



BSI Standards Publication

Solid biofuels – Safe handling and storage of solid biofuel pellets in commercial and industrial applications

National foreword

This British Standard is the UK implementation of EN ISO 20024:2020. It is identical to [ISO 20024:2020](#).

The UK participation in its preparation was entrusted to Technical Committee PTI/17, Solid biofuels.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

**Solid biofuels - Safe handling and storage of solid
biofuel pellets in commercial and industrial applications
(ISO 20024:2020)**

Biocombustibles solides - Manipulation et
stockage en toute sécurité des granulés de
biocombustibles solides dans des applications
commerciales et industrielles (ISO 20024:2020)

Biogene Festbrennstoffe - Sicherer Umgang
und Lagerung von Pellets aus biogenen
Festbrennstoffen in kommerziellen und
industriellen Anwendungen (ISO 20024:2020)

This European Standard was approved by CEN on 9 February 2020.

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EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

This document (EN ISO 20024:2020) has been prepared by Technical Committee ISO/TC 238 "Solid biofuels" in collaboration with Technical Committee CEN/TC 335 "Solid biofuels" the secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2020, and conflicting national standards shall be withdrawn at the latest by September 2020.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of [ISO 20024:2020](#) has been approved by CEN as EN ISO 20024:2020 without any modification.

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Foreword

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

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

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

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

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

This document was prepared by Technical Committee ISO/TC 238, *Solid biofuels*.

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

Introduction

There is a continuous global growth in production, storage, handling, bulk transport and use of solid biofuels especially in the form of pelletized biofuels.

The handling and storage of solid biofuels and their physical characteristics can lead to a risk for fire and/or explosion, but also health risks, for example intoxication due to exposure to carbon monoxide (CO), asphyxiation due to oxygen depletion, and allergic reactions.

There is a risk of injury or fatality associated with pellet storage so the implementation of safety measures is important. The possibility of fire and explosion incidents is a clear indicator that safety is to be prioritized, first of all for human safety but also because interruptions in energy supply will have significant consequences. The market confidence in solid biofuels as a reliable energy source will be jeopardized, and financial losses due to business interruptions could occur. Difficulty to obtain insurance coverage will also increase.

This document provides support, advice and guidance to facility owners, logistics providers, equipment suppliers/manufacturers, consultants, authorities and insurance providers to assess and mitigate risk when handling and storing solid biofuel pellets. General guidance is provided for personnel safety protection and personal precautions in accordance with generally accepted work safety requirements. As part of the determination and assessment of risks for solid biofuels, applicable quality standards and related test methods are discussed and recommendations for additional methodologies are indicated. As made of living materials, solid biofuels are subject to degradation such as ageing and moisture contamination causing variability in reactivity which requires margins in risks assessments. One shipment of solid biofuels may have substantially different physical and chemical characteristics in terms of self-heating and off-gassing than another, and therefore diligent monitoring, frequent testing and house-keeping are recommended.

Solid biofuels – Safe handling and storage of solid biofuel pellets in commercial and industrial applications

1 Scope

This document provides principles and requirements for safe handling and storage of solid biofuels pellets in commercial and industrial applications. This document is using a risk-based approach to determine what safety measures should be considered.

Facilities with a storage capacity <100 t are covered by [ISO 20023](#). Generally, for end-user facilities with a storage capacity of <1 000 t, [ISO 20023](#) could also be applicable if storage principle and facility complexity is in-line with the objectives of [ISO 20023](#).

This document covers the handling and storage process of pellets in the following applications:

- at a pellet production plant from the outlet of the cooler unit until loaded for transportation;
- at a commercial distributor from the receiving station until loaded for transportation; and
- at an industrial end-user from the receiving station until fed into the fuel preparation or combustion process.

Although unloading and loading of e.g. vessels, trains or trucks are included in the operational envelopes defined above, the safety aspect of the transportation itself is beyond the scope of this document.

This document also gives specific guidance on detection and suppression systems and preparatory measures to enable safe and efficient firefighting operations. Guidance on the management of fire and explosion incidents is also specified.

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*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 General terms

3.1.1

biofuel pellet

biofuel made with or without additives in the form of cubiform, polyhedral, polyhydric or cylindrical units with a diameter up to 25 mm, produced by compressing biomass

Note 1 to entry: Usually the biomass has been milled before densification.

Note 2 to entry: See also non-woody pellet and wood pellet.

[SOURCE: ISO 16559:2014, 4.31]

3.1.2

combustible dust

finely divided solid particles, 500 µm or less in nominal size, which may form explosive mixtures with air at standard atmospheric pressure and temperatures

Note 1 to entry: This includes dust and grit as defined in [ISO 4225](#).

Note 2 to entry: The term 'solid particles' is intended to address particles in the solid phase but does not preclude a hollow particle.

[SOURCE: ISO/IEC 80079-20-2:2016, 3.1]

3.1.3

combustible flyings

solid particles, including fibres, where one dimension is greater than 500 µm in nominal size, which may form an explosive mixture with air at standard atmospheric pressure and temperature

Note 1 to entry: The ratio of length to width is 3 or more.

[SOURCE: ISO/IEC 80079-20-2:2016, 3.2, modified — Note 2 deleted.]

3.1.4

fines

small sized particles in fuel below a certain pre-defined size, here less than 3,15 mm

[SOURCE: ISO 16559:2014, 4.90, modified — "usually" replaced by "here" to indicate exact limit.]

3.1.5

ignition source

source of energy that initiates combustion

[SOURCE: ISO 13943:2008, 4.189]

3.1.6

product safety data sheet

specification sheet defining physical aspects, characteristics and health and safety data for a product

3.1.7

self-heating

exothermic reaction within a material resulting in a rise in temperature in the material

[SOURCE: ISO 4880:1997, 55]

3.1.8

self-ignition

ignition resulting from *self-heating* ([3.1.7](#))

[SOURCE: ISO 4880:1997, 56]

3.1.9

smouldering

slow combustion of a material without light being visible and generally evidenced by an increase in temperature and/or by smoke

[SOURCE: ISO 4880:1997, 58]

3.1.10

wood pellet

biofuel made from woody biomass with or without additives in the form of cubiform, polyhedral, polyhydric or cylindrical units, random length and typically 3,15 mm to 40 mm, a diameter up to 25 mm and with broken ends

Note 1 to entry: The raw material for wood pellets is woody biomass in accordance with Table 1 of [ISO 17225-1](#). Pellets are usually manufactured in a die, with total moisture content usually less than 10 % of their mass wet basis.

Note 2 to entry: The woody biomass used as feedstock for pellet making is milled to size in accordance with customer specification. Determination of the particle size distribution of the constituent of pellets is done by [ISO 17830](#).

[SOURCE: ISO 16559:2014, 4.228]

3.2 Risk management

3.2.1

accident

incident resulting in fatality, disease, injury or other damage

[SOURCE: ISO 21101:2014, 3.25]

3.2.2

emergency

serious situation requiring immediate action

[SOURCE: ISO/TR 21102:2013, 2.8]

3.2.3

fail-safe

term applied to equipment or a system so designed that, in the event of failure or malfunction of any part of the system, devices are automatically activated to stabilize or secure the safety of the operation

[SOURCE: ISO 13628-7:2005, 3.1.49]

3.2.4

failure mode and effect analysis

FMEA

analytically derived identification of the conceivable equipment failure modes and the potential adverse effects of those modes on the system and mission

Note 1 to entry: It is primarily used as a design tool for review of critical components.

[SOURCE: ISO/TS 16901:2015, 3.11]

3.2.5

harm

injury or damage to the health of people or animals or damage to property or the environment

[SOURCE: ISO/IEC Guide 51:2014, 3.1, modified — "or animals" added.]

3.2.6

hazard

potential source of *harm* ([3.2.5](#))

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.2.7

hazardous event

event that can cause *harm* ([3.2.5](#))

[SOURCE: ISO/IEC Guide 51:2014, 3.3]

3.2.8

hazardous situation

circumstance in which people or animals, property or the environment is/are exposed to one or more *hazards* ([3.2.6](#))

[SOURCE: ISO/IEC Guide 51:2014, 3.4, modified — "or animals" added.]

3.2.9

hazard and operability study

HAZOP

systematic approach by an interdisciplinary team to identify *hazards* ([3.2.6](#)) and operability problems occurring as a result of deviations from the intended range of process conditions

Note 1 to entry: All four steps are in place and recorded to manage a hazard completely.

[SOURCE: ISO/TS 16901:2015, 3.16]

3.2.10

incident

event or occurrence, which can, but does not necessarily, create a *risk* ([3.2.14](#)) of *harm* ([3.2.5](#)), including possible risks due to shearing, crushing, falling, impact, trapping, fire, electric shock, exposure to weather etc.

[SOURCE: ISO/TS 25740-1:2011, 3.13]

3.2.11

inherently safe design

measures taken to eliminate *hazards* ([3.2.6](#)) and/or to reduce *risks* ([3.2.14](#)) by changing the design or operating characteristics of the product or system

[SOURCE: ISO/IEC Guide 51:2014, 3.5]

3.2.12

intended use

use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage

[SOURCE: ISO/IEC Guide 51:2014, 3.6]

3.2.13

reasonably foreseeable misuse

use of a product or system in a way not intended by the supplier, but which can result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified — Note 1 to entry and Note 2 to entry has been deleted.]

3.2.14

risk

combination of the probability of occurrence of *harm* ([3.2.5](#)) 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]

3.2.15

risk analysis

systematic use of available information to identify *hazards* (3.2.6) and to estimate the *risk* (3.2.14)

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

3.2.16

risk assessment

overall process comprising a *risk analysis* (3.2.15) and a *risk evaluation* (3.2.20)

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

3.2.17

risk control

process of decision-making for managing and/or reducing *risk* (3.2.14); its implementation, enforcement and re-evaluation from time to time, using the results of *risk assessment* (3.2.16) as one input

3.2.18

risk criteria

terms of reference against which the significance of a *risk* (3.2.14) 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]

3.2.19

risk estimation

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

[SOURCE: ISO 13824:2009, 3.15]

3.2.20

risk evaluation

procedure based on the *risk analysis* (3.2.15) to determine whether tolerable *risk* (3.2.14) has been exceeded

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

3.2.21

risk management

coordinated activities to direct and control an organization with regard to *risk* (3.2.14)

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

3.2.22

risk reduction measure

protective measure

action or means to eliminate *hazards* (3.2.6) or reduce *risks* (3.2.14)

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

3.2.23

residual risk

risks (3.2.14) remaining after *risk reduction measures* (3.2.22) have been implemented

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

3.2.24

safety

freedom from *risk* ([3.2.14](#)) which is not tolerable

[SOURCE: ISO/IEC Guide 51:2014, 3.14]

3.2.25

significant hazard

hazard ([3.2.6](#)) which has been identified and which requires specific action to eliminate or to reduce *risk* ([3.2.14](#)) according to the *risk management* ([3.2.21](#))

3.2.26

tolerable risk

level of *risk* ([3.2.14](#)) 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 Storage, handling and operation

3.3.1

mechanical bridging

process of forming stable bridges in a bulk storage of solids where large particles mechanically interlock and form an obstruction, preventing the discharging of the material

Note 1 to entry: Bridging is also called arching.

3.3.2

cohesive bridging

process of forming stable bridges in a bulk storage of solids when particles bond together due to effects of moisture, fines concentration, particle shape, temperature, etc. and form an obstruction, preventing the discharging of the material

Note 1 to entry: Bridging is also called arching.

3.3.3

bulk material

amount of material within which component parts are not initially distinguishable on the macroscopic level

[SOURCE: ISO 11648-1:2003, 3.1.1]

3.3.4

bunker

vessel for the storage of materials, with the main section having vertical walls and the lowermost portion usually constructed in the form of a hopper

Note 1 to entry: Large bunkers are often used at power plants for short term fuel storage before the combustion furnace.

[SOURCE: ISO 1213-1:1993, 9.1.6, modified — "bin" deleted, Note 1 to entry added.]

3.3.5

bunker floor

steel construction above the *bunker* ([3.3.4](#)) to support the conveyor system and a steel grating to allow entrance for maintenance

3.3.6

bunker covering

construction covering the *bunker floor* (3.3.5) to aid the *bunker* (3.3.4) ventilation system to create an airflow from the *bunker house* (3.3.7) into the bunker

Note 1 to entry: The bunker covering will reduce dust dispersion into the bunker house and the environment during filling but also reduce the risk of foreign objects falling into the bunker during e.g. maintenance work inside the bunker house.

3.3.7

bunker house

building construction covering the *bunker* (3.3.4), the bunker floor *bunker floor* (3.3.5) and the conveyor system, protecting it against precipitation and preventing dispersion of dust to the environment

3.3.8

core flow

material flow that is confined to a column immediately surrounding the vertical axis through the outlet and in which the material on the surface slides in towards the downward-moving column

[SOURCE: ISO 1213-1:1993, 10.1.15]

3.3.9

funnel flow

flow that occurs during gravity storage when bulk material sloughs off the surface of the material and discharges through a vertical channel which forms within the material in the bin whenever material is drawn from the outlet

Note 1 to entry: Material adjacent to the bin walls remains stationary.

Note 2 to entry: Core flow is sometimes used instead of funnel flow.

[SOURCE: ISO 15117-1:2004, 3.15, modified — Note 2 to entry included.]

3.3.10

hopper

container for a loose bulk material such as grain, rock, or rubbish, typically one that tapers downward and is able to discharge its contents at the bottom

3.3.11

maintenance manual

document detailing the disciplines and procedures to be followed to maintain an item of equipment, complete machine or system in good working order

Note 1 to entry: A maintenance manual will detail periodic checks and replacement of parts, type of lubricant and protective processes and the period of time between each check. It will include instructions on how to locate faults, carry out repairs and the replacement of components. It may also include a detailed list of the components which go together to make the complete unit, and their reference numbers and quantity required to assist purchase of replacements as required.

[SOURCE: ISO/TR 11065:1992, 385, modified — Part of definition moved as Note 1 to entry.]

3.3.12

mass flow

flow in which all the contents of a bin, silo or bunker are in motion, so that there is substantially uniform velocity of flow across the whole cross-section of the material

[SOURCE: ISO 1213-1:1993, 10.1.14, modified — "(in bunkers)" deleted in heading; bin, silo or added.]

3.3.13

operation manual

collection of documents that provide the information necessary to familiarize the personnel with the operation and maintenance of a facility, system or item of equipment

[SOURCE: ISO 26870:2009, 3.11, modified — and maintenance deleted in heading.]

3.3.14

personal protection 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]

3.3.15

powered mobile handling equipment

equipment provided with some form of self-propulsion ordinarily under the direct control of an operator

Note 1 to entry: Powered mobile handling equipment includes, earthmoving machinery (e.g. rollers, graders, scrapers, skid steer loader), wheel loaders and wheel loader equipment, trucks, excavators, mobile cranes, hoists, elevating work platforms, concrete placement booms, reach stackers and forklifts, and trains and wagons.

3.3.16

ratholing

discharging of material taking place only in a flow channel formed above the outlet of a silo, *bunker* ([3.3.4](#)) or *hopper* ([3.3.10](#))

Note 1 to entry: The reason for ratholing is the material being cohesive leading to the material outside the formed channel will not flow into it, stopping the outflow once the central flow channel is emptied.

Note 2 to entry: Ratholing is also called piping.

Note 3 to entry: See also definition on funnel flow, [3.3.9](#).

3.3.17

SCBA

self contained breathing apparatus

generic term for respiratory protective devices, designed for the wearer to carry a source of supplying air, oxygen or breathable gas to be consumed in breathing

[SOURCE: ISO 16972:2010, A.267]

3.3.18

screw conveyor

auger conveyor

mechanism that uses a rotating helical screw blade, usually within a tube, to move liquid or granular materials

3.3.19

silo

structure for the storage of a volume of *bulk material* ([3.3.3](#))

[SOURCE: ISO 6707-1:2014, 3.2.20, modified — “loose” material has been replaced by “bulk” material, “large” has been deleted.]

3.3.20

warehouse

flat storage

A-frame storage

building or structure for storage, such as garages, storage buildings and freight depots

3.4 Extinguishing media, extinguishing systems and detection

3.4.1

Compressed Air Foam

CAF

homogenous foam produced by the combination of water, foam concentrate, and air or nitrogen under pressure

[SOURCE: ISO 7076-5:2014, 3.5]

3.4.2

Compressed Air Foam System

CAFS

system in which a foam concentrate and air are continuously added under pressure to the water being discharged from a fire-fighting pump

[SOURCE: ISO 7076-6:2016, 3.5]

3.4.3

foam expansion ratio

ratio of the volume of foam to the volume of the foam solution from which it was made

[SOURCE: ISO 7076-2:2012, 3.4]

3.4.4

gas detection system

system which monitors spaces for the presence and concentration of relevant gasses (e.g. flammable and toxic gases, oxygen concentration) and initiates alarm and control actions at predetermined concentrations

Note 1 to entry: There are also personal mobile gas monitoring devices that could be applicable ([G.2.5](#)).

[SOURCE: ISO 10418:2003, 3.1.20, modified — "on an offshore installation" deleted, and "toxic" included, Note 1 to entry added.]

3.4.5

high expansion foam

foam which has an expansion greater than 200

[SOURCE: ISO 7076-4:2016, 3.1]

3.4.6

ignition source detection system

system consisting of one or more devices capable of detecting the presence of active ignition sources or warm or overheated material

Note 1 to entry: Highly sensitive detector to detect sparks, hot or glowing particles in e.g. pneumatic and mechanical conveying systems.

4 Guidance on how to use this document

The purpose of this document is to help designers, purchasers of handling systems, and operators along the pellet supply chains to ensure that safety hazards and adverse effects to the quality of the pellets that can influence safety are avoided. It uses a risk-based approach to determine what safety measures should be considered.

The requirements stated in this document as mandatory are additional wood pellet specific requirements that shall be included in the company's existing safety management system.

Users of this document are responsible for identifying local regulations.

The supply chain includes handling and storage at the pellet producers, commercial distributors/storages and end-users, which could be large scale industrial applications (e.g. power plants), medium size boilers and distributors/traders delivering to small scale boilers for private use.

The characteristics of pellets might vary depending on used raw material and production process. Information about a specific pellet brand, with respect to quality, safety and health aspects during handling and storage, is found in quality specifications and safety data sheets published by the suppliers.

The document is focused both on design and operation. [Clause 5](#) outlines the general risk management process to be applied to identify possible risks and to assess the need for risk reduction/risk control measures for each specific facility. [Clauses 6 to 11](#) provides further detailed information on specific risks and hazards, safe operation and maintenance and specific safety measures for different types of handling and storage that determine what safety measures shall be considered for each individual facility.

Storage capacity is not the only parameter on which to decide which safety measures are necessary. The pellet yearly turnover and the complexity of the on-site handling will most likely be equally or more important than storage capacity. This will include the number, type and size of conveying systems as well as number, type and size of storage units, etc.

The overall risk management process is therefore essential to ensure that all safety measures applicable to each individual facility configuration and operational as well as maintenance requirements are satisfied.

Further descriptions of the solid biofuel pellets supply chain and general safety issues for unit operations are described in [Annex A](#).

An example of a risk assessment in a commercial medium size wood pellet store is presented in [Annex H](#).

5 Risk management

5.1 General

To improve the safety during handling and storage of solid biofuel pellets, both the design and operation shall be considered. Safety is the responsibility of everyone directly or indirectly involved in operation and maintenance of a facility, here limited to the scope of this document.

For identified hazards the following hierarchy of priority should be followed as a minimum:

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

As the top item is most effective, this process shall be addressed both during design, operation and maintenance and much can be achieved already during design.

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

[Figure 1](#) illustrates the steps to follow when assessing the risk and how it relates to risk management.

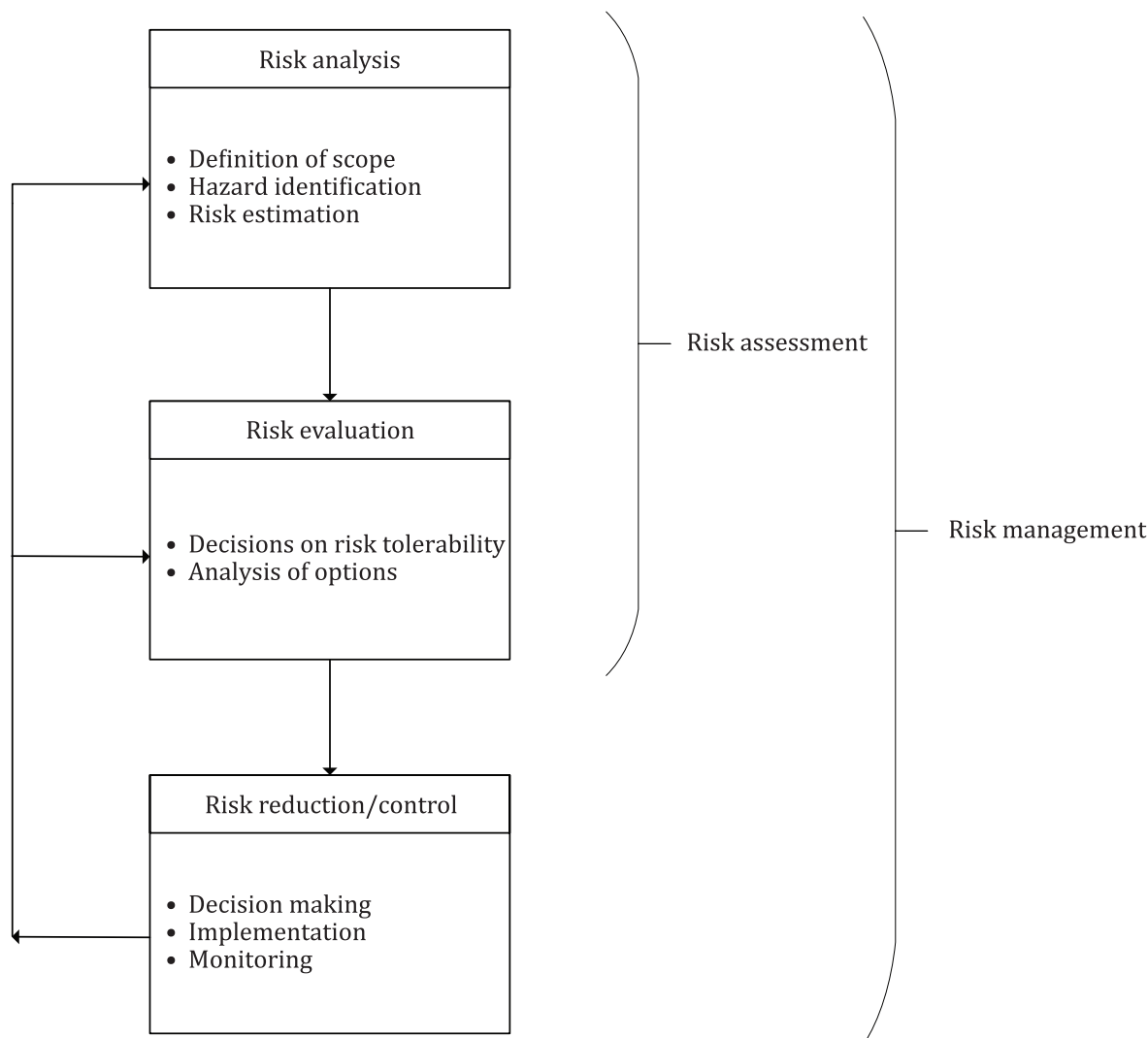


Figure 1 — Risk management

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 operation.

Risk management includes design, construction, operation, preventive and remedial maintenance as well as preplanning of emergency procedures. Specific information/guidance can be found for conveyor systems ([Clause 8](#)), silos ([Clause 9](#)), bunkers ([Clause 10](#)) and warehouse storage ([Clause 11](#)) and related annexes. The risk management shall be documented for guidance, training and record keeping purposes.

The documentation shall describe and justify the measures taken but also include aspects not considered applicable or relevant.

The person responsible for the risk management process shall have verifiable competence to conduct 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.:

- good understanding of solid biofuels;
- good understanding of the equipment and processes used for the production and along the supply chain of biofuel pellets;
- good understanding of fire related aspects of building control and function and appropriately trained and/or experienced in fire safety and fire protection issues;

- appropriate knowledge of national fire and safety regulations and the requirements of other enforcing bodies and stakeholders (i.e. insurers) and knowledge of relevant national and local codes and experience of application;
- any other specific competence requirements regulated by any local regulations.

5.2 Introduction to the risk management process

5.2.1 General

Management of risks include a number of steps and sub-steps as shown in [Figure 2](#). In [5.2.2](#) to [5.2.6](#) the different parts of risk management are defined and described.

5.2.2 Definition of scope

When performing a risk analysis, it is necessary to define the scope, 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.

5.2.3 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 should be identified and the type of hazard they pose analysed. Hazard identification methods fall mainly into three categories:

- a) comparative methods (e.g. checklists, hazard indices and reviews of historical data);
- b) 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 [hazard and operability study] and FMEA [failure mode and effect analysis]);
- c) inductive reasoning techniques (for example, 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:

- 1) actions should be taken to eliminate or reduce the hazard;
- 2) the analysis can be terminated due to the insignificance of hazard;
- 3) the analysis should be continued with a risk estimation.

There are many factors influencing the the risk management, e.g. the storage capacity, annual pellet turnover and complexity of on-site handling and to consider all the variables that could be valid for a particular facility. At least, the hazards mentioned in [Clause 6](#) and relevant parts of [Clauses 8](#) to [11](#) shall be considered in the hazard identification process. In [Clause 7](#), there are requirements for safe operation and maintenance, which also shall be considered.

5.2.4 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 humans, animals, 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 impact should the undesired event occur;
- c) risk calculations where risk should be expressed in the most suitable term, e.g.: individual risk, e.g. 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.

5.2.5 Risk evaluation

After risk estimation has been completed, risk evaluation shall be carried out in accordance with [ISO 12100](#) to determine if risk reduction is required. If risk reduction is required, then appropriate measures shall be selected and applied.

5.2.6 Risk reduction/control

Based on the risk evaluation, measures should be taken to achieve a tolerable risk level. 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.

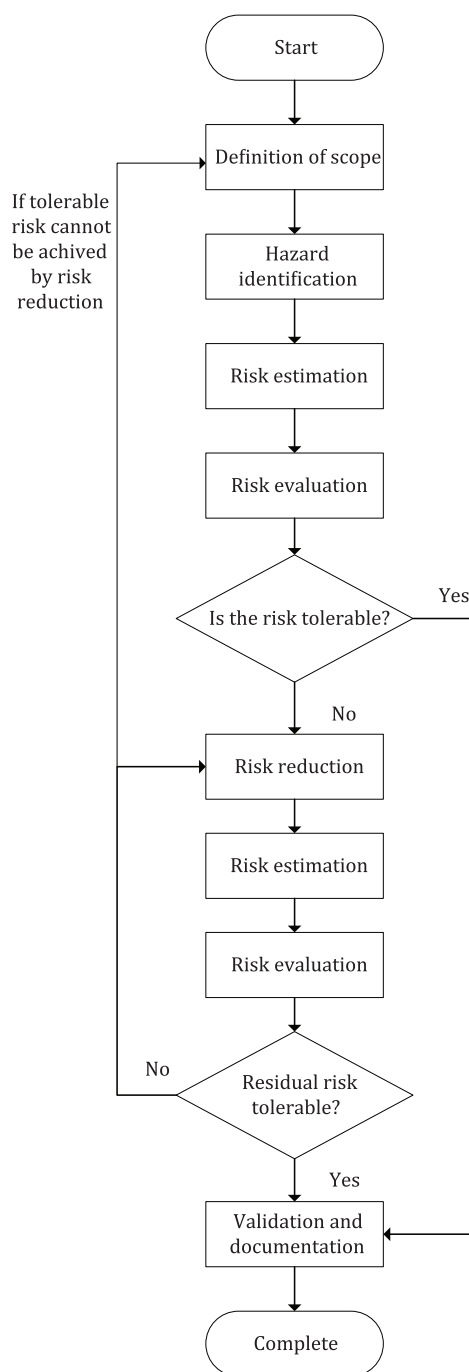


Figure 2 — Iterative process of risk assessment and risk reduction (after ISO/IEC Guide 51:2014)

An example of a risk assessment is presented for a commercial, medium size wood pellet store with relatively low complexity is shown in [Annex H](#).

6 Requirements for design and construction

6.1 General

This clause describes requirements for the general design and construction while additional requirements are described for specific objects in [Clauses 8 to 11](#).

Requirements for safe operations and maintenance are described in [Clause 7](#).

6.2 Specific risk considerations for handling of solid biofuel pellets

The following hazards conditions are common in all operations involving solid biofuel pellets during production, handling, transportation and storage and shall be considered as a minimum during the risk management process: Dust explosion, fire, pyrolysis gas explosions (which is a result of smouldering fires), off-gassing of toxic gases, areas with low oxygen concentrations, high walls of pellets in storage facilities collapsing (such as an avalanche) on personnel and mobile handling equipment. The main hazards to the quality and value of the pellets are; physical degradation (for example, breakdown); contamination by water (which could result in fungi growth), humidity, extraneous materials. Only those quality related hazards that are directly related to safety will be further discussed in this document.

The equipment and facility shall be constructed in such a way that risks are minimized. All aspects of a facility shall, to the extent possible, follow the fail-safe principle meaning that a single failure shall not cause a secondary catastrophic failure to happen.

NOTE This can be achieved by inter-locking, power backup, dumping of materials by gravity, etc.

The equipment shall cause minimal degradation to the pellets and should protect the material from the elements and keep it away from ignition sources.

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

a) Combustible or potentially explosive dust,

Solid biofuel pellets always contain dust which can easily become airborne. Dust smaller than 500 µm are explosive if in sufficiently high concentration and in contact with an ignition source (see 6.2 h). All wood dust shall be assumed combustible until demonstrated otherwise for example 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 low compared to that of a dust cloud in contact with a hot surface. Since a layer will start glowing when exposed to a hot surface for a longer period of time the temperature will rise significantly hence creating a massive ignition source for a dust cloud (see 6.2 b). All areas of an operation involving handling or storing of solid biofuel pellets where explosive dust or gases can be present, shall be divided and classified in risk zones. Risk zones shall indicate local contexts where national or regional regulations (e.g. ATEX directives, NFPA standards) are present (See Annex C).

b) Self-heating,

Solid biofuel pellets and related dust have a propensity to self-heat during storage, particularly relatively shortly after production, or at elevated moisture content (e.g. due to water intrusion) and elevated ambient temperature (see B.2). The heating can be considerable depending on the quality of the pellets 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 is important to obtain indications of self-heating. Measurements of CO just above the bulk surface could provide additional information. Possibilities for emergency discharge shall be considered.

It should also be noted that layers of dust from wood pellets on a warm surface could start a self-heating process and thereby cause ignition even below the determined minimum ignition temperature (MIT) of a dust layer (see Annex C).

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

The amount and characteristics of fine dust lofted in the air is a health risk when inhaled and some type of wood dust can be carcinogenic (NTP, 2016). Efforts to control dust exposure shall be planned and implemented during the design stage.

d) Exposure of operators to asphyxiation or intoxication,

Solid biofuel pellets release gases such as carbon monoxide (CO) and carbon dioxide (CO₂) in combination with rapid oxygen depletion. Small amounts of methane and hydrogen as well as malodorous hydrocarbons are also released (see [7.5](#) and [D.2](#)).

e) Avalanches,

Solid biofuel pellets have in general a high flowability similar to grain but can under certain circumstances cause high walls of pellets, or bridging and ratholing when stored in silos or bunkers with gravity bottom feed. Engulfment or burial can easily happen if entering a storage bin during discharge. Life-saving with life-line and "cofferdam" (a barrier to prevent burial of personnel by pellets) is one of the few options to save life in such cases.

f) Machinery,

Machinery involving moving parts (in normal operation and in case of malfunction) can involve a significant risk for personnel injuries and suitable risk reducing guarding measures shall be considered. The requirements of [ISO 12100](#) (safety of machinery) as well as any local regulations shall be fulfilled.

g) Moving vehicles,

Moving 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. wheel loaders, trucks) in operation, reduced visibility due to smoke, reduced visibility due to drivers using SCBA-equipment. Suitable risk reducing measures shall be considered.

h) Fire hazards,

Both pellets and dry wood dust pose a fire hazard and ignition sources shall be avoided. There are a number of potential ignition sources along the path of the pellets which shall be considered during risk zone classification (see [6.2](#) a and [Annex C](#)). These ignition sources can be present both during normal operation and/or in case of malfunction, and needs to be considered during design and commissioning but also during operation:

- Hot surfaces (e.g. lamp shades, lamp bulbs, overheated ball bearings and motor casings, driers, overheated rollers (idlers) and guide rollers, exhaust stems in moving equipment);
- Self-heating (exothermic reactions) (both in storage of bulk material and in dust deposits on heated surfaces);
- Flames, hot gases and hot particles (including e.g. external fires, hot work during maintenance, transport of smouldering material, gas from vehicle exhaust systems);
- Mechanically generated sparks (friction, abrasion, impact);
- Electrical apparatus;
- Stray electric currents;
- Static electricity (e.g. spark discharge, propagating brush discharge);
- Lightning.

6.3 Risk areas

There are several typical areas where the solid biofuel pellets can cause hazardous conditions for personnel or be subject to quality degradation (which could influence safety) along the chain of handling.

Below are some examples of areas (but not limited to) in which these risks will be found:

- a) Ship cargo holds, stairwells, enclosed storages, enclosed rooms (asphyxiation, envelopment);
- b) Pellet off-loading and transport system (ship unloader, train unloader, transfer points, conveyor systems, etc.)(explosive atmosphere, personal injuries, etc);
- c) Storage facilities (self-heating, off-gassing, oxygen depletion, explosive atmosphere);
- d) Powered mobile handling equipment (fire and explosion, personnel injuries);

In connection with pellet quality, the designer shall assess the design to identify the following:

- e) Places where contamination in the form of e.g. precipitation or extraneous materials can enter the pellets (during handling and storage);
- f) Places where the pellets are subject to impact or breakdown;
- g) Places where segregation can occur causing fines to become separated or concentrated.

For each of these, the designer shall make an assessment of the likely level of impact on the quality where this can be of significance for safety, and put in place appropriate measures to ensure that the quality is not reduced to an unacceptable level to the cargo owner.

The main places where these risks will usually be found will include:

- Open ship hold (contamination by precipitation);
- Ship unloader (degradation by impact and crushing);
- Conveyor transfer points (degradation by impact, excessive drop height);
- Feeder systems such as conveyor systems, drag chain feeders (degradation by pressure or attrition);
- Reclaim by handling equipment such as front loaders and trucks driving over wood pellets causing degradation and contamination.

6.4 General requirements and recommendations for safe handling

The design of facilities and equipment as well as operational guidelines (see [Clause 7](#)) can eliminate or minimize the risk for hazardous conditions during handling and storage of solid biofuel pellets. Below, some general aspects of importance are listed while more specific aspects related to certain objects (conveyors, silos, bunkers and warehouses) are presented in [Clauses 8 to 11](#).

- a) General design and construction considerations should avoid dust generation, dust settlement, material build up, etc.
 - Beams, ledges and structures, which cannot be regularly cleaned and are located inside buildings for handling and storage of biofuel pellets, shall have a cover with a sharp top angle of <60° to deflect accumulation of any build-up of dust.
 - “Dead spots” enabling accumulation of dust shall be minimized. Cover beam girders with sheet metal or fill with materials such as styrofoam to block accumulation of dust on flanges.
 - Locations of potential deposits or accretions shall be easily accessible.
 - Install monitoring and mitigating measures for early stage detection and mitigation.
- b) Processes that create dust can be avoided by the following means:
 - Using enclosed conveying routes, enclosed transfer points and/or dust removal systems
 - Minimizing the number of transfer points and their drop heights and/or impact on pellets

- c) Accessibility for regular inspections
- d) Accessibility for housekeeping
- e) Accessibility for firefighting
- f) Accessibility/possibility for emergency discharge of storage
- g) 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 (see [8.3](#), [9.3](#), [10.3](#) and [11.3](#) for details).
- h) Explosion relief systems, if necessary combined with explosion isolation components, will reduce the risk of transfer of an explosion and fire along a conveyor and secondary explosions in connected equipment. The pressure relief should be guided outdoors (see [8.3.2](#)).
- i) Areas where dust becomes lofted during handling and the occurrence of explosive dust/air mixtures cannot be fully avoided shall be classified in risk zones/areas. Within the zones, only equipment (electrical or mechanical) approved for the relevant zone shall be used (see [Annex C](#)).
- j) All identified risk zones/areas shall be clearly identified by signs and warning symbols.
- k) Electrical equipment and lightning protection. Do not use halogen or other lighting fixtures with hot surfaces. The enclosures of electrical equipment shall have a proper classification with respect to protection against personal safety, foreign objects, ingress of water and explosion protection.
- l) Risk for accumulation of gases from off-gassing or pyrolysis gases (CO, CO₂) in locations adjacent to storage facilities (e.g. offices, lunch rooms, and meeting rooms), in particular during self-heating or fire situations.

Further information about risks associated with dust is given in [Annex C](#) and some guidance on handling of emergency situations (e.g. self-heating, fire) is summarized in [Annex D](#).

7 Requirements for safe operation and maintenance

7.1 General

The following requirements, when applicable based on the risk assessment, shall become part of the operations and maintenance manuals.

7.2 General requirement for operation, maintenance and manuals

Operation and maintenance of a facility shall be organized such that hazardous situations are avoided and in the event emergency situations occur there shall be evacuation and 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 confined space entry, dust and gas explosions, limbs and clothing caught in machinery, electric shock, exposure to hot surfaces, tripping over debris etc.

To avoid such incidents, the employer shall ensure that each worker receives adequate safety and health training, in particular in the form of information and instructions specific to his workstation or job:

- on recruitment,
- in the event of a transfer or a change of job,
- in the event of the introduction of new work equipment or a change in equipment,
- in the event of the introduction of any new technology.

The training shall be adapted to take account of new or changed risks, and repeated periodically if necessary.

Personnel should regularly be informed about the risks related to confined spaces and also be equipped with personal gas detectors measuring both CO and oxygen (O₂) content as 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 lock-out of fire/explosion detection and suppression systems and ensure that they are reactivated before any operation commence. However, detection systems relevant for security should still be active if possible.

7.3 Documentation of operation procedures

The following documents shall be compiled at a facility handling and storing solid biofuel pellets and where necessary be available and maintained to be current.

- a) Procedures and guidelines:
 - daily procedures including start-up and shutdown routines;
 - emergency procedures;
 - housekeeping procedures;
 - outline of operator training;
 - worksafe guidelines from local/national authorities;
 - logandreportingrequirement(operationalconditions,incidents/abnormalconditions,accidents);
 - reporting structure of organization;
 - safe behaviour;
- b) Maintenance manual:
 - preventive maintenance routines (e.g. regular control of bearings);
 - 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 solid biofuel pellets produced and/or handled by any facility (product safety data sheet):
 - identification;
 - hazard identification;
 - composition;
 - physical properties;
 - chemical properties;
 - self-heating properties;
 - off-gassing and oxygen depletion properties;
 - safety characteristics of dust (see [Annex C](#));

— toxicological information.

Examples of specific aspects to consider during normal operation and include in the documentation/manuals are described in [7.4](#) while aspects on emergency procedures are handled in [7.5](#).

7.4 Safety during operation

7.4.1 Operation

Regular visual inspection of the entire handling system shall be performed, to identify dust accumulation, spilled material or indications of malfunction or damaged equipment requiring maintenance. The use of a handheld IR (Infrared) camera or IR-thermometer is recommended as this increase the possibilities to detect heated material/equipment.

Limit the storage time and apply the first-in-first-out principle as far as possible. Seek to avoid mixture of fuel with different type, qualities and moisture content in order to avoid stratified heating in boundary layers due to dust content, particle size etc.

Visual inspections, after taking the necessary safety precautions, of stored pellets shall be performed regularly, i.e. noting any tendencies of vapour formation. Such inspections shall be done also upon entry of delivered fuel into storage.

For storage with an expected storage time of more than 3-4 weeks without any transfer operations, control of the pellet properties loaded into the storage should be considered, e.g. tendency to self-heating

NOTE A method to determine the tendency to self-heating is being developed and ISO 20049-1¹⁾ is currently under development within ISO/TC 238/WG 7.

Regular monitoring of stored pellets should be conducted using mobile and/or fixed sensors for temperature and/or gas detection (see [Annex G](#)). As the storage facilities and storage conditions can vary considerably, monitoring of the rate of change of the bulk temperature (and/or gas concentration) are often more important than a specific threshold as an abnormal increasing rate of change indicate some form of changed conditions and a possible problem.

For intermediate storages which every week have a transfer to the stock or reclaiming, temperature monitoring of the moved pellets (at inlet and/or outlet) is recommended.

Keeping good track of normal conditions is therefore essential to learn more about the specific storage 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, inertization or cooling of the fuel (see [Annex D](#) for further guidance). Upon emptying, the storage shall be cleaned of pellets and dust before refilling. Intermediate storages need to be emptied and cleaned regularly (preferably at least once a year), to avoid accumulation of dust.

When handling and storage of pellets in bags or big-bags on pallets, the main risk is related to the stability, in particular if the pallets are stacked on height. A damage of a pallet on low level can result in the collapse of the entire pallet stack with risk for personnel injuries.

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

7.4.2 Housekeeping

Dust accumulations present both a significant explosion hazard (see [Annex C](#)) but also a health risk, and technical/organizational measures shall be taken to avoid the exposure of personnel to dust. A routine for checking dust dispersion/dust build up shall therefore be set in place. A cleaning plan shall be kept and maintained for regular removal of dust; it shall be based on frequency of cleaning or max dust layer.

1) Stage at the time of publication: ISO/FDIS 20049-1:2020.

A dust layer exceeding 0,5 mm to 1 mm in general or dust layer exceeding 3 mm covering more than 5 % of a given work area shall be considered as a potentially hazardous condition for dust explosion.

NOTE 1 It has proven successful to mark potential accretion areas in colour and when the coloured marking is no longer visible, it is an indication that cleaning should take place without delay (VGB, 2013).

NOTE 2 A "given work area" is considered to be an area of the workplace, whose boundaries are defined by the various physical structures around it, which can enclose, contain, or compartmentalize the area. These structures can include walls, floors, ceilings, process equipment, or any combination of these which have the effect of either fully or partially enclosing, containing, or compartmentalizing that work area within the facility. The greater the extent of confinement, enclosure, or containment in an area where dust has accumulated, the greater the risk that an explosion can occur.

Large wall surfaces with rough surface texture could be painted with gloss antistatic paint in order to avoid accumulation of dust and to minimize generation of electrostatic build-up.

Vacuum cleaners shall be certified for use in explosive atmosphere as recommended by local regulations. Due to the risk of raising dust, cleaning shall not be performed with compressed air or high pressure cleaners.

Fine dust will create a health risk and special attention should be given airborne dust since concentrations of wood dust above 1 mg/m³ is considered as a danger level. Exposure can be a cause for asthma, effects to skin and eyes. and can be carcinogenic. Personnel regularly exposed to dust, e.g. those working with house-keeping, operation and maintenance shall have access to respiratory protective equipment and it shall be worn when relevant.

7.4.3 Maintenance

A maintenance plan for all key mechanical equipment, e.g. conveyors, valves, various monitoring equipment, fire detection and fire protection equipment shall be kept and updated. Certified equipment shall be maintained and inspected in accordance with recommendations by suppliers and current maintenance plan to ensure safe performance.

To avoid intrusion of precipitation in stores, the building envelope shall be properly constructed and regularly inspected for defects. Rain gutters should also be regularly inspected to ensure proper function, as blockage can lead to intrusion of water into the building.

The preventative maintenance routine shall include checking the grounding of casings of motors, fans and other conductive objects. The resistance to ground or between objects shall be <1 MΩ to prevent the risk of sparking due to static discharge. A conductive object can be earthed by a direct conductive path to earth or by bonding it to another conductive object that is already connected to the earth. Some objects are inherently bonded or inherently earthed because of their contact with earth. The maximum resistance shall also include interconnecting parts e.g. flexible's and piping, belt material and drive wheels or flexible and equipment. [IEC TS 60079-32-1](#) provides further information.

Workplaces in potentially explosive areas shall be checked before the start of work by a qualified person and only opened after application of the corresponding release procedure.

Systems in potentially explosive areas shall be checked by a qualified person before first activation and repeatedly checked at regular intervals.

If explosive dust/air mixtures are avoided by permanent or occasional 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 exerting heat or sparks) shall only be conducted after receiving a written permission from an authorized person at the

facility. Before starting the work, necessary precautions should be made to eliminate any combustible material in the area of work. Fire extinguishing equipment shall be available and ready for use and the work shall be monitored by one or several fire guards. Lock-out of fire/explosion detection systems can be necessary to avoid activation. The permission procedures shall also ensure that the system is reactivated before any operation commence again. Spills of lubricants like oil and grease as well as hydraulic oils shall be removed to prevent them becoming a catalyst for self-heating.

Closed pellet stores (especially silos and bunkers) shall only be entered for repair or maintenance after it has been confirmed by specific measurements that the gas concentrations of O₂ and CO provide a safe access.

WARNING — Do not measure oxygen concentration only, both O₂ and CO shall be measured (see [D.2.2](#)).

The work shall always be conducted by the company of a second person who stays outside the hazard zone as an additional safety measure and with a safety rope attached to the entering person. The attendant should always have eye contact or at least voice contact with the person inside the store.

7.4.4 Guidelines for visitors/contractors

7.4.5 Guidelines for contractors

Contractors' staff shall be informed regarding rules for:

- wearing personal protective equipment (PPE) (helmet, protective glasses, noise protection, protective shoes, reflective clothing, respiratory protective equipment, or any other specific PPE relevant for the facility);
- areas involving specific hazards;
- entering confined spaces. A specific permission, education and training shall be required as well as the use of mobile gas detectors for at least O₂ and CO, and having escort of a second person on the outside of the entrance to the confined space;
- activities involving any hot work. A specific permission, education and training shall be required as well as having escort of a fire guard equipped with extinguishing equipment;
- action in case of a fire or other emergency situation, evacuation routes and location of "Point of assembly";
- any other specific safety considerations relevant for the facility.

The contractor(s) shall receive the information both verbally but also in written form and shall confirm this with a signature.

7.4.6 Guidelines for visitors

Visitors shall not be allowed to enter any operational areas of the facility without escort of an employee assuring that the visitors are not entering any dangerous areas. Prior to entering the operational areas, all visitors shall be informed to always stay together with the escort person and follow given advices. All visitors shall as a minimum be wearing a helmet, reflective clothing, protective glasses, but also noise protection, or any other PPE as deemed necessary for the visit.

7.5 Pre-planning of emergency operations

Where applicable, pre-planning and preparation of checklists 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:

- activation of ignition source detection systems in the conveying system,

- fire detection in the conveying system,
- indicated self-heating in a storage,
- confirmed fire in storage,
- activation of any explosion protection system in the plant,
- rescue of people from confined spaces.

The pre-fire planning shall include:

- 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 and rescue services, suppliers of inert gas and related equipment, freight companies, health and environmental authorities, etc.).
- A general risk assessment and safety rules for various expected incident scenarios and at least the six scenarios mentioned above.
- Procedure for how to perform an updated, on-site risk assessment related to the specific object and incident scenario.
- Immediate actions (preferably as a check list) to minimize the risk for the involved personnel (see below) and reduce the consequences of the incident.
- Need for warning signs and warning systems, equipment to cordon off certain areas.
- 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).
- Preparations, equipment and routines for emergency discharge of storage in case of indicated self-heating or fire.
- Emergency shut down procedures for certain equipment.
- Instructions for handling of extinguishing media and contaminated material.
- 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).
- Routines for regular updates of the emergency procedures.
- Regular inspection and replenishment of first-aid materials.

Further details to include/consider in the pre-planning work for various equipment/locations are also mentioned in [Clauses 8 to 11](#), and a general guidance on how to manage various emergency situations is presented in [Annex D](#).

The pre-planning document shall 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.

7.6 Personnel risks

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

- exposure to toxic gases (for example, high concentrations of CO as a result of off-gassing or a self-heating/fire situation);
- areas with low O₂ concentration;

- use of inert gases during the inerting/firefighting operation (asphyxiation, exposure to cold liquefied gas);
- 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;
- rapid propagation of fires and explosions in constricted spaces such as conveyor tunnels/galleries and access corridors, in particular if having steep pitch;
- backdraft (for example if opening up a silo with an ongoing smouldering fire);
- work inside confined spaces and the risk of engulfment or burial of personnel;
- instability of structure (for example, structure for elevated conveyors, collapse of silos) during fire;
- working at heights.

8 Conveyor system and transfer points

8.1 General

Typical causes of fires, specifically in conveyor systems ([A.4.3](#)), are often hot surfaces (e.g. overloading, insufficient lubrication, damaged track supporting rollers (idlers), guide rollers and internally positioned ball bearings, overheated electric motor casing, overheated brakes, belt slip, skewing of belts, friction of the belts, high speed, friction against material deposits), or forming of sparks (e.g. high speed (relative speed >1 m/s), inappropriate matching of materials, lack of or insufficient equipotential bonding causing electrostatic sparks, faults in electric devices and utilities, extraneous materials). These features shall be included in the risk assessment.

In [8.2](#) and [8.3](#), more specific aspects are listed which, as a minimum shall be considered and documented during the risk management process ([Clauses 5](#) and [6](#)) and implemented as possible risk reduction/risk control measures, if considered relevant or necessary, during the design and construction phase of the conveyings systems on the plant. If the risk assessment indicates that a specific measure should be implemented in the design, further information, recommendations and requirements are given in [8.4](#).

8.2 Detection

The following risk reduction/risk control measures shall be considered:

- Temperature monitoring of incoming material to identify abnormally warm pellets (i.e. pellets having a temperature exceeding those experienced during normal operation).
- Ignition source detection system for incoming material and in transfer points to identify hot or glowing material on the conveyor system ([8.3.1](#)).
- Motion sensing device to detect belt slipping, belt slow down or jammed conveyor, e.g. due to material build-up or blockage in transfer points.
- Measurement of the electric current consumption to detect overload in the drive.
- Sensors to detect belt misalignment.
- Vibration sensors to detect bad bearings in the drivers, rollers, etc.
- Temperature monitoring to identify hot bearings in the drivers, rollers, etc.
- Detection system along the conveyor system to identify open fire (e.g. linear temperature detection cables, flame detectors, etc.).
- Camera surveillance of areas not regularly attended by personnel.

- Interlocking of the selected detection system(s) to securely shutdown the conveyor in case of conditions that could result in a fire incident (8.4.2).
- Activation of a safe way of preventing the material being fed into a storage.

The selection of detection system should consider the possibility for maintenance and testing during operation. The ignition criteria of the material being transported shall also be considered during selection of detection system. Further information on various monitoring and detection systems is given in [Annex G](#).

8.3 Preparatory measures

8.3.1 Fire protection

The following risk reduction/risk control measures shall be considered:

- Prohibition of vehicle parking and storage of combustible material under conveyors.
- Use of fire-resistant and dissipative belts (Cat 2B or Cat 4A according to [ISO 340](#) and [ISO 284](#)).
- Possibilities for visual inspection, house-keeping and maintenance and manual firefighting.
- Accessibility to each installed sprinkler/spray nozzle, fire detector for inspection and maintenance via suitable hatches, alternatively via easy removal of the nozzle/detector for inspection and maintenance on the outside of the conveyor.
- Ignition source detection system connected to a quick activating water injection system in transfer points.
- Possibilities for material rejection in case of detection of abnormally warm, hot or glowing material on the conveyor at transfer points into a silo or flat storage.
- Preparation for emptying the conveyor system on unplanned standstill.
- Protection of covered conveyors located indoors by an automatic sprinkler system or water mist system.
- Sprinkler protection of conveyors located outdoors which are totally enclosed or partially open, made of non-combustible material and elevated above the ground.
- A deluge water spray system in conveyor galleries having a steep pitch, or for similar conditions, where the fire spread could be faster than the operation of conventional automatic sprinklers.
- A deluge water spray system in areas where fast response or immediate large area cooling is desired due to high values, unusual potential for severe loss or high frequency of fires.
- In addition to a deluge water spray system, compartmentation of large conveyor galleries in combination with fire ventilation in order to reduce the risk for a rapid fire spread.
- Interlocking of conveyors to safe shut down automatically on sprinkler water flow or fire detection (8.4.2).
- Fixed stand pipe systems with connections for the use of the fire and rescue service for additional or final firefighting.
- Access/escape possibilities at least at both ends of the conveyor system for the operating and firefighting personnel.
- Emergency lightning installed in all parts of a covered system/galleries.
- Warning/alarm systems (light/sound) available at suitable locations in all parts of the system to ensure an early evacuation.

- Push buttons for manual activation of the fire alarm as well as fire hose reels and/or fire extinguishers available at suitable locations.
- Separate conveyors to be used for emergency discharge ([8.4.3](#)).

8.3.2 Explosion protection

The following risk reduction/risk control measures shall be considered:

The risk of explosion predominately results from dust generation. If not conflicting with any local regulations, and based on a risk area classification (see [Annex C](#)), the following explosion protection measures shall be considered:

- Conveyor system construction to reduce the generation of dust ([8.4.4](#)).
- Use of covered conveyor structures designed to minimise the spreading of dust, accumulation of dust inside the structure and connection of transfer points to a dust collecting system.
- Certified explosion protection equipment installed to be corresponding with the explosion risk area classification along the conveyor system based on all operating conditions including start/stop of the equipment and maintenance.
- Enclosed/covered conveyors, including e.g. dust extraction systems equipped with explosion relief systems as part of the measures to limit the explosion overpressure to avoid flying debris.
- Type, size and location of explosion vents designed to ensure an effective pressure relief and prevent the risk for injury of personnel when activated.
- Guiding the pressure relief from an explosion to the outside of the building or using certified flameless indoor explosion venting devices ([8.4.4](#)).
- Explosion isolating systems (as a complement or alternative to explosion vents) to avoid transfer of an explosion and fire along a conveyor which could result in secondary explosions in connected equipment.
- Explosion suppression systems (as a complement or alternative to explosion vents or explosion isolation systems).
- Explosion-proof design (as a complement or alternative to other explosion protection measures).
- Interlocking of conveyors to shut down automatically on explosion detection ([8.4.2](#)).
- Cleaning of dust deposits using a suitable vacuum cleaning system certified for use in explosive atmospheres or by using a low pressure water cleaning system ([8.4.4](#)).
- Specific consideration of the risk for dust explosion and suitable relevant explosion protection measures for conveyors intended for emergency discharge.

8.4 Additional information, recommendation and requirements on design and protection of conveyor systems

8.4.1 General

If it has been determined via the risk assessment process that a specific risk reduction/control measure described in [8.2](#) and [8.3](#) needs to be included, this clause provides additional information, recommendations and requirements.

8.4.2 Detection systems

Ignition source detection system for incoming material and in transfer points to identify hot or glowing material on the conveyor system can also be connected to a quick activating water injection and/or a material rejection system (see [8.4.3](#)).

Ignition source detection systems should be interlocked to securely shutdown the conveyor in case of conditions that could result in a fire incident. The shutdown sequence should also include all contributing transport system to the stopped conveyor. The shutdown sequence should also be designed in a way so that the risk of fire is not increased due to the stop itself.

Temperature monitoring system to identify hot bearings in the drivers, rollers, etc can be obtained by using linear temperature detection cables, or if the conveyor bearings are not enclosed, by using an IR camera or an IR thermometer.

Detection system along the conveyor system to identify open fire (for example, linear temperature detection cables, flame detectors, etc.) is of particular importance for long, covered conveyors. A detection system can be replaced by an automatic sprinkler system for certain applications (see [8.4.3](#)).

8.4.3 Fire protection

At certain locations, e.g. before the discharge into a silo, the activation of a detection system should also activate a safe way of preventing the material being fed into the silo, e.g. by designing a safe way of feeding the material to an abort or a safe side dump (see [8.3.1](#)). Depending on the physical layout and material flow, it can be practical to reverse the direction of a conveyor for disposal of aborted material. Conveyors transporting aborted material should be running dry before shutting down.

Open indoor conveyors might not need a specific sprinkler protection system if the building is protected by a ceiling mounted automatic sprinkler system designed to also cover the conveyor system.

Visual inspection, house-keeping and maintenance and manual firefighting of conveyor systems can be made possible e.g. by making them accessible on both sides, adding walkways on both sides for elevated conveyors, and installing vacuum cleaning systems).

In case of repeated activations of an ignition source detections system, the system should shut down the conveyor system.

In case of cold climate where freezing could occur, a dry type or pre-action system shall be considered as an alternative to automatic sprinkler system. For dry pipe systems, the filling time shall be considered.

Deluge systems intended to protect conveyor galleries with steep pitch, where rapid fire spread could be expected or there is a potential for severe loss or high frequency of fires, shall cover the entire belt system, including the return belt. Filling time for a dry pipe system shall be considered.

Fixed stand pipe systems with connections for the use of the fire and rescue service shall have connections for fire hoses at suitable locations along the entire conveyor system.

If ignition source detection system with extinguishing is installed, manual activation of the extinguishing system via push buttons at suitable locations should be considered. Also a manual activation of the system should result in a safe shutdown sequence of the conveyor system as described in [8.4.2](#).

Conveyors to be used for emergency discharge shall be designed to endure transport of hot and smouldering material and be accessible to allow visual supervision and manual water application or equipped with a suitable ignition source/fire detection system combined with a fixed water application system to extinguish any smouldering material discharged onto the conveyor. A separate conveyor for emergency discharge should be considered if several storage units are connected to the ordinary conveyor for discharge.

NOTE For more details on sprinkler design for conveyor protection, see e.g. FM Global Data sheet 7-11 (FM Global, 2015) or NFPA 15.

8.4.4 Explosion protection

The conveyor system should be constructed to reduce the generation of dust by minimizing the number of transfer points and their drop heights.

Conveyor structures should be covered to minimise the spreading of dust, and constructed so the dust accumulation inside the structure is minimised. Transfer points should be connected to a dust collecting system or equivalent measures to reduce the dust emission.

All equipment installed along the conveyor system shall be certified to correspond with the explosion risk area classification. The risk area classification shall be based on all operating conditions including start/stop of the equipment and maintenance.

Enclosed/covered conveyors, including e.g. dust extraction systems should be equipped with explosion relief systems as part of the measures to limit the explosion overpressure to avoid flying debris.

The type, size and location of explosion vents should be chosen such that it ensures an effective pressure relief but also prevent the risk for injury of personnel when activated, e.g. prevent passage in front of the vent and/or using a flame arrester at the vent opening.

If conveyors are located indoors, the pressure relief from an explosion shall be guided to the outside of the building or using certified flameless indoor explosion venting devices. In such case, the strength of the building structure shall be considered.

Cleaning of dust deposits should be made using a suitable vacuum cleaning system certified for use in explosive atmospheres or by using a low-pressure water cleaning system. Compressed air or high-pressure water cleaning system shall not be used.

Conveyor systems for emergency discharge need special consideration with relation to the risk of fire and explosions as the discharged material will contain smouldering material which could result in open flames when the material is exposed to the air.

9 Silos

9.1 General

Typical causes of fire in silo storage of pellets are often related to

- self-heating (See [Annex B](#)) of the pellets;
- hot material introduced into the silo via the conveyor system;
- mechanical failures of e.g. discharge equipment at the bottom of the silo.

Explosions inside the silo headspace can be a result of

- smouldering material introduced into the silo via the conveyor system which can ignite a dust cloud generated inside the silo during filling;
- the consequence of a primary explosion in the conveyor system causing a secondary explosion inside the silo;
- smouldering fire inside the silo, generating high concentrations of combustible gases (CO, unburnt hydrocarbon) leading to a gas explosion.

In [9.2](#) and [9.3](#), more specific aspects are listed which, as a minimum shall be considered during the risk management process (see [Clauses 5](#) and [6](#)) and implemented as possible risk reduction/risk control measures, if considered relevant or necessary, during the design and construction phase of the silo storage. If the risk assessment indicates that a specific measure should be implemented in the design, further information, recommendations and requirements are given in [9.4](#). Guidelines for handling of various emergency situations are presented in [Annex D](#).

9.2 Detection and temperature and gas monitoring

The following risk reduction/risk control measures shall be considered:

- ignition source detection system monitoring the pellets flow into the silo to identify warm, hot or glowing material along the incoming conveyor system ([9.3.1.1](#));
- monitoring of gas composition or gas concentration in the silo headspace and close to the discharge outlet;
- monitoring of temperatures inside the bulk by temperature sensor cables suspended from the silo roof;
- ignition source detection system monitoring the pellets flow from the silo discharge opening to identify warm, hot or glowing material for control of the discharged material to the conveyor system (see [9.3.1.1](#));
- video surveillance of areas not regularly attended by personnel.

Some further information on various monitoring and detection systems are given in [Annex G](#).

9.3 Preparatory measures

9.3.1 Fire protection

9.3.1.1 General design of silo

The following risk reduction/risk control measures shall be considered:

- A minimum distance between individual silos and adjacent buildings to ensure good accessibility and possibilities for preparations for emergency discharge in the case of fire.
- Air tightness of the general silo construction, except specific ventilation arrangements (see below), to restrict air entrainment into the bulk material but also to minimize the leakage of inert gas in case of an extinguishing operation.
- Internal construction of the silo (e.g. steel beams in the roof) to prevent accumulation of dust.
- Roof construction to withstand the load from temperature detection cables attached to the roof and to minimize water condensation leading to risk of water falling into the pellets.
- Flooring top layer material to minimize risks of spark generation with mobile handling equipment.
- Minimize the risk for bridging and ratholing.
- Installation of nominally airtight valves at both inlet and discharge outlet.
- Closed and sealed doors, openings, hatches, in particular located below the maximum filling level to minimize the possibility for unintentional air entrainment.
- Prevention of backgassing or backfire into the silo from a furnace directly connected to a silo.
- Possibilities to close ventilation arrangements based on free convection or turn off and close forced ventilation systems in case of a fire situation.
- Provide sufficient height to allow free fall of the pellets at a suitable location, both before the silo inlet and after the discharge outlet to allow the installation of ignition source detectors, preferably in combination with either a suppression system or a quickly acting material rejecting arrangement.
- Arrangement and routines to lessen the dust generation from the impact of pellets falling from the top of the silo (see [A.5.2.1](#)).

- Arrangements for emergency discharge designed for handling discharged hot/smouldering/burning material.
- A specific storage area available for handling the discharged hot/smouldering/burning material.

9.3.1.2 Inert gas system for fire suppression/prevention

The following risk reduction/risk control measures shall be considered:

- Fixed inert gas distribution system at the base of the silo for inerting of the bulk material (see [9.4.3.2](#)).
- Installation of a pressure/vacuum venting valve (or other similar arrangement) with a venting capacity corresponding to the gas flow rate used during the inerting operation of the silo.
- Fixed inert gas distribution system for protection of the silo headspace (see [9.4.3.3](#)). CO₂ should not be used as extinguishing media unless using a vaporizer to guarantee a gaseous form of the CO₂ due to the risk of explosion, see [D.2.3.2](#).
- Arrangement of fixed gas sampling lines from silo headspace to a safe location where gas analysis instruments can be located during a fire situation.
- Fixed deluge (water)/foam/CAF system mounted in the silo ceiling for the protection of the silo headspace in case of an open fire situation.
- Fixed stand pipe systems with connections for the use by the fire and rescue service for additional or final firefighting.
- Injection of inert gas to reduce the oxygen concentration inside the silo for fire prevention.
- Forced ventilation system for control of the bulk temperature ([Annex E](#)).

NOTE Using large quantities of water will cause swelling of the pellets and could endanger the entire silo construction due to the forces generated, see [Annex D](#).

9.3.2 Explosion protection

During normal operation, the risk of explosion is predominately connected to dust explosions. This could e.g. be due to incoming smouldering material, igniting the dust cloud generated during the free fall into the silo. During a smouldering fire situation inside the silo, e.g. caused by self-heating, there is a significant risk of gas accumulation (for example CO and unburnt hydrocarbons) which could result in a gas explosion.

In addition to the explosion protection measures mentioned in [8.3.2](#), the following additional risk reduction/risk control measures shall be considered:

- Equipment installed at a silo in a risk classified area to be certified according to the explosion risk classification of the specific area/equipment.
- Explosion relief arrangement on the silo construction to prevent the explosion pressure to exceed the maximum design pressure for the overall silo construction.
- Preparations to seal the vent openings after release to minimize air entrainment and loss of inert gas during the inerting operation of the silo. If self closing explosion vents are used, vacuum venting valves have to be installed as the cooling of the hot gases following the combustion can create a vacuum in the silo, resulting in a deformation. The flow capacity of the venting valves shall be designed in relation to the volume and strength of the silo.

9.4 Additional information, recommendation and requirements on design and protection of silos

9.4.1 General

If it has been determined via the risk assessment process that a specific risk reduction/control measure described in [9.2](#) and [9.3](#) needs to be included, this clause provides additional information, recommendations and requirements.

9.4.2 Detection systems

Monitoring of the pellet bulk inside a silo could be made by monitoring the gas composition using gas detection system, or the gas concentration using CO/CO₂ detectors. The measurements should be made in the silo headspace and preferably also close to the discharge outlet.

When monitoring the temperature inside the bulk by temperature sensor cables suspended from the silo roof, the vertical spacing of the individual temperature sensors on each cable should not exceed 3 m. The number of sensor cables and spacing between the individual cables should be based on the specific conditions, e.g. silo diameter, construction of silo roof, duration of storage. The design of the roof need to withstand the load from temperature detection cables attached to the roof as a result of the flowing pellets during filling and discharge.

NOTE The sensor cables can be attached to the silo bottom (with a breakable connection) or by other means fastened to keep the cables in their vertical position during filling.

9.4.3 Fire protection systems

9.4.3.1 General design

The general silo construction (wall, roof, connection between the wall and roof, connection between the wall and the silo foundation) shall be as airtight as possible to restrict air entrainment into the bulk material but also to minimize the leakage of inert gas in case of an extinguishing operation.

Construct the silo so that the risk for bridging and ratholing is minimized.

Both the silo inlet and discharge outlet should be provided with nominally airtight valves. The inlet valve should close automatically in case of fire detection in the feeding conveyor system in order to prevent the spread of an external fire into the silo. Both the inlet and outlet valve should close automatically in case of fire detection at the discharge outlet.

Doors, openings, hatches, in particular located below the maximum filling level shall be closed and sealed to minimize the possibility for unintentional air entrainment which could cause localized self-heating and ignition.

Ventilation of the silo head space, either based on free convection or forced ventilation, shall be possible to close or turn off and close in the case of a fire situation. The valves should be nominally airtight and shall be remotely controlled and locally by hand. In case the silo is ventilated via free convection through an annular gap between the silo wall and roof, some arrangement should be installed making it possible to close the gap.

If the silo is equipped with a ventilation system for cooling of the bulk material, this system shall also be possible to turn off and air intakes/outlets possible to close and seal (see also [9.4.3.6](#)).

If the silo is directly connected to a furnace, suitable prevention measures of backgassing or backfire due to underpressure caused by a forced ventilation system shall be considered.

When the ventilation systems are turned off and closed, there shall be a pressure/vacuum venting valve (or other similar arrangement) with a venting capacity corresponding to the gas flow rate used during the inerting operation of the silo.

To allow the installation of an ignition source detector, both at the inlet of the silo and at the discharge outlet from the silo, chutes should be arranged creating a free fall of the pellets. The chutes should be located between the conveyor for incoming material and the silo opening or at a suitable location before the silo inlet as well as between the discharge opening and the discharge conveyor or at a suitable location after the silo outlet. This will allow the ignition source detectors to be installed in combination with either

- a quick activating water injection system or
- a quick acting material rejecting arrangement (rejection material should then be guided to a safe collecting area).

As an alternative to a free fall outlet, choke feed can be used as discharge mechanism, which does not imply free falling (dust generation). Temperature monitoring can be made with surface measurement and subsequent ignition source detection.

To lessen the dust generation from the impact of pellets falling from the top of the silo, it is recommended not to empty a silo completely, except for cleaning. The impact from pellets falling on pellets from low height is much less than pellets falling on concrete or steel boom. There are also so called “bean ladders”, “grain ladders” or “filling tubes”, positioned in the center of silos providing a slide or step-wise avalanche from top to bottom ([A.5.2](#)).

Preparations for emergency discharge should be made by installation of a separate conveyor system designed for handling the discharged hot/smouldering/burning material. This is of particular importance if several silos are served by only one conveyor system (see NOTE below). If the ordinary discharge conveyor system is planned to be used, this shall be equipped with an enhanced fire protection ([8.3.1](#)).

A specific storage area shall be available for handling the discharged hot/smouldering/burning material. The location should be carefully selected considering the possible risks for nearby objects, neighbouring activities, dominant wind directions, etc. The storage area should include possibilities to collect any extinguishing media.

NOTE There are many examples of silo fires where the lack of emergency discharge preparations has created great problems to discharge the silo in a controlled manner, and in several cases this has resulted in a total loss of both the pellets and the silo. The complexity and problems increase if only one conveyor is used for multiple silos as there will be a risk for fire spread. Accessibility to the conveyor for firefighting personnel will also be more difficult if the conveyor system is located in a culvert below the silo(s). A separate discharge possibility from each silo is therefore strongly recommended.

9.4.3.2 Inert gas system for bulk material

The fixed inert gas distribution system shall be installed at the base of the silo for inerting of the bulk material. The number of gas distribution inlets and design of the pipe arrangement shall be based on the silo cross section area.

The gas supply and the gas distribution system should be designed to provide a flow rate of not less than 5 kg/m² (silo cross section area) per hour. The flow and pressure calculation should assume that the silo is full of pellets having the lowest anticipated permeability.

The inlet opening/connection to the gas distribution system shall be sealed when not in operation to avoid air/moisture entrainment into the silo.

The gas distribution system shall be possible to flush with water during maintenance of the silo and shall therefore have an inclination towards the point of drainage.

The gas injection openings/nozzles at the silo bottom shall be designed to prevent blocking or clogging of the bulk material.

The pressure relief opening/valve shall be arranged in the silo headspace and designed to be capable of evacuating a gas flow corresponding to the injected inert gas flow. The opening should be designed

as a check valve, allowing outflow of gas by preventing inflow of air/oxygen unless a significant underpressure is obtained inside the silo (for example due to a rapid temperature decrease, see [9.3.2](#)).

Arrangement of fixed gas sampling lines from silo headspace to a safe location during a fire situation should be considered as this will provide a possibility to monitor the inerting and fire suppression process. The instruments should preferably be capable of measuring O₂ and CO/CO₂ (%-scale).

9.4.3.3 Fire protection of silo headspace

The piping and gas inlets for the inert gas distribution system should be located in the upper part of the silo wall to avoid damage to the pipe system in case of an explosion. The number of inlets should be based on the silo cross section area and the gas inlet dimension should ensure a low inlet velocity to avoid dust formation. CO₂ shall not be used as extinguishing media (see NOTE 1).

The gas supply and the gas distribution system should be designed to provide a flow rate of not less than 1 to 3 kg/m² (silo cross section area) per hour.

The gas injection openings/nozzles at the silo headspace shall be located as far away as possible from the pressure relief opening (see [9.3.1.2](#)) in order to reduce the inert gas loss as much as possible. The openings/nozzles shall be located such that they are not covered by the bulk material at maximum fill level and designed so they not get blocked or clogged by dust.

A fixed deluge (water)/foam/CAF system can be mounted in the silo ceiling as a complement to the inert gas system for the protection of the silo headspace in case of an open fire situation. Such system is important, in particular in large diameter silos or silos equipped with explosion vents which, after an explosion, can be very difficult to seal effectively making it difficult or even impossible to obtain an extinguishing effect using only inert gas. Using a foam system with high quality of expanded foam (e.g. applied as CAF) will reduce the use of water and provide a foam blanket on the top of the material reducing the entrainment of oxygen into the bulk material (see NOTE 2).

Because of the risk of a gas/dust explosion, manual foam application is not recommended due to injection of air through the openings. If manual foam application is required, openings shall be positioned such that the foam can be applied to form a uniform layer covering the entire top layer of the pellets in the silo. The openings shall be designed to limit the air entrainment as much as possible.

A fixed stand pipe system with connections for the use by the fire and rescue service for additional or final firefighting should be considered. The pipe system should have connections for fire hoses at suitable locations at the access platforms at the silo top. Access/escape routes for the firefighting personnel shall be considered.

NOTE 1 The use of CO₂ as extinguishing media is not recommended as the silo headspace is likely to have an explosive atmosphere due the generation of pyrolysis gases. The discharge of CO₂ is known to generate electrostatic charge which could generate a spark and cause an explosion inside the silo headspace (see [D.2.3.2](#)).

NOTE 2 Using large quantities of water will cause swelling of the pellets and could endanger the entire silo construction due to the forces generated, see [Annex D](#).

9.4.3.4 Inert gas system for fire prevention

If there is an increased risk for self-heating and spontaneous ignition and/or that the consequences of a fire situation is unacceptable, injection of inert gas to reduce the oxygen concentration inside the silo should be considered.

The inert gas supply shall be connected to the gas distribution system at the base of the silo (see [9.4.3.2](#)) and have a capacity enough to keep the oxygen concentration in the bulk material below about 10 %.

As an alternative to using liquefied nitrogen for producing nitrogen gas (see [9.4.3.5](#)), a nitrogen gas generator could be installed, normally generating a mixture of about 95 % nitrogen and 5 % oxygen. Also here, the capacity should be enough to keep the oxygen concentration below 10 % (see NOTE 1 and NOTE 2).