evaluation

When risk analysis has been completed, risk evaluation shall be carried out in accordance with ISO 12100, or a similar nationally or internationally standardised methodology included in the operational management of occupational health and safety of the organization, to determine if risk reduction is required. If risk reduction is required, then appropriate measures shall be selected and applied.

#### 5.2.5 Risk reduction/control

Based on the risk evaluation, measures shall be taken to achieve an adequate risk reduction. Where hazard or hazardous situations with multiple risks have been identified, care should be taken to prevent risk reduction measures chosen to reduce one risk from resulting in another intolerable risk. Risk reduction can be divided in measures taken during design and during the use phase, respectively. The measures shall in turn be divided into different steps or parts and shall be taken in the specific order:

- a) Risk reduction measures during design:
  - 1) Inherently safe design
  - 2) Guards and protective devices
  - 3) Information/instruction for use
- b) Risk reduction during the use phase:
  - 1) Additional protective devices
  - 2) Training
  - 3) Organization of work, application of equipment and supervision
  - 4) Personal protective equipment

In [Figure 2](#), the process of risk management is shown, with the iterative process of risk reduction and, if applicable, risk assessment.

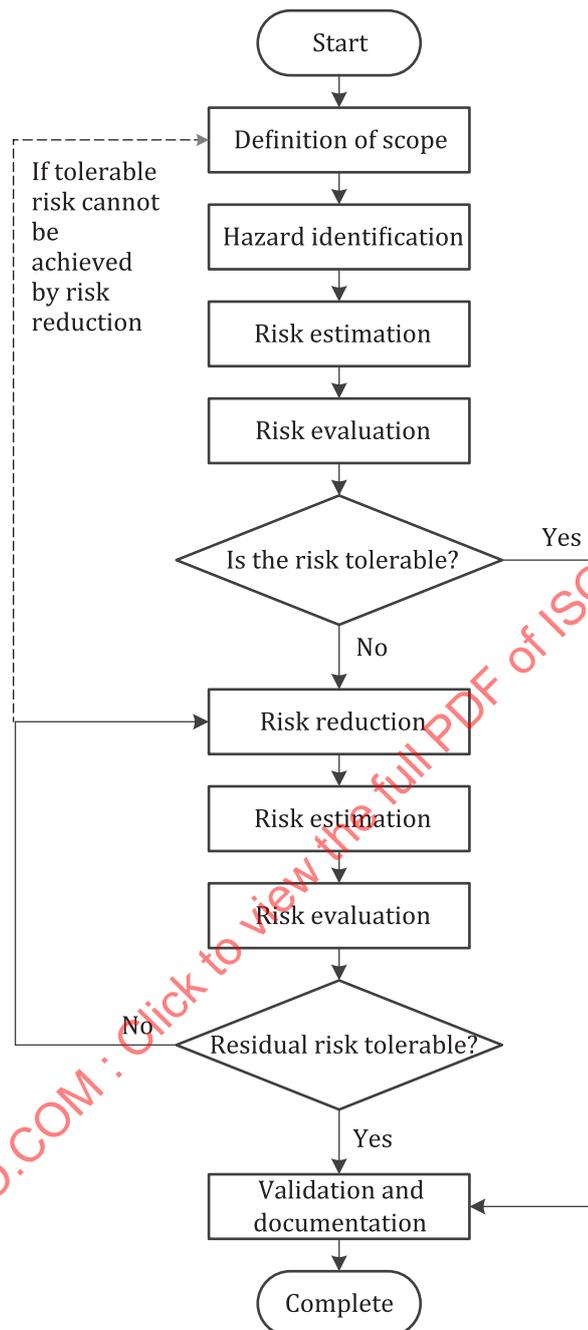


Figure 2 — Iterative process of risk assessment and risk reduction (ISO/IEC Guide 51:2014)

## 6 SRF processes

### 6.1 SRF production process

SRF production process refers to the entire process chain at which non-hazardous waste is submitted from the “point of acceptance” until the delivery of SRF at the “point of delivery” (see ISO 21637:2020, 3.55 and 3.56). The whole system consists of interlinked process equipment and conveyors.

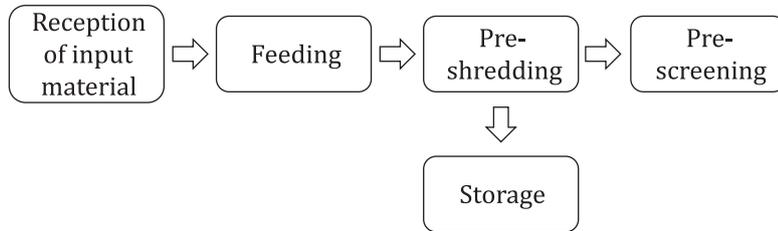
SRF production process can generally include some or all of the processing steps indicated in the figures below for:

- a) Pre-treatment process

- b) Main treatment process
- c) Storing process

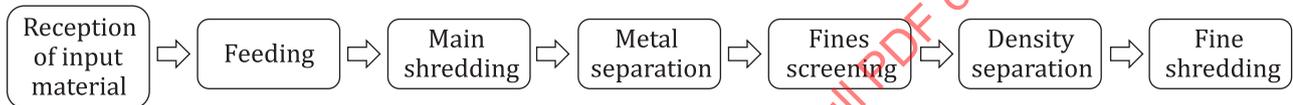
These processes are schematically described in [Figures 3](#) to [5](#). However, also some other steps can be included in the SRF-production process.

**Pre-treatment process**



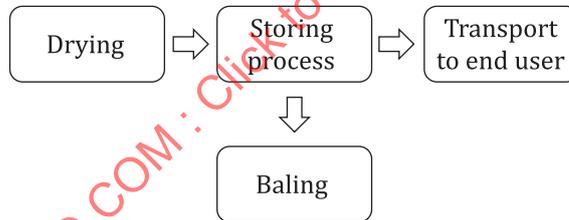
**Figure 3 — Pre-treatment process**

**Main treatment process**



**Figure 4 — Main treatment process**

**Storing process**



**Figure 5 — Storing process**

NOTE Not all steps necessarily will be present in all situations.

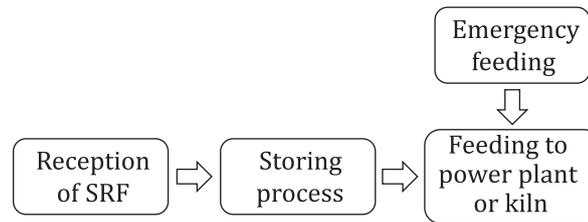
**6.2 Typical SRF receiving, storing and feeding at power plant or cement kiln**

Typical SRF receiving, storing and feeding processes at a power plant or a cement kiln, use semi-automated feeding processes to feed the fuel into storage and fully automated feeding process from storage to the power plant or cement kiln. The whole system consists of interlinked process equipment and conveyors.

Typical SRF receiving, storing and feeding process includes:

- a) Receiving process with tipping station and hopper
- b) Storing process with open bunker with crab crane or enclosed storage with screw or chain reclaimer
- c) Emergency feeding is typical option especially in power plant solutions

Typical SRF receiving, storing and feeding process at power plant or cement kiln is presented in [Figure 6](#).



**Figure 6 — Typical SRF receiving, storing and feeding process at power plant or cement kiln**

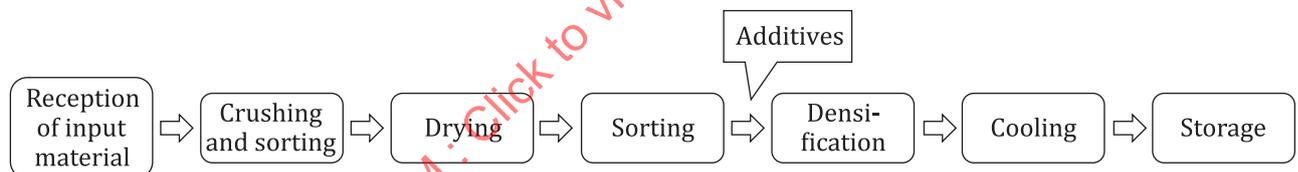
### 6.3 SRF production facilities including densifying

The densified SRF, which is typically solidified by the addition of chemical agents or spontaneously solidified by entangling or melting to produce the pellets or the briquettes, is generally produced by receiving, crushing, sorting, drying, and moulding the wastes. The SRF that is produced is then cooled and stored.

The production processes of SRF can be categorized by timing of drying and moulding and whether and when the additives are added. There are mainly three types of production process as follows (“crushing and sorting” implies either “crushing”, “sorting”, or “crushing and sorting”), see [Figures 7 to 9](#).

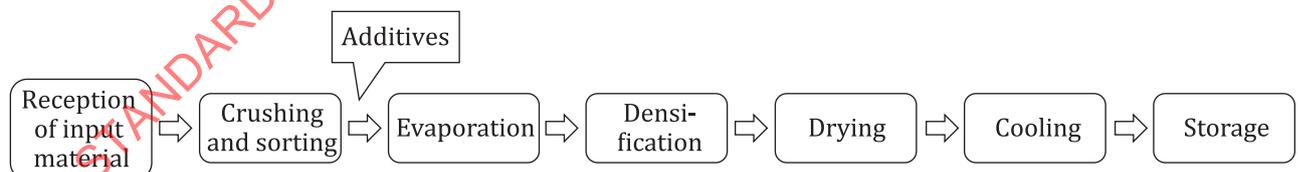
NOTE Densification and moulding are used for similar, but not the exact same processes. For simplicity the term densification is used in the rest of this document.

**Type 1:** SRF is densified (solidified) after drying the wastes



**Figure 7 — SRF production process including densification (after drying the waste)**

**Type 2:** SRF is densified (solidified) before drying the wastes



**Figure 8 — SRF production process including densification (before drying the waste)**

The sorting process includes the process of chemical reaction between wastes and additives.

**Type 3:** There is no drying process or additives

This method is used in cases where the wastes used for producing SRF are not likely to decay, where the SRF produced is consumed immediately after being produced, and where there is no need to store the produced SRF for a long period.



Figure 9 — SRF production process including densification (with no drying or additives)

## 7 Safety considerations and requirements for SRF plant

### 7.1 Safety hazards

This subclause describes general safety requirements for SRF processes. Additional requirements for specific objects are described in [Clause 8](#).

The equipment and facility shall be constructed in such a way that risks are minimized and documented. Ignition hazard assessment shall be done for electrical equipment and non-electrical equipment in an area classified as hazardous due to the risk for an explosion. By ignition sources in this document, mainly possible ignition sources are meant. Whether these possible ignition sources have the potential to become effective ignition sources shall be assessed in the risk assessment.

Design and construction of facilities (including commissioning and hand-over) and operational, preventive maintenance and emergency procedures shall be such as to minimize the exposure to risk related to the following (which shall be included in the risk assessment):

a) Fires

Both pieces of SRF and dry dust pose fire hazards, therefore ignition sources shall be avoided. There are several potential ignition sources along the path of the SRF process which shall be considered during risk zone classification. These ignition sources can be present both during normal operation and/or in case of malfunction and shall be considered during design and commissioning but also during operation.

b) Explosions

The SRF can contain fines of which a portion is very fine dust which easily becomes airborne. Dust smaller than 500 µm is considered explosive when dispersed in air in sufficiently high concentration. All dust shall be assumed combustible until demonstrated otherwise, e.g. by appropriate and representative testing. Fine dust generated during handling has a propensity to settle on flat surfaces in layers on beams, motor casings, cabinets, railings, floors, lamp shades etc. The ignition temperature for dust in layers is comparatively lower than dust cloud ignition temperature. All areas of an operation involving production, handling or storing of SRF where potentially explosive dust or gases can be present shall be divided and classified in risk zones.

c) Self-heating

Different types of waste have a propensity to self-heat during storage, particularly at elevated ambient temperature. The heating can be considerable depending on the composition of the material and can in some cases develop into smouldering requiring fire extinguishing intervention and emergency discharge. Temperature monitoring of the surface and inside the stored bulk can be important to obtain indications of self-heating. Measurements of CO just above the bulk surface might provide additional information. Possibilities for emergency discharge shall be considered.

d) Danger of dust emission to the environment and exposure of workers and others in the vicinity of the facility

The amount and character of fine dust suspended in the air is a health risk when inhaled. Efforts to control dust exposure shall be planned and implemented during the design stage.

## e) Exposure of operators to asphyxiation or intoxication

Stored SRF can release gases such as carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>) in combination with rapid oxygen depletion. Small amounts of methane and hydrogen as well as malodorous hydrocarbons are also released.

## f) Avalanche

Where there is a risk of avalanching by high walls, bridging or ratholing, standard operating procedures shall be developed and implemented to minimize the risk of avalanche. Lifesaving with lifelines and “cofferdam” (a barrier to prevent burial of personnel) is one of the few options to save lives in such cases.

## g) Machinery

Machinery involving moving parts, in case of malfunction or during misuse, can involve a significant risk for personnel injuries and suitable risk reducing measures shall be considered. The requirements of ISO 12100 shall be fulfilled.

## h) Vehicles

Vehicles, in normal operation but in particular in case of e.g. emergency discharge of a storage due to self-heating or fire, can involve a significant risk for personnel injuries. The main risk factors are the many vehicles (e.g. front loaders, trucks) in operation, reduced visibility due to smoke, reduced visibility due to drivers using SCBA (self-contained breathing apparatus) equipment. Suitable risk reducing measures shall be considered. Vehicles shall also be maintained properly according to maintaining scheme and procedures.

## i) Undesirable dangerous materials

Risk caused by undesirable dangerous materials such as large gas cartridges (i.e. from barbecues) and lithium ion batteries may pose a significant risk for personnel injuries, fires and explosions.

Fire is an important hazard in relation to production, handling and storing SRF.

Typical causes of fires, specifically, in conveyor systems, are often hot surfaces or the formation of sparks. In [Table 1](#) some common ignition sources are listed. They are ignition sources of higher relevance for production and handling of SRF, compared to the examples listed below [Table 1](#).

**Table 1 — Ignition source of specific interest**

Source of ignition	Examples of causes
Mechanically generated sparks and hot particles	Mechanical impact, friction phenomenon, abrasion, high speed (relative speed > 1 m/s), inappropriate matching of materials, lack of or insufficient equipotential bonding causing electrostatic sparks, misalignment of belts, faults in electric devices and utilities, foreign bodies
Hot surfaces	Electrical faults in motors, overloading, insufficient lubrication, damaged track supporting rollers, internally positioned bearings, overheated electric motor casing, overheated brakes, belt slip, misalignment of belts, friction of the belts, high speed, friction against material deposits
Flames and hot gases (including combustion generated particles)	Combustion reaction
Electrical issues	Various electrical faults and electrical discharges
Exothermic reaction	Self-ignition of material in stores as a result of critical self-heating. Self-heating can be caused by chemical, physical and/or biological processes.
Static electricity	With charged parts made of non-conductive materials, and these include most plastics as well as some other materials, brush discharges and, in special cases, during fast separation processes (e.g. films moving over rollers, drive belts), or by combination of conductive and non-conductive materials) propagating brush discharges are also possible.

Other examples of possible ignition sources are:

- Lightning strike
- Electromagnetic waves
- Ionising radiation
- Ultrasound
- Adiabatic compression and shock waves

For further examples and descriptions of ignitions sources, see e.g. EN 1127-1, ÖNORM 2098, and WISH “Waste 28”.

### 7.2 General requirements and recommendations for safe production and handling

The design of facilities and equipment as well as operational guidelines can eliminate or minimize the risk for hazardous conditions during production, handling and storage of SRF. Below, some general aspects of importance are listed while more specific aspects related to certain objects and processes (receiving and feeding; crushing, milling and shredding; conveying; storing; separation and screening; other systems) are presented in [8.1](#) to [8.6](#).

- a) General construction considerations to avoid dust generation, dust settlement, material build up, etc.
  - 1) If dust layers can build up on beams, ledges and structures, which cannot be cleaned and are located inside buildings, these structures should be topped off smoothly at an as high angle as possible  

NOTE A minimum angle of approximately 60° (horizontal) is generally recommended.
  - 2) Locations of potential deposits or accretions should be easily accessible
  - 3) Install warning signs and warning systems in connection to specific hazardous equipment or areas
- b) Creation and spreading of dust can be limited by the following means (including, but not limited to):
  - 1) Minimizing the number of transfer points and their drop heights and/or impact on the material
  - 2) Using enclosed conveying routes, enclosed transfer points and/or dust removal systems
  - 3) Minimizing vibration and interparticle movement during conveying
- c) Accessibility for regular inspections
- d) Accessibility for housekeeping
- e) Accessibility for firefighting
- f) Accessibility/possibility for emergency discharge of storage
- g) Safe methods to remove SRF from storage facilities in case of troubles such as heat generation should be considered in advance
- h) Preparatory measures should be considered during the design and construction phase of the plant in order to gain the prevention of fires or as they could be important to reduce the consequences of a fire/explosion incident
- i) Explosion relief systems will reduce the risk of transfer of an explosion and fire along a conveyor and secondary explosions in connected equipment. The venting should preferably be guided outdoors

- j) Areas where dust becomes lofted during production and handling and the occurrence of explosive dust/air mixtures cannot be fully avoided shall be classified in risk zones. Within the zones, only equipment approved for the relevant zone shall be used
- k) All identified risk zones/areas shall be clearly identified by signs and warning symbols
- l) Electrical equipment and lightning protection. Do not use halogen or other lighting fixtures with hot surfaces
- m) Risk for accumulation of gases from off-gassing or pyrolysis gases (CO, CO<sub>2</sub>) in locations adjacent to storage facilities (e.g. offices, lunchrooms, and meeting rooms) during self-heating or fire situations shall be considered
- n) Antistatic (or dissipative) materials (e.g. hoses) are preferred in explosion classified areas

Sufficient cleaning measures shall be introduced and reviewed regularly. If dust layers thicker than 5 mm tend to appear in the level surfaces on the area over at least 20 % of the floor area or at least 1 mm over the entire floor area, the cleaning intervals shall be re-evaluated.

When operating, cleaning and maintaining the machine suitable protective clothing should be worn. All safety equipment shall be inspected before use.

### 7.3 General requirement for operation and maintenance

Operation and maintenance of a facility shall be organized such that hazardous situations are minimized. In the event of emergency, there shall be first aid instructions in place for what to do in case of injury and shut-down procedures for minimizing damage. Typical situations which historically are known to cause injuries and even fatalities are when personnel enter confined spaces causing asphyxiation and during maintenance work where personnel are caught in machinery, exposed to electric shock, etc.

To avoid such incidents, all personnel shall regularly be informed about the risks related to confined spaces and, when required by the risk assessment, be equipped with personal gas detectors measuring both CO and oxygen (O<sub>2</sub>) content since exposure to high/low concentrations can occur under normal operation conditions.

During operation and maintenance, it is important to apply strict rules about lock-out of machinery, both mechanically and electrically, before e.g. any obstructions are cleared, or other maintenance work is conducted. These rules shall also include lockout of fire/explosion detection and suppression systems and ensure that they are reactivated before any operation commence.

### 7.4 Documentation of operation procedures

The following documents shall be compiled by the operator of the facility producing, handling and/or storing SRF and where necessary be available and maintained to be updated.

- a) Operations Manual
  - 1) daily procedures
  - 2) start-up and shutdown routines
  - 3) emergency procedures
  - 4) housekeeping procedures
  - 5) outline of operator training
  - 6) work safe guidelines from local/national authorities
  - 7) log and reporting requirement (operational conditions, incidents/abnormal conditions, accidents)

- 8) reporting structure of organization
- 9) safe behaviour
- b) Maintenance Manual
  - 1) preventive maintenance routines (e.g. regular control of bearings)
  - 2) remedial maintenance routines (e.g. access to critical spare-parts to enable a fast replacement)
- c) Safety guidelines for visitors and contractors working on-site (e.g. orientation plans, rules for entry of confined spaces, lock-out of machinery)
- d) Properties of the SRF produced and/or handled by the plant:
  - 1) Identification
  - 2) Hazard identification
  - 3) Composition
  - 4) Physical properties
  - 5) Chemical properties
  - 6) Self-heating properties
  - 7) Off-gassing and oxygen depletion properties
  - 8) Safety characteristics of dust
  - 9) Toxicological information

## **7.5 Safety during operation**

### **7.5.1 Operation**

Regular visual inspection of the entire handling system shall be performed, to identify dust accumulation, spilled material or signs of malfunction or damaged equipment requiring maintenance. This can be done manually by the personnel. Limit the storage time and apply the first-in-first-out principle as far as practical.

Visual fire inspections, after taking the necessary safety precautions, of stored SRF shall be performed regularly, i.e. noting any tendencies of vapour formation. Such inspections shall be done also on entry of delivered fuel into storage. Visual fire inspection can be assisted by handheld IR cameras.

For stores with an expected storage time longer than usual without any transfer operations, control of the SRF properties loaded into the storage shall be considered, e.g. tendency to self-heating.

NOTE 1 A method to determine the tendency to self-heating is being developed and the standard is being prepared by ISO/TC 300/WG 6.

Regular monitoring of stored material using temperature and/or gas detectors/gas detection systems shall be made.

NOTE 2 As the storage facilities and storage conditions can vary considerably, monitoring of the rate of change of temperature (and/or gas concentration) is often more important than a specific threshold as an abnormal increasing rate of change indicates some form of changed conditions and a possible problem.

For intermediate stores which every week have a transfer to the stock or reclaiming, the temperature monitoring of the moved material can be adequate.

Keeping good track of normal conditions is therefore essential to learn more about the specific storage and the material in it and to have the possibility to detect any abnormal situation in an early stage. In such situation suitable safety precautions shall be taken, e.g. removal, consumption.

Log lists of relevant actions related to the operation and reporting routines of any incidents including follow-up measures shall be created and kept.

NOTE 3 When a large quantity of SRF is stored in one place, heat can accumulate and make extinguishment of a fire more difficult if ignition occurs. The recommended maximum size depends on the type of material stored.

If it is not possible to empty or clean the bottom part of storage area, parts of SRF end up staying in the storage area for a long period, which can lead to increase in moisture content or generation of heat.

Other risks that shall be considered are for example a mechanical break down and material overfeeding which can cause friction heat or hazardous ignition sources.

### 7.5.2 Housekeeping

Dust accumulations present a significant explosion hazard. A routine for checking dust build-up shall therefore be set in place. A cleaning plan shall be created and maintained for regular removal of dust; it shall be based on frequency of cleaning or max dust layer.

Equipment, e.g. vacuum cleaners, shall be certified for the use in explosive atmosphere according to national or regional regulations. Due to the risk of raising dust, cleaning shall not be performed with compressed air or high-pressure cleaners. To avoid dust accumulation, it is necessary to implant dust collecting system protected against dust explosion.

Fine dust will also create a health risk and exposure might cause asthma and other effects to skin and eyes. Personnel regularly exposed to dust, e.g. those working with housekeeping and maintenance, shall have access to respiratory protective equipment and it shall be worn when required by the risk assessment.

### 7.5.3 Maintenance

A maintenance plan for all key mechanical equipment, e.g. conveyors, valves, various monitoring equipment, fire detection and fire protection equipment shall be derived and kept up to date.

The preventative maintenance routine shall include checking the grounding of electrical equipment e.g.: motors and other conductive process equipment such as fans and conveyors.

The resistance to ground or between objects shall be  $< 1 \text{ M}\Omega$  to prevent the risk of sparking due to static discharge. The maximum resistance shall also include interconnecting parts e.g. flexibles and piping, belt material and drive wheels or flexible and equipment. IEC 60079-31 provides further information.

If explosive dust/air mixtures are avoided by permanent inerting of an enclosed system, an additional risk assessment shall be performed including the additional risk for low oxygen areas for operating and maintenance personnel.

Emptying and cleaning of certain equipment (e.g. running certain conveyors free of material, emptying and cleaning of storage) shall be done in advance of a longer operationally stand-still or maintenance period.

Hot work (welding, cutting, brazing, machining with high-speed tools and other work involving heat or sparks) shall only be conducted after receiving a written permission from an authorized person (see NOTE) at the facility. Before starting the work, necessary precautions shall be made to eliminate any combustible material in the area of work, or by other means decreasing the risk for ignition and fire spread. Fire extinguishing equipment shall be available and ready for use and the work shall be monitored by one or several fire guards. Lockout of fire/explosion detection systems might be necessary

to avoid activation. The detection systems shall be reactivated before any operation commence again. This shall be included in the permission procedures.

NOTE There can be national requirements on education and certification of personnel performing hot work.

#### **7.5.4 Guidelines for visitors/contractors**

Instruct contractors' staff and visitors regarding rules for:

- a) wearing PPE equipment (helmet, protective glasses, noise protection, protective shoes, reflective clothing, respiratory protective equipment, etc.)
- b) areas involving specific hazards (e.g. confined spaces)
- c) rules for hot work, etc. (contractors)
- d) action in case of a fire or other emergency, evacuation routes and location of "Point of assembly"

System start and stop procedures and warnings shall be derived and be available.

#### **7.6 Pre-planning of emergency operations**

Where applicable, pre-planning and preparation of check lists shall be made in cooperation between the operator and the fire and rescue services to cover possible scenarios. Typical incidents that shall be considered are:

- a) activation of ignition source detection systems in the conveying system
- b) fire detection in the conveying system
- c) indicated self-heating in a store
- d) confirmed fire in store
- e) activation of any explosion protection system in the plant
- f) rescue of people from confined spaces

The pre-fire planning shall include:

- 1) Structure of emergency organization with contact details (e.g. mobile telephone number, private telephone number) to both all involved internal personnel and to external key persons (fire & rescue services, suppliers of inert gas and related equipment, freight companies, health and environmental authorities, etc.)
- 2) A general risk assessment and safety rules for various expected incident scenarios and at least the six scenarios mentioned above
- 3) Procedure for how to perform an updated, on-site risk assessment related to the specific object and incident scenario
- 4) Immediate actions (preferably as a check list) to minimize the risk for the involved personnel (see below) and reduce the consequences of the incident
- 5) Need for warning signs and warning systems, equipment to cordon off certain areas
- 6) Expected duration of a fire (or explosion) incident and actions with respect to this (smaller incidents can be handled during some hours while a fire in a silo can take several days or even weeks)
- 7) Preparations, equipment and routines for emergency discharge of storage in case of indicated self-heating or fire
- 8) Regular inspection of safety equipment

- 9) Emergency shut down procedures for certain equipment
- 10) Handling of extinguishing media and contaminated material
- 11) Education and training of personnel for various incident scenarios (including both operator personnel, fire and rescue personnel and if relevant, key suppliers of extinguishing equipment/media)
- 12) Routines for regular updates of the emergency procedures

Further details to include/consider in the pre-planning work for various equipment/locations are also mentioned in [Clause 8](#).

The pre-planning document should also include necessary drawings and photos of the plant to visualize where various fire protection systems are installed, id-numbers of various sensors, location of water hydrants with information about maximum flow rate and pressure, emergency routes and exits within buildings and along conveyor systems, detailed construction drawings of certain equipment, etc.

## 7.7 Personnel risks

The following risks for personal injuries shall be considered, both during pre-planning and during an ongoing emergency operation but is not limited to:

- a) Exposure to toxic gases (e.g. high concentrations of CO as a result of off-gassing or a self-heating/fire situation)
- b) Areas with low O<sub>2</sub> concentration
- c) Use of inert gases during the inerting/firefighting operation (asphyxiation, exposure to cold liquefied gas)
- d) Effects of explosions (considering both dust and gas explosions), injuries from operating explosion vents or construction parts thrown away by the explosion, risks and effects of secondary explosions
- e) Rapid fire escalation (e.g. in a conveyor gallery having step pitch, fires as a consequence of an explosion)
- f) Backdraft (e.g. if opening a silo with an ongoing smouldering fire)
- g) Work inside confined spaces and the risk of engulfment or burial of personnel
- h) Instability of structure (e.g. structure for elevated conveyors)
- i) Working at heights

## 8 Safety considerations and requirements for specific parts of the SRF production and handling process

### 8.1 Receiving and feeding

#### 8.1.1 General for all receiving and feeding solutions

The main risk for this part of the installation is the dispersion of fuel particles in the air during reception and self-heating risk during prolonged storage of fuel in the hopper.

At this process, the wastes that are collected are received, stored, and conveyed to the next step which is typically the crushing and sorting step. Generally, facilities to receive the wastes consist of combinations of “bunker and crane” or “yard and shovel car” and weighing scales.

The content of wastes greatly fluctuates depending on the region, climate, and weather. If hazardous wastes such as explosives or highly flammable objects such as gas canisters, spray cans, paint

cans, fireworks, lithium ion batteries, gasoline, or kerosene can be contained in the wastes that are received, safety measures should be taken. Other objects such as burnt residue that is not completely extinguished, or pyrophoric substances can also be contained. In addition to such undesirable material, because the physical and chemical properties of wastes have great impact on the physical and chemical properties of SRF, the amount of other incombustible wastes, such as glass or metal, should also be minimized.

If the properties of transported material or the handling process is leading to fire hazardous situation, devices such as sprinklers, fire hydrants, and fire extinguishers shall be properly installed to be used in case of fire, if found necessary via the risk assessment. This shall be included in the risk assessment.

The receiving process should include a documented receiving control to check that the incoming material corresponds to the waste declaration. If material is not in the scope of the plant, it should lead to return of the material to the sender. Because material could be unsuitable and create safety risks in the process. Errors in the mixtures should also be communicated upstream in the delivery chain.

## 8.1.2 Inputting the raw material into pre-treatment process

### 8.1.2.1 Safety risks

Raw material can be fed by hand, truck, crane, front loader or similar appliances to the pre-treatment process.

In receiving and feeding solutions, the main fuel related risks are fire, explosion, personal safety risk because of dust in the air, wrong feeding material, undesirable particles, oversized particles, sharp particles, and particles thrown in the air by the process.

Improper feeding capacity or interval can lead to risks for overloading the feeding process. Also, material particles which are too big can generate fire safety risks, by blocking or tangling the process.

The loading machines can have hot surfaces such as exhaust system and motor. Friction between loader bucket and floor can generate sparks.

Break down of the machine can be able to generate fire or explosion safety risk, for example bearing failure due to the poor maintenance.

### 8.1.2.2 Requirements and recommendations for design and construction

To control the dusting, the use of enclosed unloading areas with internal dust control shall be included in the risk assessment. Additionally, the use of fire and dust explosion prevention and protection measures (e.g. dust control water spray or water mist, inerting and controlling the feed material) when designing of the receiving area is recommended.

The constructions shall be able to meet the fire and dust explosion safety requirements, for example the fire isolation measures and dust explosion pressure control measures.

If high dust concentration in the air generates repeatedly low visibility, additional safety measures like sound-based warnings shall be included to accompany visibility-based warning systems. Additionally, if dust concentration could exist regularly in the air, it is recommended to build separate room or CCTV (closed-circuit television) system for the operator to follow safely the receiving process.

The removal of the undesirable material of oversized material should be designed so that it is easy and safe operation to the operators and users.

### 8.1.2.3 Requirements and recommendations for safe operation and maintenance

Proper feeding capacity or interval should be used, and oversized material particles should be controlled to avoid safety risks and overloading the feeding process.

Appropriate PPE appliances shall be used when working in the receiving area. The risk for sharp objects being projected from the receiving process and the risk for personnel shall be evaluated. If the environment in the receiving area contain hazardous amount of dust, protective respiratory equipment shall be worn.

Sufficient cleaning measures shall be introduced and reviewed regularly. Dust layers thicker than 5 mm shall not exist, because of the risk of dust explosion and risk of self-ignited fire. If thick dust layers tend to appear in the level surfaces on the area, the cleaning intervals shall be re-evaluated.

The process machine service and maintenance intervals recommended by machine manufacturer shall be respected. Motors (and associated parts) constitute a hot surface and may be an ignition source and shall be included in the risk assessment.

The need for earthing of the trucks and the need for hoses made of antistatic material should be included in the risk assessment.

For transfer operations, e.g. hopper, vibrator and metal separator:

- a) Metal detectors should be fitted for the machines to prevent the crushing of metal pieces. These shall be calibrated each year.
- b) Bearing temperatures shall be monitored as defined in equipment user manual. Temperature measuring (e.g. with handheld laser temperature measurer) is used to identify any bearing damage at an early stage as possible.

### 8.1.3 Feeders

#### 8.1.3.1 Safety risks

Feeding can be carried out by step feeder, chain reclaimer, belt feeder or loading chute. Feeding machines are typically operating with low speed.

When the fuel is spilled into the buffer silo, it can sometimes form an explosive dust/air atmosphere. The discharge operation is even more problematic as the accidental introduction of a hot object can result in the ignition of the dust cloud thus formed, whether at the level of the buffer silo or the auger exit of the buffer silo.

Feeding machines has typically low amount of fuel related risks. Existing fire in the received material or ignition sources from the material unloading process are possible risks.

#### 8.1.3.2 Requirements and recommendations for design and construction

The feeding material consists typically of large and heavy particles. The construction of feeding machines shall be able to handle the feeding peak load and full material bed load. If the material is wet, the feeding should be designed to have sufficient drainage system. The construction of the feeding pocket should be dust tight, so the dust generated during the unloading process is not able to have access to the electrical wires and appliances, and to bearings of the feeding machine.

#### 8.1.3.3 Requirements and recommendations for safe operation and maintenance

Proper feeding capacity or interval and oversized material particles shall be followed to avoid safety risks and overloading the feeding process.

The use of PPE equipment such as safety glasses and respiration filter should be controlled when working at receiving area.

The feeders shall be serviced and maintained according to the supplier's instructions.

## 8.1.4 Emergency feeding process

### 8.1.4.1 Safety risks

Typical emergency feeding is a combination of pocket and feeding screw, chain or belt conveyor, or only feeding pocket. Emergency feeding is typically made by front loader or truck.

In emergency feeding processes, the main fuel related risks are; fire, explosion, personal safety risk because of dust in the air, wrong feeding material, undesirable particles, oversized particles, sharp particles, and particles thrown in the air by the process, or falling objects during the loading process.

Proper feeding capacity or interval shall be followed when loading the emergency feeding to avoid safety risk of overloading the feeding process. Also, too big material particles can generate fire safety risks, by blocking or tangling the process.

When feeding wastes with properties of dusting, it recommended to use PPE appliances such as safety glasses and respiration filter when working at receiving area to minimize personnel safety risks.

If the received material bare sharp objects or if the process itself can throw particles out from the process line the use of PPE appliances such as safety glasses is recommended near any open parts of the process.

The loading machines can have hot surfaces such as exhaust system and motor. Friction between loader bucket and floor or feeding pocket can generate sparks.

Break down of the machine can be able to generate fire or explosion safety risk, for example bearing failure due to the poor maintenance.

### 8.1.4.2 Requirements and recommendations for design and construction

The use of emergency feeding is typically very rare, and because of this the probability of material related safety hazards are lower than in the rest of the process. However, the design of the feeding pocket should minimise dusting and blocking of the material.

### 8.1.4.3 Requirements and recommendations for safe operation and maintenance

Proper feeding capacity or interval and oversized material particles shall be followed to avoid safety risks and overloading the feeding process.

The use of PPE equipment such as safety glasses and respiration filter should be controlled when working at receiving area.

The emergency feeding process shall be serviced and maintained according to the supplier's instructions.

## 8.2 Crushing, milling and shredding

### 8.2.1 General for all crushers, mills and shredders

Crushing, milling and shredding can cause the generation of dust. This shall be taken into account in the risk assessment and when designing equipment. Depending on the type of waste, it can contain particles which can ignite or explode during the crushing process. Based on the risk assessment, proper protection measures shall be provided. Utilization of surveillance cameras should be considered at the inlet of crusher for constant monitoring. The dust generation depends on several factors, e.g. the moisture content and rotation speed of the machine. Shredder related work accidents can also be very serious, resulting even in death or permanent harm to an individual. Hence, the work safety is of utmost importance when designing shredding equipment and their integration into SRF manufacturing processes.

Explosions and ignitions of fuel material are also risks related to crushing, milling and shredding.

The wastes that are received are crushed to sizes that can be properly dried or densified in this process. Undesirable material such as metals, glass, or porcelain are usually removed before crushing, milling or shredding. In some cases, sorting is conducted after drying.

As wastes can ignite or explode inside the crusher depending on the type of wastes, surveillance cameras should be installed at the inlet of crusher for constant monitoring.

If a risk for ignition inside the crusher has been identified, ignition should be prevented by measures such as spraying of vapor, encapsulation of inert gas such as nitrogen, or active ventilation.

Devices such as sprinklers, fire hydrants, and fire extinguishers shall be properly installed to be used in case of fire if the risk assessment defines that material is easily ignitable in crushing process during normal operation.

## 8.2.2 Pre-shredding

### 8.2.2.1 Safety risks

In pre-shredding processes, the main fuel related risks are: fire, explosion, personal safety risk because of dust in the air, wrong feeding material, undesirable particles, oversized particles, sharp particles, and particles thrown in the air by the process, or falling objects during the loading process.

Proper feeding capacity or interval shall be followed when loading the shredder to avoid safety risk of overloading the shredding process. Too big material particles can generate fire safety risks, by blocking or tangling the process.

The loading machines can have hot surfaces such as exhaust system, breaks and motor. Friction between loader bucket and floor or feeding pocket can generate sparks.

Break down of the machine can be able to generate fire or explosion safety risk, for example bearing failure due to the poor maintenance.

The pre-shredder is often the first processing step in an SRF production process. Even if most of the pre-shredded material consists of relatively large pieces, the shredding process can create also smaller fractions, including fines and dust that eventually could collect to significant amounts inside the pre-shredder and in adjacent areas. It shall be evaluated if untreated material contains undesirable items such as stones and large solid metal pieces since the first separation step often is located after the pre-shredder. When undesirable items pass the pre-shredder, they could generate friction heat, hot particles and sparks that potentially could ignite the material or dust accumulations. Other common undesirable items are pressurized gas bottles that when shredded can cause a gas explosion and metal wires, stripes or cables that are reeled up around the shredder shafts which could generate friction heat.

### 8.2.2.2 Requirements and recommendations for design and construction

The pre-shredder feed material consists typically larger and heavy particles. The construction of shredding machines shall be able to handle the feeding peak load and full material bed load. If the material is wet, the shredding area should be designed to have sufficient drainage system. The construction of the shredding pocket shall be robust, so the machine can withhold the vibration and hits caused by the shredded material.

The shredding process shall be designed in such a way so that significant material and dust accumulations can be avoided.

The shredder shall be designed in such a way so that any area where material and dust can accumulate easily can be accessed by site operators.

The shredder shall be designed in such a way so that the appearance of ignition sources is minimized.

A dust control system shall be considered in order to minimize the occurrence of combustible dust.

### 8.2.2.3 Requirements and recommendations for safe operation and maintenance

Proper feeding capacity or interval and oversized material particles shall be followed to avoid safety risks and overloading the feeding process.

When feeding material with properties of dusting, it is recommended to use PPE appliances such as safety glasses and respiration filter when working at shredder area to minimize personnel safety risks.

If the received material bare sharp objects or if the process itself can throw particles out from the process, the use of PPE appliances such as safety glasses is recommended near any open parts of the process.

The shredder shall be serviced and maintained according to the supplier's instructions.

Doors, hatches, etc. shall remain closed during operation and if the risk assessment indicates that opening of the hatch or door can generate a safety risk, it shall be equipped with an interlock solution, if not a specific tool or key is needed to open the door or hatch. Lock-out as safety measure shall be considered in the general risk management. The interlock solution shall prevent the shredder from starting when the safety circuit is open. In case the safety circuit opens during operation, the shredder shall stop automatically.

Any equipment located in dust hazardous areas covered by the area classification plan shall meet the technical requirements that apply for the current area. According to the IEC 60079 series for type of protection for electrical equipment and ISO 80079-36:2016 for type of protection for non-electrical equipment, ignition hazard assessment shall be done for electrical and non-electrical products that have their own potential ignition sources and are intended for use in explosive atmospheres, including:

- a) Hot surfaces (maximum surface temperature)
- b) Flames and hot gases
- c) Mechanically generated sparks (single impacts sparks) (property of metal, impact velocity and maximum potential impact energy)
- d) Hot surfaces generated by friction

Suitable process monitoring devices, prevention systems, protection systems and fire mitigating systems shall be installed, if required by the risk assessment (examples: power consumption monitoring of motors, temperature sensors for motors and shaft bearings, ignition source detection system at inlet and outlet of the shredder).

The shredder shall be properly earthed.

## 8.2.3 Main shredding

### 8.2.3.1 Safety risks

When the material reaches the main shredder, most of the large undesirable items are usually separated, but the material can contain items that potentially can generate ignition sources when passing the main shredder. The running speed of a main shredder is relatively high, and the material pieces are generally smaller in size. Small material fractions and dust will be generated, and higher speeds increases the risk for friction heat and appearances of impact sparks and hot particles that potentially could ignite the material.

### 8.2.3.2 Requirements and recommendations for design and construction

The shredder shall be designed in such a way so that significant material and dust accumulations can be avoided.

The shredder shall be designed in such a way so that any area where material and dust can accumulate easily can be accessed by site operators.

The shredder shall be designed in such a way so that the appearance of ignition sources is minimized.

If explosive atmosphere occurs frequently, a dust control system shall be considered in order to minimize the occurrence of combustible dust.

The access to remove undesirable material shall be made safe for the user, because accessing the waste pit is a safety risk. Use of automated removal procedure for undesirable material is preferred.

- a) Equipment inside a zone with risk for an explosive dust atmosphere shall be certified to not pose risk for ignition
- b) The structure should be open to ventilate possible explosion pressure away from operating personnel
- c) The structure should be robust to withstand explosion pressures
- d) The shredder shall be equipped with closed discharge conveyor with efficient dust extraction equipment to mitigate dust diffusion out from the equipment, effectively under-pressurising the area

### 8.2.3.3 Requirements and recommendations for safe operation and maintenance

The shredder shall be serviced and maintained according to the supplier's instructions.

Doors, hatches, etc. shall remain closed during operation and, if the risk assessment indicates that opening of the hatch or door can generate a safety risk, it shall be equipped with an interlock solution, if not a specific tool or key is needed to open the door or hatch. Lock-out as safety measure shall be considered in the general risk management. An interlock solution shall prevent the shredder from starting when the safety circuit is open. In case the safety circuit opens during operation, the shredder shall stop automatically.

Any equipment located in dust hazardous areas covered by the area classification plan shall meet the technical requirements that apply for the current area.

Suitable process monitoring devices, prevention systems, protection systems and fire mitigating systems shall be installed, if required by the risk assessment (Examples: power consumption monitoring of motors, temperature sensors for motors and shaft bearings, ignition source detection system at inlet and outlet of the shredder).

The shredder shall be properly earthed.

Sufficient PPE shall always be worn while in vicinity of main shredder, while the shredder is in operation.

The personnel access during operation shall be organized so that rotor is not visible from any point (cover from direct splinters, shrapnel, and possible explosion ventilation). There shall be no access to shredding zone unless rotor temperature has been controlled.

## 8.2.4 Fine shredding

### 8.2.4.1 Safety risks

When the material reaches the fine shredder, most undesirable items are usually separated, but the material can still contain items that potentially can generate ignition sources when passing the fine shredder. The size reduction of the material makes it more flammable. The shredding speed and the material properties affect the amount of finely divided material, including dust, inside the fine-shredder and in adjacent areas. The peripheral speed of the shredder creates risk for friction heat as well as appearances of impact sparks and hot particles that potentially could ignite the material. Other risks that shall be considered are for example a mechanical break down and material overfeeding which can cause friction heat or hazardous ignition sources.

The presence of pulverized fuel in fine shredding in the presence of air can lead to a risk of explosion. In normal operation, a shredder is a confined enclosure where there is presence of combustible dusts

clouds with low particle size at a concentration above the lower explosible limit (between a few tens of g/m<sup>3</sup> and some kg/m<sup>3</sup>). The shredder can generate friction in the event of loss of rotation axes, in case of presence of foreigners and thus abnormally heat the fuel.

#### **8.2.4.2 Requirements and recommendations for design and construction**

The shredder shall be designed in such a way so that significant material and dust accumulations can be avoided.

The shredder shall be designed in such a way so that any area where material and dust can accumulate easily can be accessed by site operators.

The shredder shall be designed in such a way so that the appearance of ignition sources is minimized.

The peripheral speed of the shredder should not exceed 1 m/s.

A dust control system shall be considered in order to minimize the occurrence of combustible dust.

According to IEC 60079-0 for type of protection for electrical equipment and ISO 80079-36:2016 for type of protection for non-electrical equipment, ignition hazard assessment shall be done for electrical and non-electrical products that have their own potential ignition sources and are intended for use in explosive atmospheres:

- a) Hot surfaces (maximum surface temperature)
- b) Flames and hot gases
- c) Mechanically generated sparks (single impacts sparks) (property of metal, impact velocity and maximum potential impact energy); and hot surfaces generated by friction

#### **8.2.4.3 Requirements and recommendations for safe operation and maintenance**

The shredder shall be serviced and maintained according to the supplier's instructions.

Doors, hatches, etc. shall remain closed during operation and if the risk assessment indicates that opening of the hatch or door can generate a safety risk, it shall be equipped with an interlock solution, if not a specific tool or key is needed to open the door or hatch. Lock-out as safety measure shall be considered in the general risk management. The interlock solution shall prevent the shredder from starting when the safety circuit is open. In case the safety circuit opens during operation, the shredder shall stop automatically.

Any equipment located in dust hazardous areas covered by the area classification plan shall meet the technical requirements that apply for the current area.

Suitable process monitoring devices, prevention systems, protection systems and fire mitigating systems shall be installed, if required by the risk assessment (Examples: power consumption monitoring of motors, temperature sensors for motors and shaft bearings, ignition source detection system at inlet and outlet of the shredder).

The shredder shall be properly earthed.

### **8.3 Conveying**

#### **8.3.1 Chain conveyors**

##### **8.3.1.1 Safety risks**

Combustible dust is often present inside the chain conveyor, especially at material inlets and outlets. Chain conveyors can be enclosed, and an ignition of airborne dust inside the enclosure can result in a dust explosion. A chain conveyor often uses a large number of paddles and other mechanically moving

parts where friction heat can be generated. Examples of typical risks are friction heat due to metal-to-metal contact between paddles and conveyor walls, misalignments, worn out bearings and overheated electrical drive motors. If dust layers thicker than 5 mm are generated on surfaces during normal operation, more frequent cleaning intervals shall be introduced in locations where it can become exposed to heat, for example around drive equipment and electrical motors. Chain conveyors are sometimes located in underground tunnels or elevated above the ground and can be difficult to reach for rescue personnel.

Safety risks vary for different chain conveyors. Examples of typical things to consider during the risk assessment are conveyor type, construction and length, size and capacity, enclosure tightness, accessibility for maintenance personnel and for rescue service.

### 8.3.1.2 Requirements and recommendations for design and construction

The conveyor shall be designed in such a way so that significant material and dust accumulations can be avoided.

The conveyor shall be designed in such a way so that any area where material and dust can accumulate easily can be accessed by site operators.

The conveyor shall be designed in such a way so that the appearance of ignition sources is minimized.

A dust control system shall be considered in order to minimize the occurrence of combustible dust.

According to IEC 60079-0 for type of protection for electrical equipment and ISO 80079-36:2016 for type of protection for non-electrical equipment, ignition hazard assessment shall be done for electrical and non-electrical products that have their own potential ignition sources and are intended for use in explosive atmospheres:

- a) Hot surfaces (maximum surface temperature)
- b) Flames and hot gases
- c) Mechanically generated sparks (single impacts sparks) (property of metal, impact velocity and maximum potential impact energy); and hot surfaces generated by friction
- d) Sufficient explosion ventilation, away from operating personnel
- e) Robust structure to withstand the reduced explosion pressure
- f) Dust tight construction, if indoors
- g) Conveyor material selection according to handled material and environment to mitigate structural failures due to corrosion

### 8.3.1.3 Requirements and recommendations for safe operation and maintenance

The conveyor shall be serviced and maintained according to the supplier's instructions.

Any equipment located in dust hazardous areas covered by the area classification plan shall meet the technical requirements that apply for the current area.

Suitable process monitoring devices, prevention system, protection systems and fire mitigating systems shall be installed if required by the risk assessment (Examples: power consumption monitoring of motors, temperature sensors for motors and shaft bearings etc., ignition source detection system at conveyor inlets and outlets, explosion suppression system, venting).

The conveyor shall be properly earthed.

If the risk assessment indicates that open conveyor poses risk for use or maintenance, conveyor covers shall be closed while any equipment in line is in operation.

### 8.3.2 Screw conveyors

#### 8.3.2.1 Safety risks

Screw conveyors are sometimes used for conveying of processed SRF in short distances/heights.

When dry dust is present in the material stream it can become airborne inside the screw conveyor, especially at the inlets and outlets of the conveyor. An ignition of combustible airborne dust inside an enclosed screw conveyor can, under certain conditions, result in a dust explosion.

The peripheral speed of a screw can possibly be high enough to generate heat from friction, for example in the event of metal-to-metal contact between the screw and the screw conveyor housing.

Dust can collect at surfaces where it can become exposed to heat, for example around drive equipment and bearings.

#### 8.3.2.2 Requirements and recommendations for design and construction

The conveyor shall be designed in such a way so that significant material and dust accumulations can be avoided.

The conveyor shall be designed in such a way so that any area where material and dust can accumulate easily can be accessed by site operators.

The conveyor shall be designed in such a way so that the appearance of ignition sources is minimized.

A dust control system shall be considered in order to minimize the occurrence of combustible airborne dust.

#### 8.3.2.3 Requirements and recommendations for safe operation and maintenance

All conveyor covers, hatches, etc. shall be closed while the conveyor is in operation.

The conveyor shall be serviced and maintained according to the supplier's instructions. This includes periodical lubrication of bearings and gearboxes according to manufacturer's instructions. Visual inspection or temperature monitoring of bearings, gearboxes and electrical motors during normal operation shall be performed.

Any equipment located in dust hazardous areas covered by the area classification plan shall meet the technical requirements that apply for the current area.

Suitable process monitoring devices, prevention systems, protection systems and fire mitigating systems shall be installed, if required by the risk assessment (Examples: power consumption monitoring of the motor, temperature sensors for the motor, bearings etc., ignition source detection system at the conveyor inlets and outlets).

The conveyor shall be properly earthed.

### 8.3.3 Belt conveyors

#### 8.3.3.1 Safety risks

Belt conveyors are commonly used in SRF plants and can pose significant risks for fires. A belt conveyor that uses idlers to carry the belt often consists of a large number of rollers and other mechanically moving parts where friction heat can be generated. Examples of typical risks are friction heat from bearings, jammed rollers, belt misalignments and hot surfaces from overheated electrical drive motors. It is common that combustible material and dust collects in areas adjacent to the conveyor and on surfaces where it can become exposed to heat, for example around roller ends and motors. Belt conveyors are often located in underground tunnels or elevated above the ground, sometimes above material piles and buildings where they can be difficult to access for rescue personnel.

Safety risks varies for different belt conveyors. Examples of typical things to consider during the risk assessment are conveyor type and length, size and capacity, time of operation, antistatic/dissipative materials, open or enclosed, accessibility for maintenance personnel and for rescue service.

### 8.3.3.2 Requirements and recommendations for design and construction

The conveyor shall be designed in such a way so that the generation of dust is minimized e.g. by minimizing interparticle movement. The conveyor shall also be designed in such a way so that significant material and dust accumulations can be avoided, and so that any area where material and dust can accumulate easily can be accessed by site operators.

The conveyor shall be designed in such a way so that the appearance of ignition sources is minimized.

A dust control system shall be considered in order to minimize the occurrence of combustible dust.

The conveyor shall be prepared for the installation of suitable monitoring and safety equipment in accordance with the risk assessment.

### 8.3.3.3 Requirements and recommendations for safe operation and maintenance

The conveyor shall be serviced and maintained according to the supplier's instructions.

Any equipment located in dust hazardous areas covered by the area classification plan shall meet the technical requirements that apply for the current area. According to IEC 60079-0 for type of protection for electrical equipment and ISO 80079-36:2016 for type of protection for non-electrical equipment, ignition hazard assessment shall be done for electrical and non-electrical products that have their own potential ignition sources and are intended for use in explosive atmospheres:

- a) Hot surfaces (maximum surface temperature)
- b) Flames and hot gases
- c) Mechanically generated sparks (single impacts sparks (property of metal, impact velocity and maximum potential impact energy); and hot surfaces generated by friction

Suitable process monitoring devices, prevention systems, protection systems and fire mitigating systems shall be installed, in accordance with the risk assessment (Examples: belt misalignment monitoring, monitoring of slipping belt, anti-slip solution, power consumption monitoring of motors, temperature sensors for motors and shaft bearings, etc., ignition source detection system at conveyor inlets and outlets, explosion suppression system, venting).

The conveyor shall be properly earthed.

## 8.3.4 Bucket elevators

### 8.3.4.1 Safety risks

The environment inside a bucket elevator is often dusty, especially at the inlet and outlet where the material falls and where dust becomes airborne. An ignition source embedded in the material stream can ignite the airborne dust resulting in a dust explosion. Other sources of ignitions can be friction related, caused by for example misalignment of buckets or other mechanical problems. A fire in a bucket elevator can propagate quickly (chimney effect) and can be difficult to handle since an elevator is enclosed.

### 8.3.4.2 Requirements and recommendations for design and construction

The bucket elevator shall be designed in such a way so that significant material and dust accumulations can be avoided.

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The bucket elevator shall be designed in such a way so that any area where material and dust can accumulate easily can be accessed by site operators.

The bucket elevator shall be designed in such a way so that the appearance of ignition sources are minimized.

Depending on the construction, the handled material, the safety measures and the risk assessment, buckets can be constructed in materials not creating sparks in case of mechanical contact with construction walls of the elevator.

A dust control system connected to the bucket elevator in order to minimize the occurrence of combustible airborne dust shall be considered in the risk assessment.

- a) Examples of safety measures to limit ignition sources:
  - 1) Temperature sensors and rotation controllers of drums and of bearings
  - 2) Over-intensity detector for motor drum
  - 3) Over-intensity detector for motor
  - 4) Bucket deportation controllers
- b) Examples of explosion protection measures:
  - 1) Buckets made of non-flame propagation pre-treatment material (fire resistant)
  - 2) Explosion vents, explosion suppressors, etc.

### 8.3.4.3 Requirements and recommendations for safe operation and maintenance

The bucket elevator shall be serviced and maintained according to the supplier's instructions.

Any equipment located in dust hazardous areas covered by the area classification plan shall meet the technical requirements that apply for the current area. According to IEC 60079-0 for type of protection for electrical equipment and ISO 80079-36:2016 for type of protection for non-electrical equipment, ignition hazard assessment shall be done for electrical and non-electrical products that have their own potential ignition sources and are intended for use in explosive atmospheres:

- a) Hot surfaces (maximum surface temperature)
- b) Flames and hot gases
- c) Mechanically generated sparks (single impacts sparks) (property of metal, impact velocity and maximum potential impact energy); and hot surfaces generated by friction

Suitable process monitoring devices, prevention systems, protection systems and fire mitigating systems shall be installed, if required by the risk assessment.

NOTE Examples of monitoring devices and protection systems are: bucket misalignment monitoring system, ignition source detection system at inlet and outlet of the bucket elevator, explosion suppression system, venting, etc.

The bucket elevator shall be properly earthed.

### 8.3.5 Pneumatic conveying

#### 8.3.5.1 Safety risks

Pneumatic systems are sometimes used for bulk conveying of processed SRF material to storage, typically a silo. Additional protective measures should be considered when the risk assessment indicates that during operation, an ignition source created from a mechanical problem in a blower or

entering the pneumatic conveying system from previous process stages can ignite the airborne dust resulting in a dust explosion. Ignition sources in the pneumatic conveying system can travel with the air flow to the subsequent storage and when the air movement and turbulence decreases, an ignition can occur.

### 8.3.5.2 Requirements and recommendations for design and construction

The pneumatic conveying system shall be designed in such a way so that material and dust cannot accumulate inside.

The pneumatic conveying system shall be designed in such a way so that the appearance of ignition sources is minimized.

To avoid the propagation of explosion inside the pneumatic conveying, install safety barrier for non-propagation of explosion.

According to IEC 60079-0 for type of protection for electrical equipment and ISO 80079-36:2016 for type of protection for non-electrical equipment, ignition hazard assessment shall be done for electrical and non-electrical products that have their own potential ignition sources and are intended for use in explosive atmospheres:

- a) Hot surfaces (maximum surface temperature)
- b) Flames and hot gases
- c) Mechanically generated sparks (single impacts sparks) (property of metal, impact velocity and maximum potential impact energy); and hot surfaces generated by friction

### 8.3.5.3 Requirements and recommendations for safe operation and maintenance

All parts of the pneumatic conveying system, including blowers etc., shall be serviced and maintained according to the supplier's instructions.

Doors, hatches, etc. in the pneumatic conveying system shall remain closed during operation and, if the risk assessment indicates that opening of the hatch or dock can generate a safety risk, shall be equipped with an interlock solution. The interlock solution shall prevent any processing stage or part of the conveying system from starting when the safety circuit is open. In case the safety circuit opens during operation, the pneumatic conveying system and material handling process shall stop automatically. In such an event, a safe sequence of stopping the processes shall be assured.

Any equipment located in dust hazardous areas covered by the area classification plan shall meet the technical requirements that apply for the current area.

Suitable process monitoring devices, prevention systems, protection systems and fire mitigating systems shall be installed, shall be installed if required by the risk assessment (Examples: power consumption monitoring of motors, temperature sensors for motors and bearings etc., ignition source detection system in the pneumatic conveying system, venting for storage silos).

All parts of the pneumatic conveying system shall be properly earthed.

## 8.4 Storage solutions

### 8.4.1 General for all storage solutions

For the management and safe operation of stored materials, several plans and lists should be included:

- a) A storage plan;
- b) A response plan and contingency plan;
- c) Site plan;

- d) Check list to be used during a fire;
- e) Working plan/schedule;
- f) List for jour/standby; and a
- g) Run-off water investigation.

A storage plan shall be made. The storage plan shall describe how different material fractions should be handles and stored, to minimize the risk for fire.

The response plan is a complement to the storage plan and shall give the fire and rescue service a clear picture of the facility, combined with detailed information on different storage areas. Information on available extinguishing material shall also be included.

A site plan should include position of hydrants, shutoff valves, evacuation routes, entrances/exits, access to water for fire trucks.

The checklist should at least include:

- 1) Alarm the fire and rescue services
- 2) Contact the delegated management function
- 3) Contact relevant persons on the jour list
- 4) Important acute actions, e.g. close wastewater valves
- 5) Appoint person to meet the fire and rescue service at the entrance
- 6) Stop/redirect incoming deliveries of waste
- 7) Read the water consumption meter
- 8) Start the documentation of the course of events, actions, contacts, decisions etc.
- 9) Contact regulatory authority
- 10) Contact the insurance company
- 11) Prepare information to the public, media etc. (in consultation with the incident commander from the fire and rescue services)

A working plan/schedule should be established to ensure the possibility for changing personnel during a fire lasting for a long time period.

A jour list is should be available, both internally and for entrepreneurs. The list shall be accompanied with an updated phone list and routines for who has what responsibility and who communicates with whom.

Detection of fires in stored waste can be difficult and a combination of both different technical solutions (e.g. cameras, IR cameras and temperature measurements) and personnel patrolling should be considered.

A run-off water investigation shall be done and should include the handling of the run-off water, requirements and routines for sampling and testing of water and its content.

General requirements and recommendations for fire protection can be found in [9.1](#).

## 8.4.2 Storage of mechanically densified SRF

### 8.4.2.1 Safety risks

There is a risk of self-heating, especially when the material is exposed to moisture. These processes are also connected with emissions of gases, which can be hazardous to health and explosive.

### 8.4.2.2 Requirements and recommendations for design and construction

Storage sites for densified SRF are required to install receiving area which prevents the densified SRF from getting wet regardless the type of storage. If shown by the risk assessment to be needed, the following measures shall be taken:

- a) to enable well ventilation of enclosed storage area always
- b) to install the fire protection equipment such as sprinkler and extinguisher

It should be made possible to monitor temperature and moisture.

### 8.4.2.3 Requirements and recommendations for safe operation and maintenance

Densified SRF that is going to be stored should have a limited moisture content (preferably less than 10 % (by weight)). Both the moisture content and the temperature shall be monitored and recorded.

When the densified SRF is unloaded for storage, it shall be checked so that it is not remarkably powdered (much fines). When unloading, also the temperature and moisture content shall be monitored.

Measures should be taken to avoid heat accumulation.

Measures shall be taken to prevent the densified SRF from getting wet.

## 8.4.3 Open storage in piles

### 8.4.3.1 Safety risks

A common way of storage is in piles, often sorted in different material fractions.

There is a risk for self-heating leading to self-ignition and the risk for fire increases with the size of the store. Furthermore, a large store makes it more difficult for the fire and rescue services to be able to extinguish a fire in the pile.

There is also a risk for transferring ignition sources, e.g. hot or glowing material, from other parts of the handling process, or even creating them in the handling process, e.g. by vehicles.

The distance between the piles shall be enough to both minimize the risk for fire spread to other piles or to buildings, and to make it possible for the fire and rescue service to have space to perform their work. To make it practically possible to extinguish a fire in a large pile, a minimum distance of 10 to 15 m between piles is recommended.

### 8.4.3.2 Requirements and recommendations for design and construction

Established and secured water supply is essential.

Fire hydrants should be distributed and placed so that water is available (pressure and flow rate). For the position of the hydrants, consideration should be taken both to the storage plan and the response plan. In this it is important to minimize the risk for complicated lay-out of hoses and the risk for hindering the access of vehicles, e.g. fire trucks and front loaders.

If the run-off water cannot be collected in an environmentally safe way, other materials for extinguishment can be used, e.g. soil or mud. Then such extinguishment shall be planned for and the availability of such material shall be secured.

Extra surface space shall be available. This is needed during a fire for several reasons:

- a) to remove material to limit the potential size of a fire
- b) move material to reach and get access to the seat of the fire
- c) to remove glowing/burning material to be able to more efficiently extinguish it

Good lighting should be available to avoid working environment issues (e.g. tripping and incidents with vehicles) but is also needed for detection of smoke from piles and for efficient fire extinguishment.

### 8.4.3.3 Requirements and recommendations for safe operation and maintenance

The facility owner shall work continuously and systematically to achieve fire safety.

Routines for operation and maintenance shall be established.

A scheme for maintenance of machines and equipment shall be established.

## 8.4.4 Bale storing

### 8.4.4.1 Safety risks

A bale of SRF is a compact pack produced by compression of the fluffy SRF in order to enable easy handling, transportation, and storage. Self-ignition and fire can occur during storage as a result of the self-heating of the baled SRF depending on composition, particle size, density, storage size, storage time, storage temperature and condition of the bales.

Other safety related issues concern the handling of the bales. It includes falling from a bale stack or being hit by falling or dropped bales. There is also a risk of tripping or falling caused by loose bale strings.

It should also be taken into consideration in the risk assessment that extinguishment of stacks of bales can be very difficult, especially if they contain high plastic content.

### 8.4.4.2 Requirements and recommendations for design and construction

The ground planned to be used for stacks of bales shall be firm, dry, level and freely draining. The space should be open and well ventilated.

Enough space should be provided, both to allow vehicles adequate room for handling the bales safely, and to secure space for the fire and rescue service in case of fire.

### 8.4.4.3 Requirements and recommendations for safe operation and maintenance

The personnel involved in stacking bales shall know how to stack bales safely.

The risks of working at heights, when stacking and de-stacking bales, shall be included in the risk assessment.

Only bales of sound construction should be used, especially for the edges. The bales shall be stacked so that lower bales are stabilized by placing upper bales in an overlapping and interlocking way, alternating layer by layer.

All loose strings shall be removed to avoid tripping hazards.

Large parallelepiped bales can be very heavy and can be a life-threatening hazard if there is a risk of falling bales hitting a person. The bales should not be stacked higher than 1,5 times the width of the base. The stacks shall also not be higher than that the bales in the stack can be handled in a safe way.

Small bales should be interlocked closely, with alternate layers rotated and slightly offset so that each bale is locked in.

Extra care shall be taken when stacking and de-stacking wrapped bales, as the plastic wrapping can make the bales slippery.

Check the stack of bales regularly to make sure that the stack is still in good condition and that there is no danger of collapse.

The surface temperature of the stacks should be monitored regularly.

De-stack the bales in the reverse order of stacking. The bales shall not be removed from the bottom or the middle of the stack, as this can cause the stack to become unstable. Overhanging bales shall never be left unsupported.

## 8.4.5 Silo storage

### 8.4.5.1 Safety risks

The silo is the enclosed cylindrical structure to store SRF internally and can prevent SRF from getting wet in the rain. Silos for storing SRF are typically made of steel, concrete or a combination of the two. Self-ignition and fire can occur in the silo as a result of the self-heating of SRF lead by a complex mechanism related to production processes, density, composition and particle size of SRFs, construction of silo (i.e. ratio of height to diameter), storage period. As a result of the self-heating processes, CO can be produced, which can be hazardous to health and lead to an explosive environment. The self-heating can be caused by exothermal reactions of SRFs such as oxidation reactions, physical processes and biodegradation reactions. With enough moisture content, SRF containing high amounts of organic fractions can generate heat due to biodegradation.

In case of integrated moulding/drying process: without cooling of densified SRF adequately, accumulated SRF in the silo might start self-heating. The risk for self-heating of SRF in most cases increase with storage time. The self-heating of SRF depends on different weather condition such as absolute temperature, temperature variation, difference in outside and inside temperature and moisture.

### 8.4.5.2 Requirements and recommendations for design and construction

Depending on the input wastes, the SRF-production process and the type of SRF storage capacity shall be well chosen. The capacity of storage in silo shall not be oversized in order not to accumulate heat in the pile of SRF.

Be aware of the importance of ratio between height and diameter. This should not be too high. This can give problems for the reclaiming of the material, e.g. bridging. It can also lead to compression of the material.

The structure of the silo shall be sufficiently robust.

Based on the risk assessment the following sensors shall be considered: temperature sensors, CO detectors and heat detectors in the head space and temperature sensors in the bulk. IR measurements can be used to measure the surface temperature.

Depending on the result of the risk assessment, extinguishers, sprinklers or inert gas injection such as nitrogen gas shall be installed. For dry, densified material there can be a risk of swelling. Measures should be taken to prevent the SRF from being wet. Furthermore, the load of too much added water can make the silo collapse. Therefore, gas injection should be the first choice. It should be made possible to

unload the material from the silo in a controlled and safe way. Appropriate measures should be taken to limit heat accumulation.

Measures should be taken to limit the risk for an explosion, e.g. venting, suppression and inerting.

#### 8.4.5.3 Requirements and recommendations for safe operation and maintenance

The areas shall be secured for discharging all stored SRF out of silo following a fire accident.

Prolonged storage time increases the risk for self-heating. The operations manual should include information on how long a material can be stored, based on experience, measurements of material characteristics and risk assessment.

Based on the risk assessment, the following measures shall be taken if considered relevant or necessary:

- a) monitoring temperatures and concentration of carbon monoxide of ambient of storage site continuously
- b) confirming that measured temperatures and concentrations are within appropriate range for operation of storage
- c) avoiding moisturization of stored densified SRF
- d) periodically cleaning up storage site
- e) taking measures to avoid heat generation by oxidation of SRF and to avoid heat accumulation. (e.g. continuous filling of inert gas to storage, periodical replacement of SRF)
- f) continuously monitoring temperatures when SRF is loaded to the store
- g) monitoring temperatures and concentrations of CO of storage site continuously (other parameters such as carbon dioxide, total hydrocarbon, or moisture are optional)
- h) confirming that measured temperatures and concentrations are within appropriate range for operation of storage

#### 8.4.6 Bunker and box storage

##### 8.4.6.1 Safety risks

A bunker is a construction with four walls and can be covered. A box is a construction with three walls and can be covered. A cover can prevent SRF from getting wet in the rain. Self-ignition and fire can be caused in the bunker as a result of the self-heating of SRF caused by a complex mechanism related to production processes, density, composition and particle size of SRFs, size of bunker/boxes, storage period, ambient temperature. The self-heating can be caused by exothermal reactions of SRFs such as oxidation reactions, physical processes and biodegradation reactions. With enough moisture content, SRF containing high amounts of organic fractions can generate heat due to biodegradation.

In case of integrated moulding/drying process: without cooling of mechanically densified SRF adequately, accumulated SRF in the bunker can start self-heating. SRF stored for prolonged period can have a higher possibility to be self-heated.

Bunkers that not have the possibilities for first in – first out principle shall in the risk assessment include the risk for waste being left for a long time at the bottom of the bunker and the potential risk for self-heating, and the possible need for regular cleaning of the bunker.

##### 8.4.6.2 Requirements and recommendations for design and construction

Depending on the input wastes, the SRF-production process and the type of SRF storage capacity should be well chosen. A large amount of waste increases the risk for self-heating. This depends also on e.g. the

type of material and the moisture content and the handling and size limit should be part of the risk assessment. If shown to be needed in the risk assessment, the following measures shall be taken:

- a) Consideration of additional measures if the crane cannot reach all the material leaving some material for a prolonged time
- b) Ensuring that the bunker or box shall be durable to withstand foreseeable use, e.g. accidental impact of a front-loader
- c) Ensuring a roof is used where the contents of the bunker or box are susceptible to moisture accumulation due to precipitation
- d) Ensuring that the bunker or box is prepared for the installation of suitable monitoring and safety equipment
- e) Installation of an extinguishing system e.g. fixed water spray systems (open heads) or water cannon. It is important to be able remove material to reach the site of the fire. There shall be a plan for handling of the run-off water.
- f) Taking measures to limit the risk for an explosion, e.g. venting, suppression and inerting.

The risk for people falling into the bunker or box shall be considered. Example of measure could be railings. Means for self-rescue out of the bunker or box shall be installed, e.g. a ladder.

Barriers preventing vehicles from accidentally entering the bunker or box shall be installed.

#### 8.4.6.3 Requirements and recommendations for safe operation and maintenance

SRF shall be stored so the height does not exceed the design height. The compression of waste can increase the risk for self-heating.

The effect of prolonged storage time of SRF in bunker or box being stocked for prolonged periods shall be included in the risk assessment. In this case the internal temperature of SRF in bunkers or boxes shall be monitored on regular basis, e.g. with a spear. If bunker indoor, monitor the environment (including CO) and/or the surface temperature with IR, continuously.

Based on a risk assessment, the following measures shall be taken if considered relevant or necessary:

- a) Regularly measuring the temperature of the SRF in box or bunker at randomly selected positions
- b) Periodically cleaning storage site
- c) Turning SRF around, or any other measures to avoid the unusual rise of temperature
- d) Monitoring temperatures of SRF surface and ambient of storage site continuously
- e) Confirming that measured temperature is within appropriate range for operation of storage. If storage sites for SRF are ventilated enough, continuous monitoring and recording is not mandatory, due to lower risk of heat accumulation.

#### 8.4.7 Hoppers

##### 8.4.7.1 Safety risks

Storage of SRF in the hopper can result in self-heating with the generation of fire risks and the formation of explosive atmosphere (air/CO).

Storage of fuel in the semi-confined hopper can result in self-heating with a risk of fire and an explosive atmosphere (air/CO).

In the case of prolonged residence time of the wet fuel, fermentation can occur and raise the temperature to 70 °C, possibly activating the self-heating. The runaway of this self-heating during abnormally

prolonged storage of the fuel (normally, the residence time is less than one day, which can be extended during a production stop) can produce CO and thus form an explosive air/CO mixture.

The sources of ignition can be due to the introduction of hot particles (particles from the exhaust gases of the truck, projection of particles from welding work nearby) or to the introduction of a foreign object that could ignite the fuel (work by hot spot, external source) or incandescent particles, resulting from self-ignited fuel during extinguishing or emptying the hopper.

#### 8.4.7.2 Requirements and recommendations for design and construction

Depending on the input wastes, the SRF-production process and the type of SRF storage capacity should be chosen appropriately. A large amount of waste increases the risk for self-heating. This also depends on, for example, the type of material and the moisture content, and the handling and size limit should be part of the risk assessment. If the crane cannot reach all the material leaving some material for a prolonged time, this should also be considered in the risk assessment. Other requirements include:

- a) Ensuring that the hopper is durable to withstand foreseeable use, e.g. accidental impact of a front-loader
- b) Ensuring that a roof is used in cases where the contents of the hopper are susceptible to moisture accumulation due to precipitation
- c) Ensuring that the hopper is prepared for the installation of suitable monitoring and safety equipment based on the risk assessment
- d) Determining the number and positions of, for example, sensors determined in the risk assessment
- e) Installation of a fixed water spray system (open heads). It is important to be able to remove material to reach the site of the fire. There shall be a plan for handling of the run-off water.

The risk for people falling into the hopper shall be considered. Example of measure could be railings. Means for self-rescue out of the hopper shall be installed, e.g. a ladder.

Barriers preventing vehicles from accidentally entering the hopper shall be installed.

#### 8.4.7.3 Requirements and recommendations for safe operation and maintenance

SRF shall be stored so the height does not exceed the design height.

The effect of prolonged storage time of SRF in a hopper shall be included in the risk assessment. In this case the internal temperature of SRF in hoppers shall be monitored on regular basis, e.g. with a spear. Based on the risk assessment the following sensors shall be considered: temperature sensors, monitoring of surface temperature and flame detectors.

### 8.5 Separation and screening

#### 8.5.1 Screening

##### 8.5.1.1 Safety risks of screening

Screening of material can be carried out in different ways. Examples of different screen types are disc screens, trommel screens and vibrating deck screens. Common for most screening methods is that a significant number of fines and dust is created and dispersed in connection with the screening process. If the screening process is generating a significant amount of airborne dust, utilisation of dust control unit is recommended to minimize dusting.

When a disc screen is used, the material is moved forward on top of rotating disc shafts. Material pieces that are smaller than the spacing between the discs fall through and are separated from the bigger material pieces which are moved on top of the discs to the end of the screen. A disc screen consists of several mechanical rotating shafts, often with metal discs. Friction related problems can occur in the