BS EN 1539:2015

BSI Standards Publication

Dryers and ovens, in which flammable substances are released — Safety requirements

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National foreword

This British Standard is the UK implementation of EN 1539:2015. It supersedes BS EN 1539:2009 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/3/8, Thermoprocessing equipment - Safety.

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

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Dryers and ovens, in which flammable substances are released - Safety requirements

Séchoirs et fours dans lesquels se dégagent des substances inflammables - Prescriptions de sécurité

Trockner und Öfen, in denen brennbare Stoffe freigesetzt werden - Sicherheitsanforderungen

This European Standard was approved by CEN on 27 June 2015.

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European foreword

This document (EN 1539:2015) has been prepared by Technical Committee CEN/TC 271 “Surface treatment equipment - Safety”, the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by April 2016, and conflicting national standards shall be withdrawn at the latest by April 2016.

This document supersedes EN 1539:2009.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of the EU Directive 2006/42/EC.

For relationship with the EU Directive, see informative Annex ZA, which is an integral part of this document.

This European Standard is part of a series of standards in the area of safety for development and construction of machines and plants for the coating of surfaces with organic substances (paints, lacquers and similar products).

This European Standard was prepared with contribution of the following TCs:

— TC 186 "Industrial thermoprocessing - Safety";

— TC 198 "Printing and paper machinery - Safety";

— TC 200 "Tannery machinery - Safety";

— TC 202 "Foundry machinery".

NOTE 1 Although a dryer as a whole is not subject to the ATEX Directive 94/9/EC in a formal way, this document is based on a fundamental risk assessment according to this Directive.

NOTE 2 This European Standard is based on an explosion protection concept which does not define zones for areas with potentially explosive atmosphere.

In relation to the previous version of the standard, the following main modifications have been made

— the scope has been adjusted to meet the fields of application of the standard;

— the requirements for safety related controls have been modified for clarification;

— guidance for implementation of safety related control systems has been included;

— requirements for monitoring of heating system have been implemented;

— requirements for type B dryers have been detailed;

— requirements for minimization of energy usage and environmental impact have been included.

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

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

Introduction

This document is a type C standard as stated in EN ISO 12100.

This document is of relevance in particular for the following stakeholder group representing the market players with regard to machinery safety:

— machinery manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance).

The machinery concerned and the extent to which hazards, hazardous situations and hazardous events are covered are indicated in the scope of this European Standard.

When provisions of this type C standard are different from those which are stated in type A or B standards, the provisions of this type C standard take precedence over the provisions of the other standards, for machines that have been designed and built according to the provisions of this type C standard.

1 Scope

This European Standard deals with all significant hazards, hazardous situations and hazardous events relevant to ovens and dryers in which flammable substances are released by evaporation from and curing of coating materials.

The specific significant risks related to the use of this machinery with foodstuff and pharmaceutical products are not dealt with in this European Standard.

This European Standard is only applicable to machines which are used as intended and under the conditions which are foreseeable as malfunction by the manufacturer (see Clause 4).

For ovens and dryers in which flammable substances are released by evaporation from and curing of coating materials, in which the concentration of these flammable substances shall not, under no circumstances, exceed 3 % of the LEL, EN 746-1 and EN 746-2 may be applied instead of this European Standard.

This European Standard is not applicable to:

— ovens for hardening metals;

— enamelling plants;

— portable heating systems for drying (for instance infrared radiant heaters, hot-air blowers, blow-dryers);

— solvent recovery plants;

— distillation and/or refraction plants;

— textile dry-cleaning systems.

This European Standard is not applicable to machinery manufactured before the date of its publication as EN.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 547-1, *Safety of machinery — Human body measurements — Part 1: Principles for determining the dimensions required for openings for whole body access into machinery*

EN 619, *Continuous handling equipment and systems — Safety and EMC requirements for equipment for mechanical handling of unit loads*

EN 746-1, *Industrial thermoprocessing equipment — Part 1: Common safety requirements for industrial thermoprocessing equipment*

EN 746-2, *Industrial thermoprocessing equipment - Part 2: Safety requirements for combustion and fuel handling systems*

EN 953, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

EN 1127-1, *Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology*

EN 12198-1:2000+A1:2008, *Safety of machinery - Assessment and reduction of risks arising from radiation emitted by machinery - Part 1: General principles*

EN 12198-2, *Safety of machinery — Assessment and reduction of risks arising from radiation emitted by machinery — Part 2: Radiation emission measurement procedure*

EN 12433-1, *Industrial, commercial and garage doors and gates - Terminology - Part 1: Types of doors*

EN 12433-2, *Industrial, commercial and garage doors and gates - Terminology - Part 2: Parts of doors*

EN 12445, *Industrial, commercial and garage doors and gates - Safety in use of power operated doors - Test methods*

EN 12453, *Industrial, commercial and garage doors and gates - Safety in use of power operated doors - Requirements*

EN 12635, *Industrial, commercial and garage doors and gates — Installation and use*

EN 12978, *Industrial, commercial and garage doors and gates — Safety devices for power operated doors and gates — Requirements and test methods*

EN 13023, *Noise measurement methods for printing, paper converting, paper making machines and auxiliary equipment — Accuracy grades 2 and 3*

EN 13463-1, *Non-electrical equipment for use in potentially explosive atmospheres - Part 1: Basic method and requirements*

EN 14462, *Surface treatment equipment - Noise test code for surface treatment equipment including its ancillary handling equipment - Accuracy grades 2 and 3*

EN 14994, *Gas explosion venting protective systems*

EN 15061, *Safety of machinery — safety requirements for strip processing line machinery and equipment*

EN 50104, *Electrical apparatus for the detection and measurement of oxygen - Performance requirements and test methods*

EN 60079-0, *Explosive atmospheres - Part 0: Equipment - General requirements (IEC 60079-0)*

EN 60079-29-1, *Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases (IEC 60079-29-1)*

EN 60079-29-4, *Explosive atmospheres - Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases (IEC 60079-29-4)*

EN 60204-1:2006, *Safety of machinery - Electrical equipment of machines - Part 1: General requirements (IEC 60204-1)*

EN 61000-6-2, *Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments (IEC 61000-6-2)*

EN 60405, *Nuclear instrumentation - Constructional requirements and classification of radiometric gauges (IEC 60405)*

EN 60519-1, *Safety in electroheat installations — Part 1: General requirements (IEC 60519-1)*

EN 60519-6, *Safety in electroheat installations - Part 6: Specifications for safety in industrial microwave heating equipment (IEC 60519-6)*

EN ISO 12100:2010, *Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100:2010)*

EN ISO 10218-1, *Robots and robotic devices - Safety requirements for industrial robots - Part 1: Robots (ISO 10218-1)*

EN ISO 10218-2, *Robots and robotic devices - Safety requirements for industrial robots - Part 2: Robot systems and integration (ISO 10218-2)*

EN ISO 13732-1, *Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces - Part 1: Hot surfaces (ISO 13732-1)*

EN ISO 13849-1, *Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design (ISO 13849-1)*

EN ISO 14122-2, *Safety of machinery - Permanent means of access to machinery - Part 2: Working platforms and walkways (ISO 14122-2)*

EN ISO 14122-3, *Safety of machinery - Permanent means of access to machinery - Part 3: Stairs, stepladders and guard-rails (ISO 14122-3)*

EN ISO 14122-4, *Safety of machinery — Permanent means of access to machinery — Part 4: Fixed ladders (ISO 14122-4)*

ISO 19353, *Safety of machinery — Fire prevention and protection*

3 Terms and definitions

For the purposes of this document the terms and definitions given in EN ISO 12100 and the following apply.

3.1
dryer
oven
machine in which, by a drying process, flammable substances are released by evaporation and curing

Note 1 to entry: See 3.7 for the definition of drying process.

3.2
chamber dryer
dryer in which the temperature of workpieces and the concentration of flammable substances are a function of time

Note 1 to entry: Uniform temperature distribution is intended in the effective volume. This dryer is typically loaded in batches.

3.3
continuous flow dryer
dryer in which the temperature of workpieces and the concentration of flammable substances are a function of location

Note 1 to entry: This dryer may be subdivided into several sections with specific temperature and forced ventilation. Uniform temperature distribution is intended in the effective volume of sections. This dryer is typically loaded continuously or quasi continuously.

3.4
accessible dryer
dryer in which provision is made for the presence of persons inside the dryer during normal operation

3.5
type A-dryer
dryer in which by design, the concentration of flammable substances in the total volume is limited below values of maximum concentration of flammable substances given in Figure 1

3.6
type B-dryer
dryer in which by design the formation of hazardous explosive mixtures is prevented in any part of the dryer by limitation of the oxygen concentration

3.7
drying
process of evaporation or volatilisation of components of the printing or coating material and the products to be dried, as well as the curing of the printing or coating material

3.7.1
mould varnish drying
process of drying of mould varnishes for casting moulds and foundry cores, in which volatile components have a longer travel to the surface (range from some mm up to about 1 cm) compared with the drying of a surface coated part to be dried (µm range)

3.7.2
resin varnish drying
process of drying of products impregnated with resin products (impregnating resin or resin varnish), in which volatile components have a longer travel to the surface (cm range) compared with the drying of a surface coated part to be dried (µm range)

3.7.3
rapid evaporation
evaporation for which the concentration maximum of released flammable substances is reached relatively quick, in average in 180s

Note 1 to entry: For coating thickness ≤ 1 mm, the warming of the coating material is typically significantly faster than the warming of the coated substrate. The release of flammable substances is constricted only little by the thin coating, over the progressing drying process.

Note 2 to entry: The time at which the concentration maximum of released flammable substances is reached, is practically not influenced by the warming of the workpiece or the ventilation number.

3.7.4
slow evaporation
evaporation for which the concentration maximum of released flammable substances is reached significantly later, than for surface coated workpieces, in average around 30 min

Note 1 to entry: For very thick coatings or for coatings which deeply penetrate the workpiece ($\gg$1 mm) the evaporation rate of the released flammable substances is driven by the warming of the workpiece and the progress of curing of the coating material (e.g. for mould or resin varnish drying).

3.8
curing
transformation of a liquid or pasty printing or coating material or powder coating into a solid film of dried coating material

Note 1 to entry: This process is also known as gelling, through curing or through drying.

3.9
flammable substances
predominantly volatile organic compounds (VOC) which can be present as gases, vapours, liquids, solids, or mixtures of these, and which are able to undergo an exothermic reaction with air when ignited

Note 1 to entry: Flammable substances can be solvents which are flammable or slow burning; e. g. aldehydes, alcohols, hydrocarbons, esters, ketones, mineral oils, as well as mixtures containing these substances.

Note 2 to entry: Mixtures containing solvents can be printing and coating materials, e.g. inks, varnishes, lacquers.

Note 3 to entry: Solvents are also used as cleaning or washing agents, and could enter the dryer.

Note 4 to entry: The terms "flammable" and "combustible" are equivalent in this European Standard.

[SOURCE: EN 13237:2013, 3.36]

3.10
released flammable substances
gases and vapours released during drying which could form an explosive mixture with air

3.11
coating materials
products, in liquid or in paste or powder form, that when applied to a substrate forms a film possessing protective, decorative and/or other specific properties

Note 1 to entry: In general coating materials consist of binders, pigments, dyestuff, fillers and other additives. Moreover, liquid coating materials can contain solvents.

Note 2 to entry: Coating materials are, for instance, paints, lacquers, varnishes, impregnating resin varnishes, paste fillers, filling materials, impregnating agents, anti-noise agents, fire resisting agents, stains, burnishes, flock, adhesives, sealing compounds, as well as coating powders.

[SOURCE: EN ISO 4618]

3.12
drying temperature
higher temperature value of respectively

— the heating medium (air or gas within the total volume) at contact to the materials being processed or

— of the printing or coating material during drying

3.13
ignition temperature
lowest temperature of a heated wall as determined under specified test conditions, at which ignition of a combustible gas or liquid, in the form of gas or vapour mixture with air, will occur

Note 1 to entry: The terms "flammable" and "combustible" are equivalent in this European Standard.

[SOURCE: EN 13237:2013, 3.45]

3.14
flammability temperature
lowest temperature at which symptoms of combustion can be found on the coated or uncoated material

Note 1 to entry: Flammability temperature of a material is a safety parameter for which a continuous combustion could be stimulated under specified test conditions. It can be determined for combustible solid substances such as paper or similar base stock and their coating. Signs of combustion are flames, glowing or pyrogenic symptoms.

3.15
limiting temperature
corresponds to the lower of the following values:

— the flammability temperature (see 3.14); or

— 0,8 times the ignition temperature (see 3.13)

3.16
lower explosion limit
LEL
lower limit of the explosion range

Note 1 to entry: "Explosion limit" and "ignition limit" are equivalent. In accordance with international usage only the term "explosion limit" is used in this European Standard. See 3.19.1 of EN 13237:2013.

Note 2 to entry: Explosion limits are the limits of the explosion range. Explosion range is the range of concentration of a flammable substance within air, in which an explosion can occur. See 3.22 of EN 13237:2013.

3.17
explosive mixture
mixture with air and combustible substances in the form of gases, vapours, mist or dust, in which after ignition has occurred, combustion spreads to the entire unburned mixture

Note 1 to entry: Explosive atmosphere is an explosive mixture under atmospheric conditions, see 3.28 of EN 13237:2013.

3.18
normal operation
situation when the dryer performs its intended function within its design parameters

3.19
forced ventilation
technical ventilation consisting of one or more of the following systems:

— fresh air supply system;

— air recirculation system;

— air exhaust system

3.20
required exhaust flow rate
controllable exhaust flow rate maintaining the concentration of released flammable substances within the total volume at any time below the maximum admissible concentration

3.21
minimum exhaust flow rate
constant air flow rate maintaining the maximum concentration of released substances within the total volume below the maximum admissible concentration

3.22
maximum admissible quantity of released flammable substances
maximum quantity of flammable substances which may be released within the chamber dryer per charge, corresponding to the minimum forced ventilation flow rate with consideration of the drying temperature corrections

3.23
maximum admissible throughput of flammable substances
maximum quantity of flammable substances per unit time which may be released within a continuous flow dryer corresponding to the minimum forced ventilation flow rate with consideration of the drying temperature corrections

3.24
maximum admissible concentration of flammable substances
maximum concentration of flammable substances within the total volume of the dryer

3.25
total volume
net volume within the dryer in which flammable substances can be present

Note 1 to entry: The total volume includes ventilation of all section(s) and the recirculation systems of the dryer and ends at the outlet connection of the dryer housing to the external exhaust device.

Note 2 to entry: The total volume does not include any charged materials, supports, transport systems, thermal cleaning systems, chimneys or other ducts between sections or equipment.

3.26
effective volume
part of the total volume in which the material to be dried is charged or moved

3.27
main vaporization time
period of time during which the major quantity of flammable substances is released

Note 1 to entry: See A.1.2.

3.28
pre-drying loss
reduction in the amount of releasable flammable substances due to drying by air before the coated material is charged into the dryer

Note 1 to entry: See A.1.2.

3.29
peak release rate
maximum release of flammable substances per unit time within the dryer

3.30
gate
device for closing an opening which is provided for passage of conveyors and workpieces

3.31
boundary layer
process related layer of gaseous potentially explosive atmosphere in direct proximity of the workpiece

Note 1 to entry: The thickness of the boundary layer typically is several millimetres.

3.32
oxygen limit concentration
lowest value of the oxygen concentration within a mixture of flammable substances in gas at which a potentially explosive atmosphere is generated

3.33
positive operating pressure
pressure inside a type B-chamber dryer preventing inflow of atmospheric oxygen by intended or unintended leaks

3.34
course of minimum drying temperature
required lowest drying temperature depending on time (chamber dryers) or location (continuous flow dryers) at which the intended release of flammable substances is ensured

Note 1 to entry: It may be required to consider other process parameters, especially the conveying speed of continuous flow dryers

3.35
lower explosion point
LEP
temperature at which the concentration (substance amount fraction) of the saturated vapor of a flammable substance in a mixture with air reaches the lower explosion limit

Note 1 to entry: Unknown LEP’s can be estimated as follows: pure, non-halogenated liquids: LEP 5 °C below the flash point; solvent mixtures without halogenated component: LEP 15 °C below the flash point.

4 Significant hazards

Table 1 — List of significant hazards

Hazard factors	**Location or situation of the hazard**	**Specific requirements Applicable clauses of this European Standard**	**General requirements Applicable clauses of** EN ISO 12100:2010
4.1 General	This clause contains all hazards, hazardous situations and events as far as they are dealt with in this document, identified by risk assessment significant for this type of machinery and which require action to eliminate or reduce the risk. NOTE EN ISO 12100 contains information for the procedure of risk assessment.	5.1	4.1
4.2 Mechanical hazards		5.2, 7.2	4.2
4.2.1 Shearing, crushing and drawing-in hazards by unprotected moving parts of the machine, parts with hazardous surfaces and parts moving in an uncontrolled way	a) actuators, hoisting devices and automatic handling systems (e.g. robots) during charging and discharging of dryers; b) charging assistances and conveying systems for continuous flow dryers; c) fans (e. g. injuries caused by rundown of fan wheel) and air inlets; d) damper adjuster; e) moving parts of dryers (e.g. doors, gates, hoods, top and bottom boxes of continuous flow dryers).	5.2.1, 7.2.1	4.2.1, 4.2.2
4.2.2 Missing means of escape for operators in dryers which could be entered	a) when obstacles or obstructions can impede a quick evacuation by the operator(s) from the dryer in case of mechanical accident or fire; b) in case of an accidental significant lowering of pressure inside a dryer (e. g.: obstruction of air inlet) capable: 1) of clamping the doors by mechanical deformation of the structure of the dryer; and/or 2) of increasing the door opening effort beyond human capability.	5.2.2, 7.2.1	
4.2.3 Personnel's slip, trip, twist and fall hazards	a) on ladders, gangways, platforms or stairs; b) on gratings at floor level; c) on non-slip resistant floors; d) due to insufficient lighting.	5.2.3, 7.2.1, 7.2.4	4.10

4.3 Electrical hazards	Shock currents (by direct or indirect contact) caused by e.g.: a) electrically live parts that are not insulated for operational reasons (e.g. on IR-radiators); b) electrically live parts when the insulation is damaged by contact with solvents or by mechanical effects.	5.3	4.3
4.4 Thermal hazards	Burns and scalds, caused by contact with hot media, for instance: a) contact with hot surfaces of the dryer; b) radiation of heat sources; c) flame, electric arcs or explosions, see also 4.8.	5.4, 7.2.1	4.4
4.5 Hazards generated by noise	Noise exposure, hearing loss and/or physiological impacts caused by noise emissions from e.g.: a) fans; b) high air velocities in ducts and equipment; c) drives and conveyors; d) resonant vibrations; e) burners.	5.5, 7.2.1	4.5
4.6 Hazards generated by radiation	Significant hazards for the eyes by: a) infrared radiation; b) visible radiation; c) ultraviolet radiation; d) microwave radiation. Significant hazards for the skin by: e) infrared radiation; f) ultraviolet radiation; g) microwave radiation. Significant hazards for body and organs by: h) microwave radiation; i) infrared radiation; j) X-radiation; k) electron beams. NOTE For further information regarding the effects of hazards generated by radiation, see EN 12198-1, EN 12198-2 and EN 12198-3.	5.6, 7.2	4.7

4.6.1 Hazards generated by electromagnetic fields	Caused by e.g.: a) burns by metal heated by induction which is in contact with the body; b) effects on cardiac pacemakers and physiological effects; c) hazardous malfunctions, like for instance shortcut of electronic safety circuits, guards at access to danger zones, warning devices, due to interferences between live parts of control systems and safety systems generated by dryers with high current strength, for instance by induction dryers	5.6	4.7
4.7 Hazards generated by health hazardous substances	By entry of health hazardous liquids, gases, vapours, mists, fumes and dusts, for instance, via a) absorption of health hazardous liquids (e.g. coating materials, solvents, hydraulic or heat-carrier liquids) coming into contact with the skin; b) inhalation of health hazardous gases or vapours released during drying (e.g. solvent vapours, nitric oxides, ozone); c) inhalation of health hazardous gases; d) inhalation of health hazardous gases and vapours released by the automatic fire extinguishing system (e.g. CO_2).	5.7, 7.2	4.8
4.7.1 Hazards due to lack of oxygen	Asphyxiation due to inhalation of inert gas escaping from the dryer or from the inert gas supply system.	5.7, 5.9.3, 7.2	

4.8 Fire hazards	Generated by contact with or ignition of flammable substances by: a) heating systems (e.g. burner flame); b) hot surfaces (e.g. of heating systems, of electrical equipment); c) mechanically induced sparks (e.g. by fans and/or conveyors); d) electrostatic and atmospheric discharges; e) electrical sparks; f) welding and other sources of thermal energy (e.g. during maintenance). NOTE Examples of flammable substances are: — coating materials, solvents or thinners; — products to be dried; — components of dryers; — condensates and deposits of coating material in insulations, pits, exhaust air ducts and filters; — combustibles used in burners of the heating and drying system; — flammable substances used for cleaning purposes.	5.8, 7.2	4.8

4.9 Explosion hazards	In case of generation of an explosive mixture as a result of — an increase of concentrations of flammable substances above the lower explosion limit (LEL); — overrunning the oxygen limit concentration in type B-dryers and due to ignition by: a) heating systems (e.g. burner flame); b) hot surfaces (e.g. of heating systems, of electrical equipment); c) mechanically induced sparks (e.g. by fans and/or conveyors); d) electrostatic and atmospheric discharges; e) electrical sparks; f) welding and other sources of thermal energy (e.g. during maintenance). NOTE Examples of released flammable substances are: — solvent vapours and gas emissions from the printing or coating material and the products to be dried; — vapours of combustibles and/or of the combustion products of the heating system; — vapours released from deposits; — controlled quantity/throughput of solvents during blanket washing and/or other operations; — manually added and thus uncontrollable addition of solvents during rubber blanket washing and/or other processes; — fuel gases; — flammable heating gases.	5.9.2, 5.9.3, 7.2	4.8

4.9.1 Formation of explosive atmosphere in type A dryers	Exceeding the maximum admissible concentration of flammable substances in a part of the total volume by — falling below the minimum required exhaust flow rate; — exceeding the maximum admissible temperature; — underrunning the course of the minimum drying temperature — exceeding the maximum admissible conveying speed of the conveyor; and/or — exceeding the maximum admissible input of flammable substances generated by — failure, unexpected start-up or overrun of the heating system; — failure of the conveyor (e.g. dryers of printing machines, wood materials, overheating of items); — unexpected start-up or overrun of the conveyor; — failure of forced ventilation (including recirculation air); — failure of energy supply; and/or — failure of control unit/control system, like for instance malfunction of temperature or concentration monitoring device.	5.9.2, 5.10.2, 7.2.2	
4.9.2 Formation of explosive atmosphere in type B dryers	Overrunning the oxygen limit concentration in a part of the total volume as a result of — overrunning the minimum required volume flow of the inert gas; — underrunning the required positive operating pressure; — underrunning the course of the minimum drying temperature; due to — failure, unexpected start-up or overrun of the heating system; — failure of the inert gas supply system (including recirculation); — failure of energy supply; — failure of control unit / control systems, for instance malfunction of temperature or concentration measuring system.	5.9.3, 5.10.3	4.4, 4.11.1 to 4.11.10, 4.12.1 to 4.12.3, 4.13, 4.14

4.10 Failure of energy supply	Generation of explosive atmosphere due to — exceeding of maximum concentration of flammable substances in a part of the total volume; — overrun of maximum admissible oxygen concentration due to loss of inertisation.	5.9.2.5.10, 5.9.3, 7.2.2	
4.11 Hygiene	Not dealt with		

5 Safety requirements and/or protective measures

5.1 General

Dryers shall comply with the safety requirements and/or protective measures of Clause 5. In addition, dryers shall be designed according to the principles of EN ISO 12100 for relevant but not significant hazards (for instance sharp edges), which are not dealt with by this European Standard.

5.2 Safety requirements against mechanical hazards

5.2.1 Shearing, crushing, drawing-in

Injuries by shearing, crushing or drawing-in by movements of machine parts and equipment shall be prevented by design and construction. A contact with hazardous parts of the machine shall be prevented by the following measures:

— on fans and automatic damper adjusters: installation of guards;

— on power-operated doors: guards or protective devices.

If automatic devices, like for instance robots or reciprocators or similar systems are installed, access to hazardous areas

— shall be prevented by fixed guards or

— shall be interlocked with the hazardous movement/event by guards or protective devices in a hydraulic, pneumatic or electrical way (see 5.10).

Fixed or movable guards shall comply with EN 953.

Robots shall comply with EN ISO 10218-1 and EN ISO 10218-2.

Conveying systems shall comply with EN 619 or EN 15061.

Power-operated doors shall comply with EN 12433-1, EN 12433-2, EN 12445, EN 12453, EN 12635 and EN 12978.

5.2.2 Means of escape

Dryers shall be equipped with means of escape (e.g. doors, panels), if they are designed to be entered.

Means of escape shall be capable of being easily opened from the inside and without any auxiliary means.

Dryers equipped with power operated gates and/or vertical or horizontal sliding gates shall be equipped with additional means of escape. The additional means of escape shall not be part of the power operated gate.

Doors giving access during operation shall have a minimum width of 800 mm and a minimum height of 2 000 mm (free opening). In the sense of this European Standard maintenance openings are not considered to be doors.

Maintenance openings shall comply with EN 547-1.

See 5.10.2, Table 4 and 5.10.3, Table 5 for requirements on interlocking of doors and maintenance openings with safety related functions.

Information on means of escape and lighting shall be given in the information for use, see Clause 7.

5.2.3 Safety requirements against slip and fall hazards

Floor gratings, platforms and other treads which can be trodden shall be designed in such a way that hazards by slipping or falling are reduced to a minimum.

Ladders, gangways and railings shall comply with EN ISO 14122-2, EN ISO 14122-3, and EN ISO 14122-4.

Gratings, platforms or similar devices shall be fixed in their frames to prevent displacements or instability.

Information on cleaning and maintenance shall be given in the information for use, see Clause 7.

5.3 Safety requirements against electrical hazards

5.3.1 General

The electrical equipment shall comply with EN 60204-1.

The additional requirements of EN 60519-1 shall be observed.

5.3.2 Electrical equipment

Protection against electrical shock shall comply with requirements of EN 60204-1:2006, 6.2.

All conductive parts shall be earthed.

The electrical equipment shall be selected and installed in such a way to prevent damage by:

— influences of temperature due to thermal conduction, convection and/or radiation;

— contact with hot parts, drips or molten particles of the materials being processed;

— chemical attack by substances released or processed during treatment, like, for instance, solvents and other aggressive liquids;

— external mechanical loads.

References to repeated tests of the electrical equipment according to EN 60204-1:2006, 18.1 and 18.6 shall be given in the information for use, see Clause 7.

5.3.3 External influences on the electrical equipment

All systems and apparatus relevant for safety shall be constructed in such a way that, in accordance with EN 61000-6-2, they cannot be influenced by interaction with electromagnetic fields.

5.4 Safety requirements against thermal hazards

Protection against burns by hot surfaces shall be ensured by appropriate insulation or protection against contact within hand's/arm's reach and the working area. The surface temperature shall not exceed the burn thresholds given in EN ISO 13732-1. Exceptions are allowed for small localised areas of the surface (for example flanges of burners, bolts, fans, and roller shaft).

NOTE Maximum allowable surface temperatures according to EN ISO 13732-1 depend on various parameters, e.g. duration of contact, material.

If these measures are not practicable, areas of elevated temperatures shall be indicated by means of suitable marking, warning signs, etc. In addition attention shall be drawn to the presence of such hazards in the information for use (see 7.2.3 d)).

If a contact with operation systems (e.g. doors, control levers) which are at temperatures above those specified in EN ISO 13732-1 cannot be avoided, suitable protective clothing shall be used. Requirements for such clothing shall be included in the information for use (see 7.2.1).

5.5 Safety requirements against noise hazards

Dryers shall be so designed and constructed that risks resulting from the emission of airborne noise are reduced to the lowest level taking account of technical progress and the availability of means of reducing noise, in particular at source.

For example the following measures can be adopted – if possible:

— equipment set on anti-vibratory supports;

— flexible connections between the ducts and especially between fans and ducts;

— choice of fan speed according to the most favourable noise curves;

— air velocity reduction in ducts;

— ducts soundproofing;

— other means able to avoid vibrations, resonances and any other noise generated by ancillary equipment permanently installed and connected to the dryer that should not propagate to the dryer's structure.

NOTE 1 This list is not exhaustive. EN ISO 11688-1 gives general technical information on widely recognised technical rules and means for the design and construction of low-noise machinery.

NOTE 2 EN ISO 11688-2 gives useful information on noise generation mechanisms in machinery, plants and systems.

The determination, declaration and verification of airborne noise emission levels of dryers shall be carried out according to EN 14462 except for continuous flow dryers for paper, board and foil for which EN 13023 shall be used.

The noise emission values according to EN 14462 or EN 13023 shall be indicated in the information for use, see Clause 7.

5.6 Safety requirements against radiation hazards

Dryers shall be designed and constructed in such a way as to minimize hazards by radiation.

Dangerous emission of radiation into the working area shall be prevented by specific shielding measures (for instance screen plates, filter disks, screen grids).

NOTE EN 12198-3 deals with a design strategy to reduce the flow of radiation by attenuation or screening.

Accesses and openings shall be interlocked with the radiation source in such a way to cut-off or screen the source of radiation before a hazard by radiation is generated.

The risks of hazards by radiation shall be assessed according to EN 12198-1. The dryer shall be classified into an emission category according to EN 12198-1:2000+A1:2008, 7.2, Table 2. The classification shall be done by the manufacturer and shall be based on measuring according to EN 12198-2 and/or prediction of emission of radiation.

Microwave devices shall comply with EN 60519-6.

Electron beam equipment shall comply with EN 60405.

The radiation emission values according to EN 12198-2 and the marking according to EN 12198-1 shall be given in the information for use (see 7.2).

5.7 Safety requirements against health hazardous substances

Dryers shall be designed in such a way to prevent a health hazardous load of the inhaled air within the working area inside and outside the dryer. The relevant exposure limit values for gases, mists or dusts shall be observed.

NOTE Exposure limit values for health hazardous substances are subject to national regulation.

The following measures shall be applied – as far as required by risk assessment:

— extraction at dryer openings by forced ventilation together with local extraction, if necessary;

— ventilated flash-off areas in front of continuous flow dryers;

— purging of chamber dryers by ongoing operation of the exhaust fan after cut-off of the heating system and before opening the dryer's door.

Accessible dryers shall be designed in such a way to ensure the required oxygen concentration inside the dryer before entering.

Prior to the release of the guard locking of openings type B-dryers shall be purged with fresh air. Hazards resulting from gases escaping from permanent openings at inlet and outlet shall be prevented by measures according to 5.9.3.2.

5.8 Fire protection and prevention

5.8.1 General

The required fire protection and prevention measures depend on the amount of the fire load of the dryer, the presence of persons and the fire hazards (present ignition sources, type and quantity of released flammable substances and products to be dried). The requirements of ISO 19353 shall be observed.

NOTE For the selection of fire protection and prevention measures existing company fire protection and prevention concepts can be taken into consideration.

5.8.2 Materials and construction

The following elements of construction shall be made of non-flammable material

a) fixed elements of construction (for instance floors, walls, ceilings, fittings, air ducts);

b) movable elements (for instance doors for charging and access).

The fire resistance of non-flammable elements of construction shall not change during normal operation.

The following elements of construction shall not support or propagate a fire or increase the fire hazard:

c) heat insulation;

d) small elements of construction.

In order to reduce potential fire loads (for instance by condensates or accumulation of coating powder):

e) walls and ceilings shall be easy to clean;

f) gratings shall be demountable for cleaning purposes;

g) the forced ventilation and the conveying technique shall be designed in such a way that the coating powder remains on the workpieces;

h) the generation of condensates within the heat insulation shall be minimised (for instance construction tight to the total volume);

i) exhaust gas and recirculation air ducts shall be constructed and installed in such a way that deposits

    1) are reduced to a minimum,

    2) can be detected and removed easily via inspection ports or demountable parts of the ducts.

NOTE Deposits preferably occur at abrupt changes in cross-section or direction.

References concerning cleaning and maintenance shall be given in the information for use, see Clause 7.

5.8.3 Heating systems

Heating systems and temperature limiting devices shall comply with the requirements of 5.9.2.3. The requirements of 5.9.2.5.4 and 5.9.2.5.6 shall be considered.

5.8.4 Prevention of ignition by hot surfaces

Ignition of the coating materials and/or products on hot surface of the dryer shall be prevented. Hot surfaces occur e.g. at the heating device. Typical measures are the installation of drip pans, baffles or deflector plates or shields and/or appropriate arrangement of surfaces of the heating device.

References concerning cleaning and maintenance shall be given in the information for use, see Clause 7.

5.8.5 Prevention of ignition by overheating

Ignition of workpieces, transport components, residues of coating materials, etc. shall be prevented.

For radiation dryers in which the workpieces, or rather the coating layer, are heated by the corresponding radiation, the radiant power shall match the residence time of the flammable substances within the field of radiation (for instance time control, transport interlocked with power, temperature monitoring) and shall be verified during commissioning (see Clause 6).

5.8.6 Prevention of auto-ignition

Dryers shall be designed to prevent auto-ignition of the materials processed.

NOTE 1 Nitro-varnishes auto-ignite at temperatures above 130 °C.

NOTE 2 Auto-ignition can be avoided by limitation of exposure time to temperatures above the auto-ignition temperature (e.g. by process speed in the heat-set process).

5.9 Explosion protection and prevention requirements

5.9.1 General

Explosion protection and prevention is based on the prevention of hazardous explosive mixtures

— in type A-dryers, by observing the concentration limits by means of forced ventilation and/or by avoiding ignition sources;

— in type B-dryers, by limiting the oxygen concentration by displacement of atmospheric oxygen by inert gas.

If a dryer is subdivided into several dryer sections (ventilation sections) the explosion protection and prevention requirements shall be ensured for each section separately, as well as for their interactions.

5.9.2 Type A-dryers

5.9.2.1 General

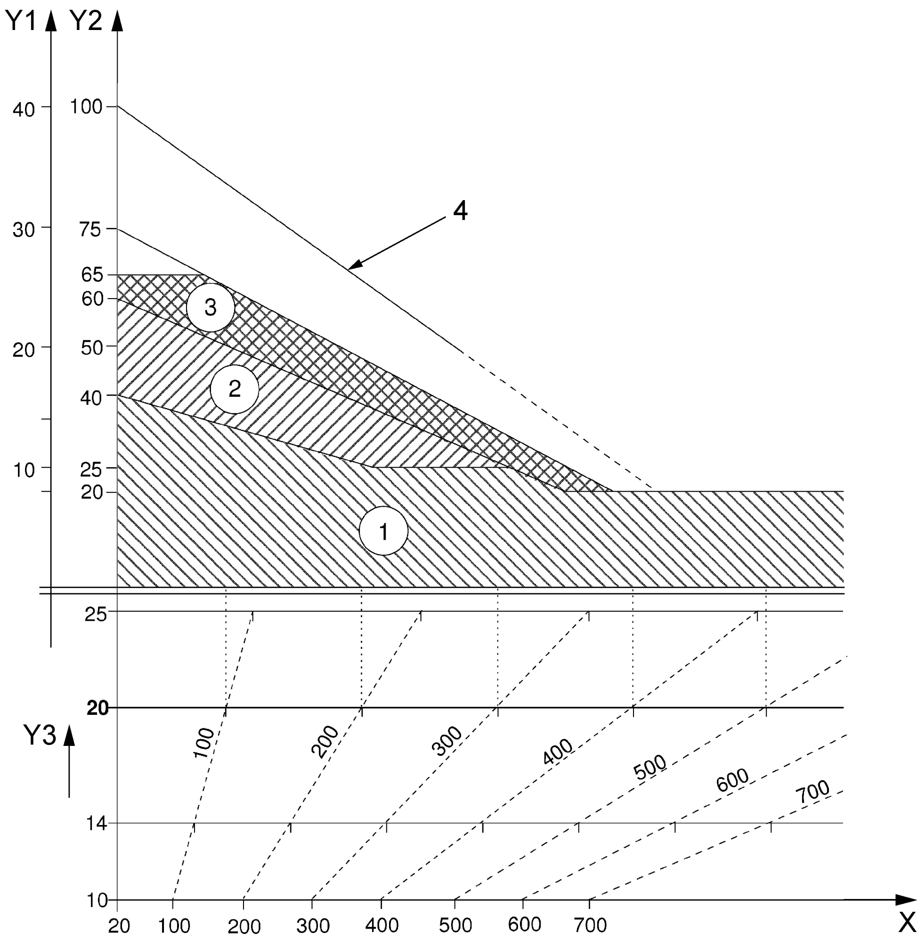
Type A dryers shall be equipped with a forced ventilation system to ensure the maximum admissible concentration according to Figure 1 for the maximum admissible quantity or the maximum admissible throughput of flammable substances. Excluded of this is the boundary layer of the treated product.

NOTE 1 Different operating conditions can result in different minimum exhaust flow rates.

NOTE 2 The boundary layer typically contains concentrations of flammable substances above the maximum admissible concentration of flammable substances according to Figure 1.

— The forced ventilation shall prevent dead areas within the total volume of the dryer (e.g. by a recirculation air system).

— Doors, gates and other openings with hazardous influence on the uniformity of the ventilation shall be guardlocked to prevent formation of hazardous explosive atmosphere.



Key

X maximum drying temperature in °C

Y1 $C_{adm\ 20°C}$ in gm^{-3} for C_{LEL}= 40 gm^{-3}

Y2 $C_{LEL\ adm}$ in % of the $LEL_{20°C}$

Y3 Δ_{LEL} in %/100K (e.g. 20%/100K)

4 100% of the LEL (ϑ), the auto-ignition temperature for common solvents can be reached when exceeding 250°C.

Figure 1 — Operating ranges for Type A dryers

Figure 1 defines the three admissible operating ranges corresponding to 5.9.2.2 with respect to the admissible drying temperature and the maximum admissible concentration of released flammable substances. The temperature dependence of the LEL is taken into account in Y3, which determines the progression of the temperature scale X. Depending on the value of Δ_{LEL} the X-axis shall be set to this level. The intersections of the temperature level curves at 100°C, 200°C are defining the temperature scale which shall be used. The concentration of released flammable substances is given by the axes Y2 (in % of the LEL) and Y1 (equivalent in gm^{-3} for 100% at LEL = 40 gm^{-3}).

For the calculation of the maximum concentration or throughput of flammable substances, see Annex A.

5.9.2.2 Requirements depending on the maximum concentration of flammable substances

5.9.2.2.1 General

Depending on the operating range (see Figure 1) the requirement of Table 2 shall be fulfilled. Each row represents an equivalent alternative for the corresponding operating range.

Table 2 — Requirements according to the operating ranges

	Monitoring of minimum exhaust flow rate	Concentration monitoring		Monitoring of input of flammable substances	Prevention of ignition sources	Explosion relief
		Without control of required exhaust volume flow	With control of required exhaust volume flow			
Range 1	5.9.2.2.2	—	—	—	—	—
	—	5.9.2.2.3	—	—	—	—
	—	—	5.9.2.2.4	—	—	—
	For dryers connected to automatic coating processes in which malfunction may cause an overrun of the LEL monitoring of minimum exhaust volume flow only may not be sufficient. Additional requirements shall be applied based on the risk assessment: — Monitoring of concentration of flammable substances — Monitoring of input of flammable substances. NOTE This is applicable, for instance, for coil coating systems.					
Range 2	5.9.2.2.2	5.9.2.2.3	—	—	—	—
	5.9.2.2.2	—	—	—	5.9.2.2.6	—
	—	5.9.2.2.3	—	—	5.9.2.2.6	—
	5.9.2.2.2	—	—	5.9.2.2.5	—	—
	—	5.9.2.2.3	—	5.9.2.2.5	—	—
	—	—	5.9.2.2.4	—	5.9.2.2.6	—
	—	—	5.9.2.2.4	5.9.2.2.5	—	—
Range 3	5.9.2.2.2	—	—	5.9.2.2.5	5.9.2.2.6	—
	—	5.9.2.2.3	—	5.9.2.2.5	5.9.2.2.6	—
	5.9.2.2.2	5.9.2.2.3	—	—	5.9.2.2.7	—
	5.9.2.2.2	5.9.2.2.3	—	—	—	5.9.2.2.8
	—	—	5.9.2.2.4	5.9.2.2.5	5.9.2.2.6	—
	—	—	5.9.2.2.4	—	5.9.2.2.7	5.9.2.2.8

For requirements for performance level of safety related control systems see 5.10.

5.9.2.2.2 Monitoring of minimum exhaust flow rate

The dryer shall be equipped with a minimum exhaust flow rate monitoring device and, if required for safe operation, with an additional monitoring of the recirculation flow rates. The monitoring shall be carried out by measuring of flow rates (see Annex F).

During drying, the heating system and the forced ventilation shall be interlocked. The heating system shall be active only when the required corresponding exhaust flow rate is ensured.

5.9.2.2.3 Monitoring of concentration

For monitoring of concentration of released flammable substances dryers shall be equipped with gas monitoring systems according to EN 60079-29-1.

Concentration monitoring devices shall comply with C.1. They shall be selected with respect to:

— released flammable substances;

— response times;

— temperature ranges (temperature of the measuring gas and ambient temperature at the installation site).

Operational influences like condensation, pollution, sensor contamination, mechanical exposure shall be considered.

NOTE See also EN 60079-29-2.

5.9.2.2.4 Control of exhaust flow rate

If the required exhaust flow rate is controlled via the release of flammable substances, the dryer shall be equipped with a concentration monitoring system according to 5.9.2.2.3. The gas monitoring systems used shall comply with PL d of EN ISO 13849-1 as a separate entity.

NOTE This requirement can also be satisfied, for instance, by a divers or redundant arrangement of gas monitoring systems.

If the required exhaust flow rate is controlled via the input of flammable substances (e.g. measurement of the coating material flow), the exhaust flow rate shall be interlocked with the input of flammable substances.

5.9.2.2.5 Monitoring of input of releasable flammable substances

Dryers shall be equipped with an automatic charging device.

Dryers shall be equipped with a monitoring of all parameters (for instance amount of varnish, amount of ink per square metre, solvent input per second, film thickness, solvent content, conveyor speed) relevant for the input of releasable flammable substances.

The monitoring shall be made at the appropriate position to ensure, that the maximum admissible concentration of releasable flammable substances is not exceeded.

NOTE The measuring device could be part of upstream machinery (e.g. coating machinery).

5.9.2.2.6 Prevention of ignition sources by equipment and installations of category 3G

Equipment and installations at least of category 3G of EN 13463-1 or EN 60079-0 shall be installed within the total volume. In addition, the temperature-resistance of the components used shall be considered.

The boundary layer shall not contain ignition sources.

5.9.2.2.7 Prevention of ignition sources by equipment and installations of category 2G

Equipment and installations at least of category 2G of EN 13463-1 or EN 60079-0 shall be installed within the total volume. In addition, the temperature-resistance of the components used shall be considered.

The boundary layer shall not contain ignition sources.

5.9.2.2.8 Explosion relief

Dryers shall be equipped with an explosion relief according to Annex E.

5.9.2.3 Requirements for heating systems

5.9.2.3.1 General

Heating systems operated with combustibles or with electro-heat shall be designed according to EN 746-1 and EN 746-2. Additional, the requirements of 5.10. apply.

5.9.2.3.2 Monitoring of heating system against overrun of the limit temperature

Dryers in which exceeding of the limit temperature can result in hazards, shall be equipped with a temperature limiting system.

The temperature limiting system shall cut-off the heating system automatically in case of overrun of the maximum drying temperature by more than 10 %. If the heating system itself, even in case of failure, cannot increase the dryer's temperature, to a value above the limit temperature, a temperature limiting system is not required.

5.9.2.3.3 Monitoring of heating system against underrun of the course of the minimum drying temperature

Dryers in which underrun the course of the minimum drying temperature can result in hazards, shall be equipped with a temperature limiting system.

In dryers, in which underrun of the course of the minimum drying temperature can result in exceeding the maximum admissible concentration of flammable substances, the temperature limiting system shall be interlocked with functions according to 5.9.2.5.6.

NOTE This hazard may occur in continuous flow dryers due to transfer of concentration in downstream sections or systems; or in chamber dryers due to reduction of the minimum exhaust volume flow after the main vaporization time, see 5.9.2.5.3.

5.9.2.4 Requirements for the input of flammable substances

The maximum admissible input of flammable substances shall be calculated according to Annex A.

Information on the maximum input of releasable flammable substances shall be given in the information for use, see Clause 7.

5.9.2.5 Interlocking of forced ventilation, heating system and input of flammable substances

5.9.2.5.1 General

The interlock between forced ventilation, heating system and input of flammable substances shall ensure that the LEL is not exceeded.

Dryer sections shall be considered separately and with respect to their interactions.

Information for safe operation shall be given in the information for use, see Clause 7.

5.9.2.5.2 Purging

The dryer shall be purged

— before the first start-up;

and

— after each stop of forced ventilation.

The total volume of the dryer shall be purgeable with fresh air. Purging shall be integrated in the safety related control. The requirements for forced ventilation apply (see 5.9.2).

The heating system and the forced ventilation shall be interlocked that the heating system cannot be started before the purge process is completed.

NOTE 1 Purging reduces the concentration of remained flammable substances or other combustibles (for instance escaping from fuel supplies or which could be generated by insufficient combustion) within the total volume. The required number of air exchanges depends on the concentration of flammable substances within the total volume at the beginning of the purge operation and is influenced by, for instance:

— contaminations (resin varnish, paint residues);

— condensation products;

— cleaning and maintenance works (for instance when using materials containing solvents);

— rundown period of exhaust flow rate;

— leakage of fuel.

NOTE 2 In practice a minimum purging of the total volume with a quantity of fresh air minimum five times of this volume is considered to be safe.

Gas monitoring devices (see 5.9.2.2.3) which are used for determination of the purging time shall detect all released flammable substances within the total volume during all operating conditions of the dryer.

5.9.2.5.3 Drying

Before charging, the required drying temperature and the required exhaust flow rate or the minimum exhaust flow rate shall be ensured.

For chamber dryers according to 5.9.2.2.2 and 5.9.2.2.3 the exhaust flow rate after the main vaporisation time shall be at least 25 % of the minimum exhaust flow rate.

5.9.2.5.4 Shut-down of the dryer

In case of operational shut-down of the dryer (e.g. end of process)

— the input of flammable substances shall be stopped;

— the heating system shall be cut off;

— the required forced ventilation flow rate shall be ensured until the hazard of overheating and concentration increase is prevented (rundown).

Interactions between the dryer's sections shall be considered.

5.9.2.5.5 Failure of forced ventilation

In case of failure of forced ventilation or underrun of the required minimum exhaust flow rate, the heating system shall be cut-off and the input of flammable substances shall be stopped. The heating system and the input of flammable substances shall not re-start automatically.

5.9.2.5.6 Failure of heating system

In case of failure of the heating system, the minimum exhaust flow rate or the maximum value of the required forced ventilation flow rate shall be ensured and the input of flammable substances shall be stopped. The input of flammable substances shall not re-start automatically.

5.9.2.5.7 Failure of conveying system

In case of failure of the conveying system in continuous flow dryers, the minimum exhaust flow rate or the maximum value of the required forced ventilation flow rate shall be ensured and in case of a hazard of overheating and/or a hazard of exceeding the maximum admissible concentration of flammable substances the heating system shall be cut-off. The heating system shall not re-start automatically.

5.9.2.5.8 Failure of a safety-relevant control system

In case of failure of a safety-related control system the minimum exhaust flow rate or the maximum value of the required forced ventilation flow rate shall be ensured, the heating system shall be cut-off and the input of flammable substances shall be stopped. The heating system and the input of flammable substances shall not re-start automatically.

5.9.2.5.9 Failure of the control system

A failure of the entire control system shall result in a cut-off of the heating system and a stop of the input of releasable flammable substances.

Further measures shall be defined according to type of construction and mode of operation on the basis of a risk assessment. Measures could be:

a) interruption of charging;

b) Measures to prevent or reduce the effects of a reduction of the forced ventilation flow rate, for instance:

   1) emergency ventilation;

   2) extended run-down characteristic of the fan;

   3) set dampers to appropriate position;

   4) uninterrupted energy supply or substitute or auxiliary drive system;

c) operating method to be followed in case of breakdown see Clause 7;

d) inertisation.

5.9.2.5.10 Failure of energy supply

For requirements, see 5.9.2.5.9.

5.9.3 Type B-dryers

5.9.3.1 General

In type B-dryers dangerous explosive mixtures shall be avoided by displacement of atmospheric oxygen with an inert gas.

By design and construction the inerting shall be maintained inside the dryer during the drying process. Unintended escape of the dryer's atmosphere shall be prevented.

Equipment (e.g. fans) for homogenising the dryer's atmosphere shall be provided if required, for instance, due to the size and design of the total volume and to the type of charging. Dead areas within the total volume shall be prevented.

Lockable access openings and lockable openings for introduction of workpieces shall be equipped with guard locking. The guard locking shall be active during the drying process, build-up and termination of the inerting. Appropriate measures shall be provided for unlocking the access in case of emergency (e.g. rescue of persons). Warning signs shall be placed appropriately on the dryer.

By design and construction the unintended formation of condensates of deposits of flammable substances shall be prevented to the greatest possible extend.

5.9.3.2 Additional requirements for continuous flow dryers

In continuous flow dryers the escape of hazardous amounts of gas and flammable substances as well as the inflow of atmospheric oxygen shall be avoided by one or more of the following measures at the in- and outlet:

— closing devices (e.g. doors or shutters);

— inert gas curtains;

— additional extraction devices.

These measures shall be monitored.

Continuous flow dryers shall be equipped with a pressure monitoring system to ensure that the dryer is operating within its specified pressure limits.

The escape of flammable substances shall be detected with concentration monitoring devices that shall

— comply with EN 60079-29-1 or EN 60079-29-4;

— not be affected by oxygen deficiency.

Sample points for concentration monitoring shall be located in order to detect the release of flammable substances before explosion hazards may occur in the case of failure, based on the risk analysis.

5.9.3.3 Additional requirements for chamber dryers

5.9.3.3.1 General

Type B-chamber dryers are distinguished in dryers with or without measures for prevention of ignition sources. Chamber dryers with measures for prevention of ignition sources shall be designed with equipment according to 5.9.3.3.2 or 5.9.3.3.3. Requirements for chamber dryers without prevention of ignition sources are given in 5.9.3.4.2, 5.9.3.5.2 and 5.9.3.6.

NOTE Continuous flow dryers are completely inertised before finishing the charging up to the end of unloading. For this reason, measures for prevention of ignition sources are not reasonable for continuous flow dryers.

5.9.3.3.2 Equipment with ignition protection

Within the total volume, chamber dryers shall be equipped with equipment and installations of category 2G of EN 13463-1 or EN 60079-0. In addition, the temperature resistance of the components used shall be considered.

5.9.3.3.3 Equipment without ignition protection

In chamber dryers, potential ignition sources within the total volume shall not become effective until buildup of inerting is completed (e.g. by disconnecting the electrical power supply). Penetration of flammable substances, e.g. into the housing of this equipment, shall be prevented.

5.9.3.4 Buildup of inerting

5.9.3.4.1 General

Dryers shall be equipped with devices for purging the total volume with inert gas to reduce the oxygen concentration before start of drying to the following limit values:

a) for drying temperatures up to 150 °C

— 50 % of the temperature dependent oxygen concentration at drying temperature;

— if temperature dependency is not known, maximum of 5 volume per cent;

b) for drying temperatures above 150 °C, up to 250 °C

— 50 % of the temperature dependent oxygen concentration at drying temperature;

— if temperature dependency is not known, maximum of 3 volume per cent;

c) for drying temperatures over 250 °C the same level of safety shall be ensured by measures derived from an individual risk assessment.

The complete buildup of inerting shall be ensured

a) for continuous flow dryers by monitoring of oxygen concentration;

b) for chamber dryers by

1) monitoring of oxygen concentration

or

2) monitoring of

— minimum volume flow rate of inert gas at the inlet and the inflow time

and

— the overpressure within the total volume or the volume flow at the outlet.

In chamber dryers, pressure monitoring shall be located where the lowest positive pressure is expected.

Oxygen monitoring devices shall comply with 5.9.3.7.

Loading of continuous flow dryers shall be prevented until complete buildup of inertisation.

If the buildup of inerting in continuous flow dryers is done with an enhanced inert gas flow, the escape of inert gas shall be prohibited by closing devices (see 5.9.3.5.4) at inlet and outlet.

5.9.3.4.2 Additional requirements for chamber dryers without prevention of ignition sources

During buildup of inerting, the temperature in the total volume of chamber dryers shall be limited to LEP - 15K of the flammable substance released. If required a cooling device shall be installed.

The closing of openings shall be announced by an acoustic signal, leaving sufficient time for persons inside the dryer to escape. It shall not be possible to close the openings before the escape time has elapsed. The buildup of inerting shall start as soon as the openings have closed.

5.9.3.4.3 Failures

An optical and acoustical alarm shall be released when the limit values specified in 5.9.3.4 are overrun or underrun during buildup of inerting. For chamber dryers the drying shall not be started and for continuous flow dryers the charging shall not be started.

NOTE For information related to procedures in case of an operational failure (see 7.2.3).

5.9.3.5 Drying (Maintaining the inerting)

5.9.3.5.1 General

Inerting shall be monitored

— for continuous flow dryers by monitoring of oxygen concentration;

— for chamber dryers by

  — monitoring of oxygen concentration

  or

  — monitoring of

  — minimum volume flow rate of inert gas at the inlet

  and

  — the overpressure within the total volume or the volume flow at the outlet.

The heating device of chamber dryers shall be cut-off at the end of the drying process.

Oxygen monitoring devices shall comply with 5.9.3.7.

5.9.3.5.2 Additional requirements for chamber dryers without prevention of ignition sources

Chamber dryers shall be equipped with temperature measuring devices to monitor the course of the drying temperature. Inerting shall be maintained until the drying process is finished.

5.9.3.5.3 Measures in case of failures for chamber dryers

If

— the maximum admissible oxygen concentration is overrun or

— the required inert gas volume flows or the positive operational pressure are underrun,

then

— the dryer shall be purged according to 5.9.3.6;

— the heating shall be cut-off and not restart automatically;

— an optical and acoustical alarm shall indicate operational failures.

The control system of the dryer shall maintain the volume flow as long as the total volume has been purged 8 times.

NOTE For information to be given on procedures in case of failure (see 7.2.3).

5.9.3.5.4 Measures in case of failures for continuous flow dryers

If

— the maximum admissible oxygen concentration is overrun or

— any of the monitoring devices (see 5.9.3.2) detects critical deviations

then measures shall be applied in the following order:

— an optical and acoustical alarm, stop of transportation system and cut-off of the heating and ensuring no restart;

— closing of the feeding openings at inlet and outlet (e.g. with mechanical shutters);

— purging with an enforced inert gas volume flow and an adjusted exhaust flow.

The control system of the dryer shall maintain the volume flow as long as the total volume has been purged 8 times.

NOTE For information to be given on procedures in case of failure (see 7.2.3).

5.9.3.6 Termination of the inerting

5.9.3.6.1 General

Dryers shall be equipped with devices for purging the total volume diluting the concentration of flammable substances within the total volume to less than 50% of the temperature dependent LEL in air.

In continuous flow dryers and chamber dryers without prevention of ignition sources purging shall be done with an inert gas or a purge gas having an appropriate composition (e.g. low oxygen concentration) in order to prevent safely the formation of explosive atmosphere.

Dependent on a risk assessment, health protection may require a subsequent purge cycle with fresh air, see 5.7.

NOTE In general, purging with air is possible in chamber dryers with prevention of ignition sources.

To ensure safe termination of inerting the concentration of flammable substances or alternatively

— for continuous flow dryers the minimum volume flow of the purge gas at the inlet;

— for chamber dryers

  — the minimum volume flow of the purge gas at the inlet

  and

  — the overpressure within the total volume or the volume flow at the outlet,

shall be monitored.

Concentration monitoring devices shall

— comply with EN 60079-29-1 or EN 60079-29-4;

— not be affected by oxygen deficiency.

In continuous flow dryers all sources of flammable substances (e.g. work pieces) shall be removed from the total volume before termination of the inerting.

For measures regarding health protection during opening the dryer, see 5.7.

If the termination of inerting in continuous flow dryers is done with an enhanced inert gas flow, the escape of inert gas shall be prohibited by closing devices (see 5.9.3.5.4) at inlet and outlet.

5.9.3.6.2 Failures

An optical and acoustical alarm shall indicate failures during termination of the inerting. The guard lockings shall remain active.

Closing devices of continuous flow dryers shall be closed.

NOTE For information regarding the procedures after a failure occurred (see 7.2.3).

5.9.3.7 Monitoring of oxygen concentration

For monitoring of oxygen concentration dryers shall be equipped with oxygen monitoring systems according to EN 50104.

Concentration monitoring devices shall comply with C.2. They shall be selected with respect to:

— all substances released in the dryer;

— inert gas;

— response times;

— temperature ranges (temperature of the measuring gas and ambient temperature at the installation site).

Operational influences like condensation, pollution, sensor contamination, mechanical exposure shall be considered.

NOTE See also EN 60079-29-2.

5.10 Control systems

5.10.1 General

Control systems shall be designed in compliance with the principles of EN ISO 13849-1. This is also applicable for input and processing of safety related parameters (e.g. operating parameters).

5.10.2 Requirements for type A-dryers

With regard to the monitoring required by

— the selected row from Table 2, the safety functions from rows 1 to 3 of Table 3 shall ensure that the LEL is underrun during all modes of operation;

— 5.9.2.3, the safety functions from rows 4 and 5 of Table 3 shall avoid hazards resulting from the heating system.

The monitoring functions (rows of Table 3) which are related to the selected row of Table 2 or related to 5.9.2.3 shall be dealt with.

NOTE 1 In Table 3 the safety functions are created by the combination of a monitoring function with a protective measure.

The most effective safety function of

- rows 1 to 3, shall be selected and shall comply with a PL d according to EN ISO 13849-1 (see Annex H). The other required safety functions shall correspond to a PL c;
- row 4 shall comply with a PL d. The other safety functions of this row shall comply with a PL c;
- row 5 shall comply with a PL d. The other safety functions of this row shall comply with a PL c.

The dryer sections shall be considered separately and with respect to their mutual interference.

Table 3 — Selection of suitable safety functions

Safety functions				
Monitoring function		**Protective measure**		
		Prevent input of flammable substances[a]	**Cut-off heating system**[b]	**Maximize exhaust volume flow**[c]
1	Monitoring of minimum exhaust volume flow (5.9.2.2.2)	Yes	Yes	Yes
2	Monitoring of concentration of releasable flammable substances (5.9.2.2.3)	Yes	Yes	Yes
3	Monitoring of input of flammable substances (5.9.2.2.5)	Yes	Yes	Yes
4	Monitoring of maximum drying temperature (5.9.2.3.2)	Yes	Yes	Yes
5	Monitoring of course of the minimum drying temperature (5.9.2.3.3)	Yes	No	Yes

[a] Not applicable for powder dryers and manually charged chamber dryers; for organisational measures, see Clause 7.

[b] Not required if a cut-off of the heating system does not reduce the hazard.

[c] Only required if exhaust volume flow can be changed by the control system.

NOTE 2 Annex H describes the procedure for implementing the requirements for control systems.

NOTE 3 PL d for the maximization of the volume flow (right column of Table 3) can typically be realized with a single fan, because the volume flow itself is controlled at PL d (see 5.9.2.2.2). This typically results in control category 2 according to EN ISO 13849-1.

If the exhaust volume flow is controlled according to 5.9.2.2.4, the monitoring of the concentration of releasable flammable substance shall correspond to PL d in any case.

After activation of a safety function the dryer shall not return to normal operation automatically.

Safety functions for type A dryers shall meet the performance level as required (PLr) in Table 4.

Table 4 — Requirements for safety functions of type A-dryers described in this European Standard

Safety function	**Clause**	**PLr**
Interlocking of movable guards or safety devices with the dangerous movement/event	5.2.1	RA[a]
Interlocking of accesses and openings with radiation sources	5.6	RA[a]
Safety function to ensure sufficient oxygen concentration and non-hazardous atmosphere	5.7	RA[a]
Interlocking of dwell with radiation power	5.8.5	RA[a] at least PL c
Guardlocking of access openings	5.9.2	RA[a]
Drying: Interlocking of heating system and minimum exhaust volume flow	5.9.2.5	RA[a]
Purging: Interlocking of heating system with purge process	5.9.2.5.2	PL c
Drying: Ensuring the minimum exhaust volume flow and the drying temperature before charging (Heating before starting to charge the dryer)	5.9.2.5.3	RA[a]
Drying: Reduction to 25% of the minimum exhaust volume flow after main evaporation time (chamber dryers)	5.9.2.5.3	PL d
Stop input of flammable substances on shut-down of the dryer	5.9.2.5.4	RA[a]
Cut-off of heating system on shut-down of the dryer	5.9.2.5.4	RA[a]
Ensuring the forced ventilation on shut-down of the dryer	5.9.2.5.4	RA[a]
Interlocking of forced ventilation and heating system	5.9.2.5.5	Table 3
Interlocking of forced ventilation and input of flammable substances	5.9.2.5.5	Table 3
Interlocking of heating system with maximum ventilation	5.9.2.5.6	Table 3
Interlocking of heating system and input of flammable substances	5.9.2.5.6	Table 3
Interlocking of conveyor system with maximum ventilation	5.9.2.5.7	Table 3
Interlocking of conveyor system with heating system	5.9.2.5.7	Table 3
[a] Determination of PL_r according to risk assessment (RA)		

NOTE 4 Typical components for the safety function “purging” are: Systems for monitoring the minimum volume flow taken as basis for calculation of the purging cycle, timing elements for ensuring the calculated purging time, and interlocking devices for the heating system and input of flammable substances.

5.10.3 Requirements for type B-dryers

With regard to prevention of explosion hazards caused by inerting the safety functions according to Table 5 shall ensure that the maximum admissible oxygen concentration is underrun safely in all operation modes. Here, a distinction is made between continuous flow dryers and chamber dryers with and without ignition protection.

Table 5 — Requirements for safety functions of type B-dryers described in this European Standard

Description of the safety function	Clause	PLr for continuous flow dryers	PLr for chamber dryers without prevention of ignition sources	PLr for chamber dryers with prevention of ignition sources
Interlocking of movable guards or safety devices with the dangerous movement/event	5.2.1	RA[a]	RA[a]	RA[a]
Interlocking of accesses and openings with radiation sources	5.6	RA[a]	RA[a]	RA[a]
Purging with fresh air after inerting is terminated	5.7	RA[a]	RA[a]	not required
Equipment for detection of health hazardous concentration at inlet and outlet openings of continuous flow dryers	5.7	d	not required	not required
Interlocking of dwell with radiation power	5.8.5	RA[a] at least PL c	RA[a] at least PL c	RA[a] at least PL c
Monitoring of forced ventilation for homogenisation of inert gas	5.9.3.	RA[a]	RA[a]	RA[a]
Guard locking for lockable access openings during inerting and in case of failures	5.9.3.	c	d	c
Devices for monitoring the concentration of flammable substances at inlet and outlet openings of continuous flow dryers	5.9.3.2	c	not required	not required
Deactivation of potential ignition sources	5.9.3.3.3	not required	not required	d
Monitoring of oxygen concentration	5.9.3.4, 5.9.3.5	d	d	c
Monitoring of inert gas flow and overpressure	5.9.3.4, 5.9.3.5	not allowed	d	c
Purging before drying process; drying or charging shall not be started in case of failures	5.9.3.4	d	d	c
Cooling of the total volume when inerting is generated	5.9.3.4.2	not required	RA[a]	not required
Automatic start after closing the access opening	5.9.3.4.2	not required	c	not required
Opto-acoustical alarm in case of any failure	5.9.3.4.3, 5.9.3.5.3, 5.9.3.6.2	b	c	b
Cut-off of heating system after drying process	5.9.3.5	not required	d	d[b]

Description of the safety function	Clause	PLr for continuous flow dryers	PLr for chamber dryers without prevention of ignition sources	PLr for chamber dryers with prevention of ignition sources
Cut-off of heating system in case of failures (including overrunning the admissible drying temperature)	5.9.3.5	not required	d	d[b]
Monitoring of inerting and emergency purging in case of failures during drying	5.9.3.5, 5.9.3.6	d	d	c
Monitoring of the course of the minimum drying temperature	5.9.3.5.2	not required	d	not required
Purging with purge gas in order to terminate the inerting	5.9.3.6	d	d	C
[a] Determination of PLr according to risk assessment (RA) [b] Only required if heating system presents a potential ignition source				

6 Verification of the safety requirements and/or measures

Table 6 shall be used as a check list for manufacturers to derive their own specific methods to verify that the safety requirements and measures described in Clause 5 are complied with. Table 6 contains references to the respective clauses of this European Standard.

Table 6 — Verification of safety requirements

Clause	Safety requirements and/or measures	Visual inspection See Note 1	Functional test See Note 2	Measuring See Note 3	Examination of drawings/ Calculations See Note 4
5.1	General				
5.2	Mechanical requirements				
5.2.1	Shearing, crushing and drawing-in	X	X	X	X
5.2.2	Means of escape	X	X	-	-
5.2.3	Safety requirements against slip and fall hazards	X	X	-	-
5.3	Safety requirements against electrical hazards				
5.3.1	General	X	X	X	X
5.3.2	Electrical equipment	X	X	X	X
5.3.3	External influences on electrical equipment	X	X	X	-
5.4	Safety requirements against thermal hazards	X	-	X	-
5.5	Safety requirements against noise hazards	X	-	X	-
5.6	Safety requirements against radiation hazards	X	X	X	X

Clause	Safety requirements and/or measures	Visual inspection See Note 1	Functional test See Note 2	Measuring See Note 3	Examination of drawings/ Calculations See Note 4
5.7	Safety requirements against health hazardous substances	X	X	X	X
5.8	Fire protection and prevention				
5.8.2	Materials and construction	X	-	-	X
5.8.3	Heating systems	X	-	X	X
5.8.4	Prevention of ignition by hot surfaces	X	-	-	X
5.8.5	Prevention of ignition by overheating	X	X	X	X
5.8.6	Prevention of auto-ignition	X	X	X	X
5.9	Explosion protection and prevention requirements				
5.9.2	Type A-dryers	-	-	-	-
5.9.2.2	Requirements depending on the maximum concentration of flammable substances	X	X	X	X
5.9.2.2.2	Monitoring of minimum exhaust flow rate	X	X	X	X
5.9.2.2.3	Monitoring of concentration	X	X	X	X
5.9.2.2.4	Control of exhaust flow rate	X	X	X	X
5.9.2.2.5	Monitoring of input of releasable flammable substances	X	X	X	X
5.9.2.2.6	Prevention of ignition sources by equipment and installations of category 3G	X	-	-	X
5.9.2.2.7	Prevention of ignition sources by equipment and installations of category 2G	X	-	-	X
5.9.2.2.8	Explosion relief	X	-	-	X
5.9.2.3	Requirements for heating systems	-	-	-	X
5.9.2.3.2	Monitoring of heating system against overrun of the limit temperature	X	X	X	X
5.9.2.3.3	Monitoring of heating system against underrun of the course of the minimum drying temperature	X	X	X	X
5.9.2.4	Requirements for the input flammable substances	X	X	X	X
5.9.2.5	Interlocking of forced ventilation, heating system and input of releasable flammable substances	-	X	-	X
5.9.2.5.2	Purging	X	X	-	X
5.9.2.5.3	Drying	X	X	X	X
5.9.2.5.4	Shut-down of the dryer	X	X	-	X
5.9.2.5.5	Failure of forced ventilation	X	X	-	X

Clause	Safety requirements and/or measures	Visual inspection See Note 1	Functional test See Note 2	Measuring See Note 3	Examination of drawings/ Calculations See Note 4
5.9.2.5.6	Failure of heating system	X	X	-	X
5.9.2.5.7	Failure of conveying system	X	X	-	X
5.9.2.5.8	Failure of a safety-relevant control system	X	X	-	X
5.9.2.5.9	Failure of the control system	X	X	-	X
5.9.2.5.10	Failure of energy supply	X	X	-	X
5.9.3	Type B-dryers	X	X	-	X
5.9.3.2	Additional requirements for continuous flow dryers	-	X	X	X
5.9.3.3	Additional requirements for chamber dryers	-	-	-	-
5.9.3.3.2	Equipment with ignition protection	X	-	-	X
5.9.3.3.3	Equipment without ignition protection	X	X	-	X
5.9.3.4	Buildup of inerting	-	X	X	X
5.9.3.4.2	Additional requirements for chamber dryers without prevention of ignition sources	-	X	X	X
5.9.3.4.3	Failures	X	X	-	X
5.9.3.5	Drying (Maintaining the inerting)	-	X	X	X
5.9.3.5.2	Additional requirements for chamber dryers without prevention of ignition sources	-	-	-	X
5.9.3.5.3	Failures	X	X	-	X
5.9.3.5.4	Failures	X	X	-	X
5.9.3.6	Termination of the inerting	-	X	X	X
5.9.3.6.2	Failures	X	X	-	X
5.10	Control systems	-	X	-	X
5.10.2	Requirements for type A-dryers	X	X	X	X
5.10.3	Requirements for type B-dryers	X	X	X	X

NOTE 1 Visual inspection is carried out for testing the required characteristics and properties by visual study of the delivered equipment and components.

NOTE 2 The functional test will show whether the parts in question function in such a way as to satisfy the requirements.

NOTE 3 Verification by means of measuring instruments is used to check whether the requirements are fulfilled within the specific limits (e.g. the safety distance between the guard and the in running nip according to EN 13857). Regarding measurement of concentration and requirements relating to gas monitoring systems, see Annex C.

NOTE 4 Drawings and calculations are used to check whether the design characteristics of the components used satisfy the specific requirements.

7 Information for use

7.1 General

The manufacturer shall supply

— an information for use for each dryer being a final machinery;

— an assembly instruction and a declaration of incorporation for each dryer being a partly completed machinery.

The information for use shall comply with EN ISO 12100:2010, 6.4 and especially with 6.4.5 concerning the instruction handbook and 6.4.4 concerning marking. All machinery shall be accompanied by instructions in the official Community language or languages of the Member State in which it is placed on the market and/or put into service.

The instructions accompanying the machinery shall be either "Original instructions" or a "Translation of the original instructions", in which case the translation shall be accompanied by the original instructions.

The information for use shall give information concerning installation, commissioning and use, together with references to the general maintenance of dryers and the intended use defined by the manufacturer.

7.2 Instruction handbook

7.2.1 General

The instruction handbook shall contain at least the following:

a) exact description of the dryer and the safety devices;

b) instruction for operation;

c) requirements for training of operators;

d) intended use;

e) noise emission values according to EN 14462 or EN 13023;

f) radiation emission values according to EN 12198-2;

g) data on vibration, gases, vapours, dusts which can be emitted by the dryer, with reference to the measuring method used;

h) warning references:

   1) to prohibit any storage of flammable substances or their empty containers or any other materials which have been in contact with these products (rags, paper, etc.) inside the dryer or in its vicinity;

   2) in case of radiation curing (IR/UV/EB): warning signs on all openings;

i) warning notice specifying the following: "the dryer shall only be operated by instructed personnel and according to the operating conditions defined by the manufacturer";

j) reference that the dryer shall be included into the company fire protection and prevention concept;

k) information on the purpose of explosion relief panels and reference, that they shall be ready for operation throughout the life of the dryer. Advice, that the panels shall be kept free from obstruction, not be painted over and that the areas where they discharge shall be free from personnel or flammable materials;

l) information on de-commissioning, dismantling and safe disposal see EN ISO 12100:2010, 6.4.5.1 f);

m) information for emergency situations, for instance: type of firefighting equipment to be used, warning about possible emission/leakage of substance(s) which are hazardous to health, and, if possible, indication of how to minimise or eliminate their effects of EN ISO 12100:2010, 6.4.5.1 g).

7.2.2 Information related to installation

The information related to installation shall contain the following:

a) References and instructions for installation (e.g. foundation plans, required floor space);

b) references and instructions for transport;

c) required space of the dryer;

d) requirements for ambient ventilation (fresh air supply), especially for type-B continuous flow dryers;

e) installation requirements for air ducts of the dryer (i.e. to maintain the fire resistance of walls when air ducts are led through them);

f) the conditions in which the machinery meets the requirement of stability during use, transportation, assembly, dismantling when out of service, testing or foreseeable breakdowns.

7.2.3 Information related to operation

The information related to operation shall contain the following:

a) instruction for safe operation (e.g. start-up, stopping, charging, adjustment);

b) instruction to keep the surrounding of the dryer free of flammable substances;

c) warning against risk of excessive concentration of flammable substances due to e.g.

    1) modification of coating system;

    2) modification of base stock;

    3) overloading;

d) instruction on the protective measures to be taken by the user, including, where appropriate, the personal protective equipment to be provided;

e) the operating method to be followed in the event of accident or breakdown;

f) the operating method to be followed safely unblock the equipment for blockages likely to occur;

g) warning against risk of hot air and operating method to be followed;

and additionally for

h) chamber dryers:

    1) data on the maximum admissible quantity of flammable substances for every operating stage;

i) continuous flow dryers:

   1) information on the maximum throughput of flammable substances;

   2) information on manual or technical processes (for instance blanket washing) which could have an influence on the throughput of flammable substances;

j) inertised dryers (type B-dryers):

   1) indications on the maximum admissible oxygen concentration at the highest drying temperature;

   2) information of required amount of inert gas to be available at any time (i.e. sufficient for purging in case of emergency, see 5.9.3.5.3 or 5.9.3.5.4);

   3) if applicable, information regarding requirements for redundant inert gas supply;

k) dryers not designed for (see 5.9.2.5):

   1) reference that drying of nitro-varnishes is not allowed.

7.2.4 Information related to maintenance

The information related to maintenance shall contain the following:

a) measures to be taken against unintended re-start during maintenance and repair;

b) specification of maintenance intervals and measures of i.e.

   1) deposits of coating materials;

   2) heating system;

   3) forced ventilation system;

   4) filters;

   5) earthing;

c) instructions on repair and correction of faults;

d) specification of the spare-parts to be used, when these affect the health and safety of operators;

e) safety measures to be taken in case of introduction of any kind of ignition sources into the dryer (e.g. grinder);

f) materials and tools recommended by the manufacturer;

g) required personal protective equipment (e.g. breathing protective devices with fresh air supply when working in an insufficiently purified atmosphere);

h) use of sufficient lighting (e.g. mobile lamp, open door).

7.3 Marking

The machine shall be marked with the following information:

a) business name and full address of the manufacturer and, where applicable his authorized representative;

b) designation of the machinery;

c) designation of series or type of the dryer (see 3.5 and 3.6);

d) year of construction, that is the year in which the manufacturing process is completed;

e) serial number (if any available);

f) power:

   1) electrical …… (in kilowatts (kW));

   2) other;

g) maximum drying temperature in degrees Celsius (nominal temperature);

h) maximum admissible quantity or throughput of flammable substances;

i) required minimum exhaust flow rate at 20 °C in cubic metres per hour (m^3/h) for maximum admissible quantity or throughput of flammable substances;

j) if relevant: marking according to EN 12198-1 referring to hazards generated by radiation;

k) chamber dryers shall be additionally marked with:

   1) effective volume in cubic metres (m^3);

   2) total volume in cubic metres (m^3).

Annex A
(normative)

Basis for air flow calculation of chamber dryers and continuous flow dryers

A.1 Calculation basis for chamber dryers

A.1.1 General

Industrial experience showed that the nature of the workpieces being dried, the type of printing or coating material and the drying temperature are the main factors in determining the minimum exhaust flow rate.

NOTE 1 Different types of workpieces (e.g. single metal sheets, car bodies, casting moulds and cores, motor windings for electro-motors, thick textiles, leather, papers with absorbent substrates) produce different release rates.

The following calculation/determination methods consider these facts and shall be chosen accordingly after careful evaluation, especially of the evaporation rates of the releasable flammable substances.

Calculation method A (see A.1.2) shall be chosen for drying processes with rapid evaporation, like for instance low mass materials which could be heated rapidly or in case of using highly volatile flammable substances. Calculation method A is also the basis for mould varnish drying and resin varnish drying.

NOTE 2 Rapid evaporation occurs in general when drying thin films or thin substrates (e.g. printing, coil-coating).

Determination method B (see A.1.3) shall be chosen, if, due to process reasons, slow evaporation of the flammable substances is used.

NOTE 3 For instance in case of:

1) Drying of heavy, dense and/or large workpieces.

2) Coating materials with solvent components having considerably lower release rates compared to commonly used solvents.

3) Large thickness of coating (order of several millimetres) showing a different drying behaviour than in case of mould varnish and impregnated resin varnish drying according to method A.

A.1.2 Calculation of chamber dryers in case of rapid evaporation - Method A

The following parameters shall be taken into account:

a) Maximum admissible quantity of flammable substances

If chamber dryers are used for mould varnish drying, the indications on the maximum admissible quantity of flammable substances for surface drying may be increased by factor 10.

If chamber dryers are used for impregnated resin drying, the indications on the maximum admissible quantity of flammable substances for surface drying may be increased by factor 20.

b) Main vaporisation time

After charging the main vaporisation time of a pre-heated chamber dryer is at least

— 5 min for drying surface coated goods;

— 15 min for mould varnish drying;

— 60 min for impregnated varnish drying.

If the dryer is charged before being pre-heated, the main vaporisation time is equal to the time necessary for reaching the drying temperature. In case of mould varnish drying, the main vaporisation time is equal to the time necessary for reaching the drying temperature plus 5 min at minimum. In the case of impregnated resin varnish drying, the main vaporisation time is equal to the time necessary for reaching the drying temperature plus 30 min.

c) Pre-drying loss

For coated parts, the pre-drying loss of the applied quantity of releasable flammable substances (solvents) after an average pre-drying time can be approximated by the following values:

Table A.1 — pre-drying loss

average pre-drying time [min]	**pre-drying loss** **of the applied quantity of releasable flammable substances (solvents)**
10	25 %
20	45 %
30	50 %

For mould varnish drying the pre-drying loss of the applied quantity of releasable flammable substances (solvents) can be approximated by the following values:

Table A.2 — pre-drying loss for mould varnish drying

average pre-drying time [min]	**pre-drying loss** **of the applied quantity of releasable flammable substances (solvents)**
10	15 %
20	25 %
30	35 %
40	40 %
50	45 %
60	50 %

The average pre-drying time for chamber dryers is half the time required for coating the material of one charge plus the elapsed time between coating the material and charging it into the dryer.

Explanation of symbols and units:

M_{max}	g	maximum amount of releasable flammable substances introduced into the dryer (total amount of solvents) (see 3.22).
ϑ	°C	drying temperature (see 3.12). For radiant heating, the maximum drying temperature is the sum of maximum exhaust gas temperature plus 50 °C.
V	m^3	total volume of the dryer (see 3.25).

LEL_{20}	$g/m^3_{(S)}$	lower explosion limit of releasable flammable substances at 20 °C and 1013 mbar. It is recommended to use the values indicated by the manufacturer/ supplier of the printing or coating material. If the components of the solvent mixtures are known, but the LEL of the mixture is unknown, then the LEL of the solvent component with the lowest value shall be taken. If the data is not available, 40 $g/m^3_{(S)}$ is used.
γ		The ratio of maximum admissible concentration of releasable flammable substances to the concentration present, if no air exchange took place.
C_{LELadm}	(% of LEL)	Maximum admissible concentration of releasable flammable substances within the dryer, see Figure 1.
t_o	h	theoretical vaporisation time of the total amount of releasable flammable substances M_{max} introduced into the dryer at drying temperature with the theoretical assumption, that the evaporation speed at the beginning remains constant over the total drying process.
t_w	h	time of one air exchange in the total volume of the dryer.
$Q_{min,\vartheta}$	m^3/h	minimum exhaust flow rate at drying temperature, measured under consideration of aerodynamic resistance in dryers and air ducts (see 3.20).
C_{adm}	$g/m^3_{(S)}$	maximum admissible quantity of releasable flammable substances within the total volume;

$$C_{adm} = \frac{C_{LELadm} \times LEL}{100} \quad (A.1)$$

The calculation basis of air circulation in chamber dryers shall be carried out according to the following formulas:

$$\gamma = \frac{C_{adm} \times 293 \times V}{M_{max} \times (273 + \vartheta)} \quad (A.2)$$

The dependency of γ *versus* $\frac{t_o}{t_w}$ is shown in Figure A.1. Corresponding values shall be taken from this diagram.

Alternatively the dependence can be calculated by the following formula:

$$\tau = \frac{t_o}{t_w} \quad (A.3)$$

If τ is known,

$$\gamma = \frac{1}{\tau} \times e^{-\frac{\ln \tau}{\tau - 1}} \quad (A.4)$$

Interval range of (A.4): $0{,}01 < \tau < 100$

τ can be calculated by the following formula:

$$\tau(\gamma) = \frac{a + c \times \gamma}{1 + b \times \gamma + d \times \gamma^2} \quad (A.5)$$

Interval range of (A.5): $0{,}01 < \tau < 0{,}9$

where

a = - 2 946;

b = - 3 096;

c = 3 045;

d = - 5 222 .

Then, the calculation of the theoretical vaporisation time t_o of the total amount of releasable flammable substances introduced into the dryer at drying temperature ϑ, is

$$t_o = \frac{2{,}58}{\vartheta} \tag{A.6}$$

for the time t_w which is necessary for air exchange within the total volume V of the dryer

$$t_w = \frac{V}{Q_{min,\vartheta}} \tag{A.7}$$

and therefore for the minimum exhaust flow rate at drying temperature $Q_{min,\vartheta}$

$$Q_{min,\vartheta} = \frac{V}{t_w}. \tag{A.8}$$

The maximum quantity of releasable flammable substances charged into the dryer can be calculated according to the following formula:

$$M_{max} = \frac{C_{adm} \times 293 \times V}{(273 + \vartheta) \times \gamma} \tag{A.9}$$

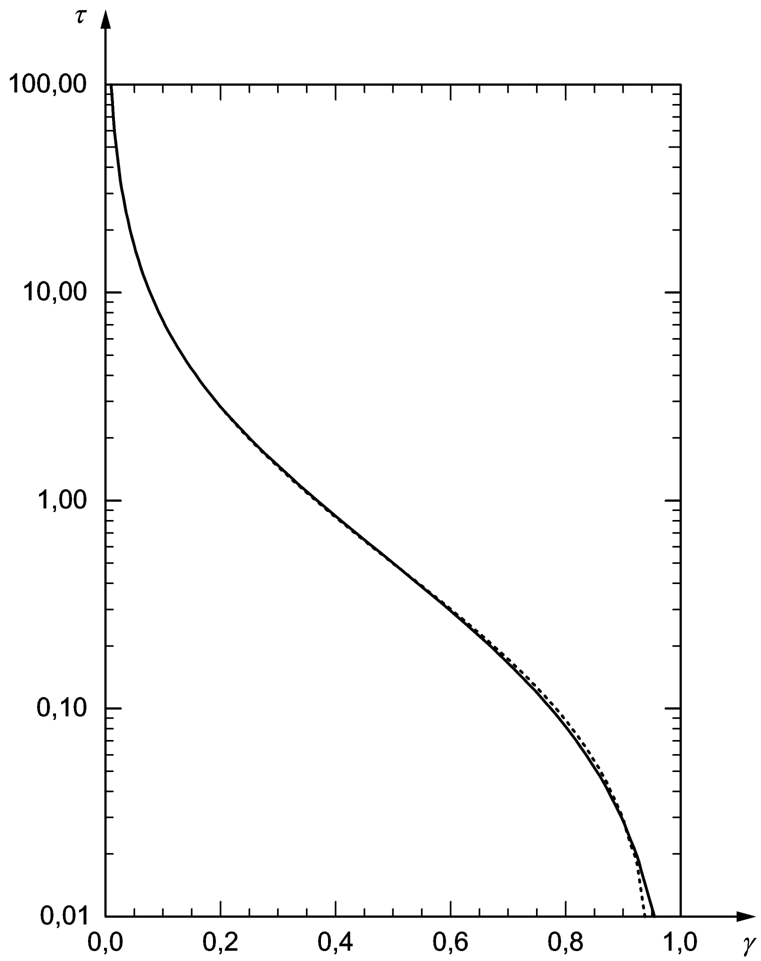


Figure A.1 — Dependency of γ versus τ

In Figure A.1 the curves resulting from formulas (A.4) and (A.5) are shown. The curve resulting from formula (A.4) is represented as a continuous line. This function is not defined for $\tau = 1$. The curve of formula (A.5) is dashed.

A.1.3 Determination in case of slow evaporation – Method B

At the time no calculation method for air circulation in chamber dryers in case of slow release rate is available. If such a calculation method is available it will become part of this European Standard. Meanwhile the forced ventilation flow rate can only be estimated.

On the basis of reliable experience or of the maximum release rate determined by tests run under operational conditions, sufficient ventilation shall be provided in order to prevent concentrations in the dryer exceeding 40 % of the lower explosion limit (LEL) for range 1.

A forced ventilation flow rate of 4 m^3/min per litre solvent shall be the minimum. Otherwise the use of a gas monitoring system according to 5.9.2.2.3 is recommended even in normal operation.

In any case, gas monitoring systems according to 5.9.2.2.3 shall be used during the test phase of the dryer and/or for new drying processes.

This method is not applicable for materials of low mass that can heat up quickly (such as paper or textiles) or materials coated with very highly volatile releasable flammable substances. In these cases the peak release rate can increase to such an extent that the determination method does no longer give a safe result.

A similar procedure is recommended for drying of powder coating material in chamber dryers.

A.2 Calculation basis for continuous flow dryers

The basis of the following calculation is an average molar mass of 100 g/mol, selected because the molar mass of releasable flammable substances generally is between 60 g/mol and 150 g/mol.

Explanation of symbols and units for liquid coatings:

M_{max}	g/h	maximum throughput of releasable flammable substances which is introduced into or released within the dryer per hour.
$Q_{min,(S)}$	$m^3{}_{(S)}$/h	minimum exhaust flow rate, related to 20 °C and 1013 mbar, measured under consideration of aerodynamic resistance in dryers and air ducts.
$Q_{min,\vartheta}$	m^3/h	minimum exhaust flow rate at drying temperature measured under consideration of aerodynamic resistance in dryers and air ducts.
ϑ	°C	drying temperature (see 3.12).
LEL_{20}	g/$m^3{}_{(S)}$	lower explosion limit of releasable flammable substances at 20 °C and 1013 mbar. The values indicated by the manufacturer/supplier of the printing or coating material should be applied. If the components of the solvent mixtures are known, but the LEL of the mixture is unknown, then the LEL of the solvent component with the lowest value should be taken. If the data is not available, 40 g/$m^3{}_{(s)}$ is used.
LEL_{ϑ}	g/m^3	lower explosion limit of the releasable flammable substances at the drying temperature.
$C_{LEL\ adm}$	(% of LEL)	maximum admissible concentration of releasable flammable substances in the dryer, see Figure 1.
C_{adm}	g/$m^3{}_{(S)}$	maximum admissible quantity of releasable flammable substances within the total volume;

$$C_{adm} = \frac{C_{LELadm} \times LEL}{100} \tag{A.10}$$

Explanation of symbols and units for powder coatings:

W	g/h	maximum rate of powder coatings delivered into the dryer per hour.
R		percentage of powder coating constituents released during a dryer cure cycle. If the exact value for R is not known, a value of 5 % by weight (R = 0,05) shall be used.
M_{max}	g/h	$R \times W$

If the continuous flow dryer is divided into drying sections (ventilation sections), then the following ventilation calculation shall be carried out accordingly for each section using the amount of flammable substances released in each section per hour. If airflow between sections has an effect on solvent concentrations it is necessary to measure the concentration in each section during the commissioning process and at any time when a change to ventilation is affected, in order to ensure that all settings are correct and in accordance with the design.

For measurement of concentration of flammable substances in the dryer, see Annex C.1.

The calculation of forced ventilation for continuous flow dryers shall be carried out according to the formulas A.11, A.12, A.13 and A.14.

The minimum exhaust flow rate related to 20 °C is calculated according to

$$Q_{\min,(S)} = \frac{M_{\max}}{C_{\text{adm}}} \tag{A.11}$$

The minimum exhaust flow rate at drying temperature is calculated according to

$$Q_{\min,\vartheta} = Q_{\min,(S)} \times \frac{(273 + \vartheta)}{293} \tag{A.12}$$

This results in the maximum throughput of releasable flammable substances in the continuous flow dryer which is admissible at a given exhaust flow rate

$$M_{\max} = Q_{\min,(S)} \times C_{\text{adm}} \tag{A.13}$$

Or

$$M_{\max} = \frac{Q_{\min,\vartheta} \times C_{\text{adm}} \times 293}{273 + \vartheta} \tag{A.14}$$

Annex B
(informative)

Examples of calculation

B.1 Chamber dryers

B.1.1 Example 1: Calculation of the required minimum exhaust flow (see 3.20)

Substrates coated with 250 g varnish are charged into a chamber dryer with a total volume of 1,5 m^3 at a drying temperature of 260 °C. The coating process of the substrates, which are charged simultaneously into the dryer, takes 40 minutes and the amount of releasable flammable substances in the varnish is 50 %. The LEL_{20} is 59 g/$m^3_{(S)}$, the temperature dependency is 7,5 %/100 K. The average pre-drying time is half the coating time of 20 min and thus the pre-drying loss is 45 % (see Table A.1).

What is the minimum exhaust flow rate?

Known parameters are:

— amount of varnish: 250 g, 50 % releasable flammable substances;

— pre-drying: 20 min, resulting in a pre-drying loss of 45 %;

— drying temperature: 260 °C;

— total volume: 1,5 m^3;

— LEL_{20}: 59 g/$m^3_{(S)}$;

— Δ_{LEL} 7,5 %/100 K (0,00075/K);

— For 250 g initial varnish coating with a content of releasable flammable substances of 50 %.

$\frac{250 \times 50}{100} g = 125\, g$ releasable flammable substances are contained in the varnish.

Considering the pre-drying loss of 45 %, then

$\frac{(100 - 45) \times 250 \times 50}{100 \times 100} = 69\, g$ releasable flammable substances

are charged into the chamber dryer.

Due to reaction kinetics, the LEL decreases with an increase in temperature. This is described by Formula (D.2):

$$LEL_g = 59 \times \left(1 - (0{,}000\,75 \times (260 - 20))\right) = 48{,}4\, g/m^3{}_{(S)}$$

The dryer shall be operated in range 2 of Figure 1 (see Table 2 for requirements).

$$C_{adm} = 0{,}6 \times 48{,}4\, g/m^3 = 29{,}0\, g/m^3(s) \quad \text{(see also Figure B.1)}$$

According to Formula (A.2),

$$\gamma = \frac{29{,}0 \times 293 \times 1{,}5}{69 \times (273 + 260)} = 0{,}3466$$

According to Figure A.1 or calculated with Formula (A.5)

$$\tau = \frac{t_o}{t_w} = 1{,}1125$$

Since, according to Formula (A.6)

$$t_o = \frac{2{,}58}{260} = 0{,}0099\ h$$

it can be concluded that

$$t_w = \frac{0{,}0099}{1{,}1125} = 0{,}0089\ h$$

and according to Formula (A.8) the minimum exhaust flow rate is

$$Q_{min,\vartheta} = \frac{1{,}5}{0{,}0089} = 168{,}5\ \text{m}^3/\text{h} \text{ at drying temperature}$$

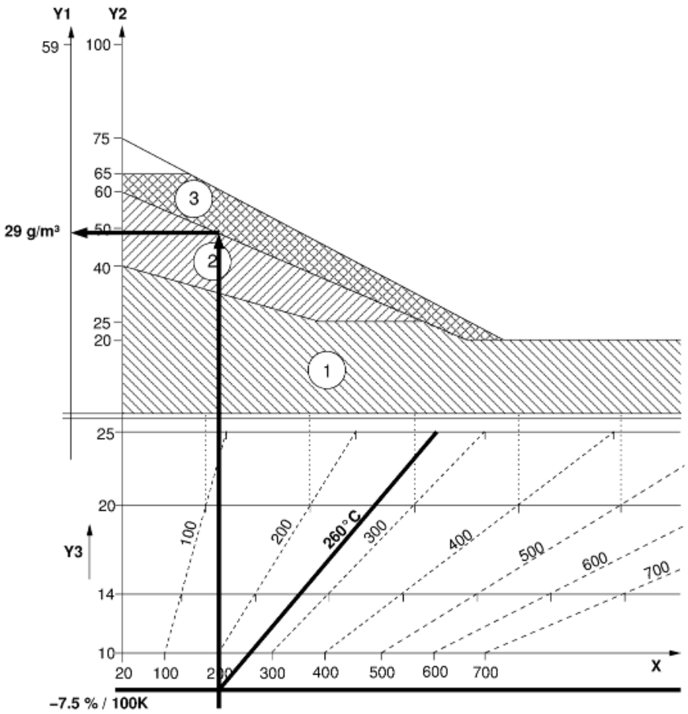


Figure B.1 — Determination of C_{adm} for example 1

B.1.2 Example 2: Calculation of the maximum admissible amount of varnish

Varnished parts are dried in a chamber dryer with a total volume of 36,8 m^3 at a drying temperature of 210 °C. The measured minimum exhaust flow rate at this drying temperature was measured to be 2 100 m^3/h.

How much varnish may be applied at maximum, if it contains 60 % by weight of releasable flammable substances (solvents) and the average pre-drying time in air is 20 min?

Since the lower explosion limit and the molar mass of the releasable flammable substances (solvents) are unknown, $C_{LEL,20°C} = 40\,g/m^3{}_{(S)}$ is used. The unknown temperature dependence of the LEL is approximated by 20 %/100 K.

Known parameters are:

— exhaust flow rate: 2 100 m^3/h;

— total volume: 36,8 m^3;

— pre-drying: 20 min;

— drying temperature: 210 °C;

— LEL_{20} and Δ_{LEL} unknown, therefore LEL_{20} = 40 g/$m^3{}_{(S)}$ and Δ_{LEL} = 20 %/100 K (0,002/K).

At a drying temperature of 210 °C the vaporisation time calculated according to Formula (A.6) is

$$t_o = \frac{2{,}58}{210} = 0{,}0123\,\text{h}$$

The time for an air exchange in the total volume of the dryer calculated according to Formula (A.7) is

$$t_w = \frac{36{,}8}{2100} = 0{,}0175\,\text{h}$$

Thus, the ratio is

$$\frac{t_o}{t_w} = \frac{0{,}0123}{0{,}0175} = 0{,}7029$$

According to Figure A.1 or calculated with Formula (A.4)

$$\gamma = 0{,}434$$

The LEL_ϑ at drying temperature according to Formula (D.2) is:

$$\text{LEL}_{\vartheta=210°\text{C}} = 40 \times (1 - 0{,}0020 \times (210 - 20)) = 25\ \text{g/m}^3$$

For an operation in range 2 of Figure 1, the maximum permissible concentration is 60 % of the LEL, i.e. 14,8 g/$m^3{}_{(s)}$ (see also Figure B.2).

According to Formula (A.9) the total quantity of releasable flammable substances (e.g. solvents) to be charged is

$$M_{\max} = \frac{14{,}8 \times 293 \times 36{,}8}{0{,}434 \times (273 + 210)} = 755\,g$$

The pre-drying loss (see Table A.1) after a average pre-drying time of 20 min is 45 %. Thus, M_{max} corresponds to 55 % of the quantity of releasable flammable substances (e.g. solvents) contained in the printing or coating material before pre-drying, that is, the maximum admissible quantity of flammable substances in the varnish to be applied is

$$\frac{755 \times 100}{55} = 1373\,g$$

For a percentage of released flammable substances of 60 % in the varnish, the result is

$$\frac{1\,373 \times 100}{60} = 2288\, g$$

Therefore, the maximum amount of applied varnish per charge is 2,288 kg.

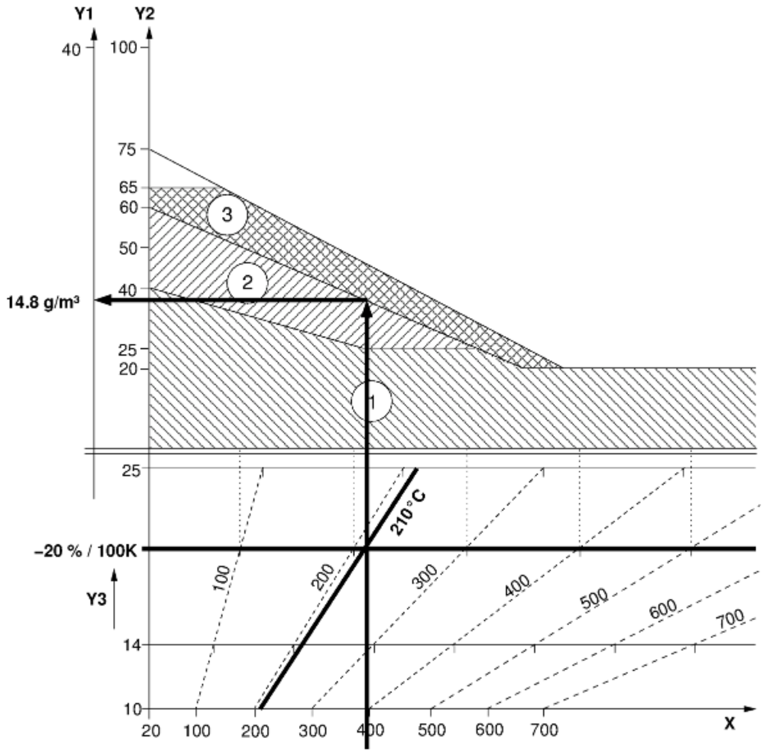


Figure B.2 — Determination of C_{adm} for example 2

B.2 Continuous flow dryers

B.2.1 Example 3: Calculation of the minimum exhaust flow rate

Steel plates with different surface sizes are dried in a continuous flow dryer at a drying temperature of 260 °C. The maximum throughput of releasable flammable substances is 48 kg/h. The released flammable substance has an LEL_{20} = 59 g/$m^3_{(S)}$. The temperature dependency of the LEL of this substance is 11 %/100 K.

The dryer is operated in range 3 of the Figure 1.

Known parameters are:

— drying temperature: 260 °C;

— throughput of releasable flammable substances: 48 kg/h;

— LEL_{20}: 59 g/$m^3_{(S)}$;

— Δ_{LEL}: 11 %/100 K (0,0011/K).

Due to reaction kinetics, the LEL decreases with an increase in temperature. This is described by Formula (D.2):

$$LEL_{\vartheta} = 59 \times (1 - 0{,}001\,1 \times (260 - 20)) = 43{,}4\,\text{g/m}^3$$

It follows that

$$C_{\text{LELadm},\vartheta} = 0{,}75 \times 43{,}4\ \text{g/m}^3 = 32{,}6\ \text{g/m}^3$$

According to Formula (A.11) the minimum exhaust flow rate related to 20 °C is

$$Q_{\min,(s)} = \frac{48\,000}{32{,}6} = 1472\ m^3{}_{(s)}/h$$

Thus, the minimum exhaust flow rate at drying temperature according to Formula (A.12) is

$$Q_{\min,\vartheta} = \frac{1472 \times (273 + 260)}{293} = 2678\ m^3/\text{h}.$$

The dryer is divided into two sections, which are independent of each other regarding ventilation (separate inlet and exhaust air). 70 % of the charged flammable substances are released within the first dryer section and 30 % within the second section.

The dryer is operated in range 3 of Figure 1. The concentration of released flammable substances is measured by gas monitoring systems in both sections of the dryer and the maximum admissible throughput is limited to a safe level by means of a special coating device (see 5.9.2.2.5).

According to Figure 1 the factor C_{LELadm} is 75 % of the *LEL* at a drying temperature of 260 °C. Due to reaction kinetics, the LEL_{20} decreases with an increase in temperature. This is described by Formula (D.2):

$$C_{\text{LELadm},\vartheta} = 75 \times \big(1 - 0{,}0011 \times (260 - 20)\big) = 55{,}2\,\%\ \text{of the}\ LEL_{20} \qquad \text{(see also Figure B.3)}$$

Therefore, the maximum admissible quantity of releasable flammable substances within both dryer sections is C_{adm} = 30,9 g/m$^3{}_{(S)}$.

70 % of 48 kg/h, that is 33,6 kg/h, are released within the first dryer section.

According to Formula (A.11) the minimum exhaust flow rate related to 20 °C within the first dryer section is

$$Q_{\min,(S)} = \frac{33600}{30{,}9} = 1087\ m^3_{(S)}/\text{h}.$$

In the first dryer section the minimum exhaust flow rate at drying temperature according to Formula (A.12) is

$$Q_{\min,\vartheta} = 1087 \times \frac{(273 + 260)}{293} = 1977\ m^3/\text{h}.$$

In the second dryer section 30 % of 48 kg/h, that is 14,4 kg/h, are released.

According to Formula (A.11), the minimum exhaust flow rate related to 20 °C within the second dryer's section is

$$Q_{\min,(S)} = \frac{14400}{30{,}9} = 466\ m^3_{(S)}/\text{h}$$

According to Formula (A.12), the minimum exhaust flow rate at drying temperature within the second dryer section is

$$Q_{\min,\vartheta} = 466 \times \frac{273 + 260}{293} = 848\ \text{m}^3/\text{h}$$

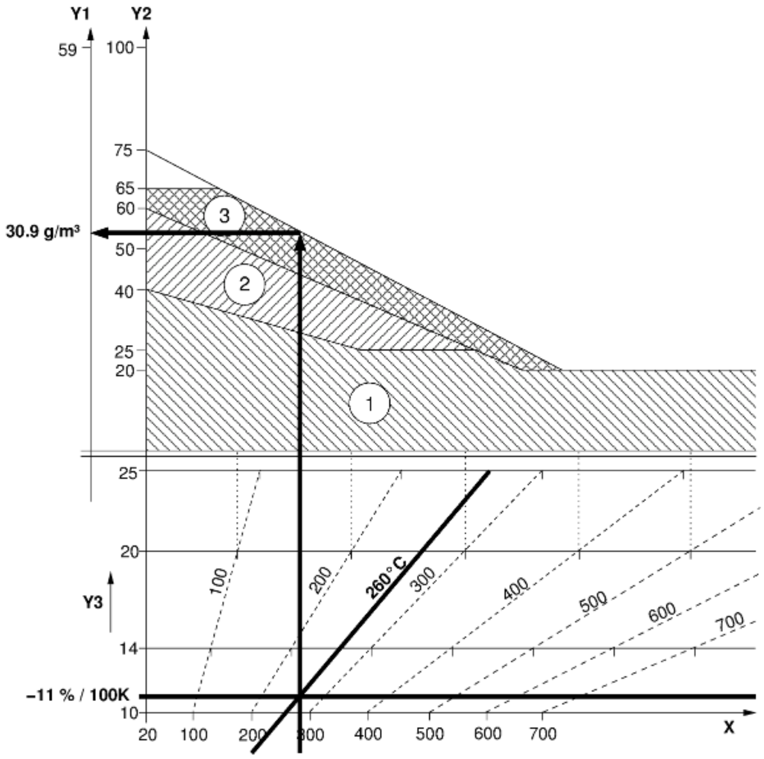


Figure B.3 — Determination of C_{adm} for example 3

B.2.2 Example 4: Calculation of the minimum exhaust flow rate

In a continuous flow dryer at a drying temperature of 250 °C a maximum throughput of flammable substances of 32 kg/h is released. The flammable substance has an LEL_{20} = 46 g/$m^3_{(S)}$. The temperature dependency of the LEL of this substance is 14 %/100 K.

Known parameters are:

— drying temperature: 250 °C;

— throughput of releasable flammable substances: 32 kg/h;

— LEL_{20}: 46 g/$m^3_{(S)}$;

— Δ_{LEL}: 14 %/100 K.

The dryer is operated in range 1 of the Figure 1.

Based on Figure 1 follows that C_{LELadm} is 27% of LEL_{20} (see also Figure B.4)

$$C_{\text{LELadm}} = 0{,}27 \times 46 \text{ g/m}^3 = 12{,}42 \text{ g/m}^3{}_{(S)}$$

According to formula (A.11) the minimum exhaust flow rate related to 20 °C is

$$Q_{\min,(s)} = \frac{32\,000}{12{,}42} = 2576\ m^3{}_{(S)}/h$$

Thus, the minimum exhaust flow rate at drying temperature according to formula (A.12) is

$$Q_{\min,\vartheta} = \frac{2576 \times (273 + 250)}{293} = 4598\, m^3/\text{h}$$

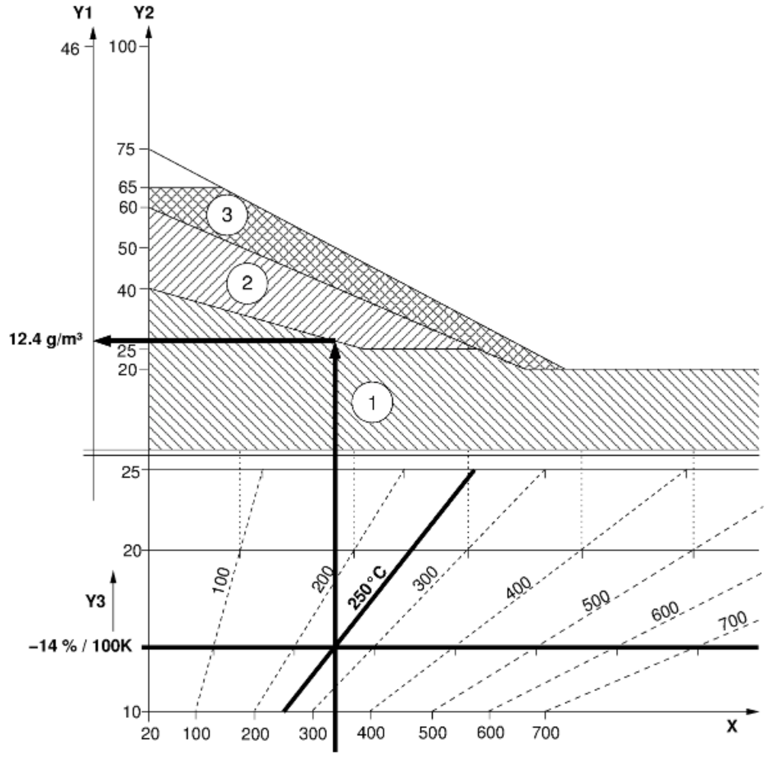


Figure B.4 — Determination of C_{adm} for example 4

B.2.3 Example 5: Calculation of the maximum admissible throughput of flammable substances

In a continuous flow dryer printed webs shall be dried at a drying temperature of 160 °C. The lower explosion limit of the solvent been used at 20 °C is 35 g/m³ (S). The minimum exhaust flow rate is 24060 m³/h, measured at drying temperature.

Which is the maximum amount of solvent to be introduced into the dryer per hour?

Known parameters:

— drying temperature: 160 °C;

— minimum exhaust flow rate: 24060 m³/h;

— LEL_{20}: 35 $g/m^3{}_{(S)}$;

— Δ_{LEL}: unknown, therefore 20 %/100 K (0,002/K).

The total volume within the dryer is not free from ignition sources and the concentration of flammable substances is measured by a gas monitoring system.

Therefore, the dryer is classified into range 2 of Figure 1. According to Figure 1 Formula (D.2) yields the following result at a drying temperature of 160 °C:

$$C_{\text{LELadm},\vartheta} = 60 \times (1 - 0{,}002\,0 \times (160 - 20)) = 43\ \%\ \text{of the}\ LEL_{20}$$ (see also Figure B.5)

Thus, the maximum admissible quantity of flammable substances within the total volume is C_{adm} = 15,1 g/m³$_{(S)}$.

According to Formula (A.14)

$$M_{max} = \frac{24\,060 \times 15{,}1 \times 293}{273 + 160} = 245840\ g$$

Consequently, a maximum amount of 246 kg of solvent may be introduced into the continuous flow dryer per hour.

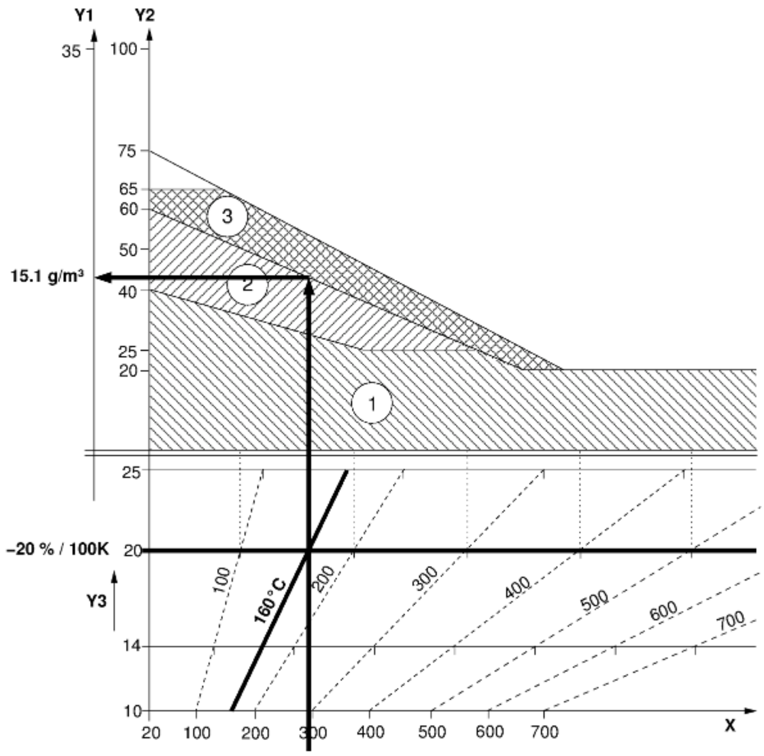


Figure B.5 — Determination of C_{adm} for example 5

Annex C
(normative)

Concentration measurement in dryers

C.1 Measurement of flammable substances

C.1.1 General

The sample points shall be arranged in such a way, that the gas monitoring system will detect any exceeding of the admissible concentration of the flammable substances released within the dryer in time.

NOTE An exception is the boundary layer of the objects to be coated.

In case of appropriate goods (e.g. sheets) the sample points shall be installed – if possible – at a distance of about 5 cm to 10 cm from the coated surface, downstream the air flow.

If the sample points are arranged in the area of the recirculation duct they shall be located in flow direction of the dryer's effective volume (downstream region). Sample points within the exhaust duct shall be as close as possible to the effective volume at a place, where a uniform mixture of flammable substances in air exists.

Differences of concentration between sample points and the regions with maximum concentration shall be considered.

In order to detect the regions with the highest concentrations of flammable substances the check measurements of concentrations in the dryer during commissioning shall be carried out separately for each dryer section.

C.1.2 Requirements for concentration monitoring systems

In general, concentration monitoring systems comprise a gas measuring system and, if required, an additional sampler.

Concentration monitoring systems shall detect concentration changes in time in order to prevent the generation of hazardous conditions.

The maximum increase in concentration over time within the total volume shall be determined by a risk assessment. Here, the normal operation and operational failures shall be considered.

For the determination of the total response time of the concentration monitoring system the following parameters shall be considered:

— runtime of the gas within the total volume up to the sample point;

— dead time of the sampler (for the minimum admissible flow rate of the gas sample);

— response time of the gas measuring system;

— time up to counter measures becoming effective.

For complex installations, the upstream installations shall also be considered.

NOTE 1 This implies knowledge of the dynamic behaviour of the dryer – including all control systems and units.

The sampler shall be designed in a way to minimise the dead time generated by the transport of measuring gas and to prevent formation of condensates.

NOTE 2 The dead time is influenced by the delivery flow rate of the pump of the measuring gas, length and cross section of the sample line and volumes of the filter.

The sampling system shall be appropriate for all flammable substances released during drying. A failure shall be indicated, if the flow rate of the gas sample falls below the minimum admissible value.

Adjustment of the gas measuring system shall be carried out according to one of the following procedures:

a) on the basis of the flammable substances released during operation;

or

b) by a substitute test gas; in this case the response factor of the flammable substance to be measured related to the substitute test gas of the gas measuring system shall be used. For mixtures of substances all components shall be considered.

C.2 Monitoring of oxygen concentration

C.2.1 General

The sample points shall be arranged in such a way, that the oxygen monitoring system will detect any exceeding of the admissible oxygen concentration within the dryer in time.

Sample points for oxygen monitoring shall be located in the dryer where

— maximum oxygen concentration is expected;

— hazardous oxygen concentration is expected (especially at openings for introduction of items).

Differences of oxygen concentration between sample points and the regions with maximum concentration shall be considered.

In order to detect the regions with the highest concentrations of oxygen the check measurements of concentrations in the dryer during commissioning shall be carried out separately for each dryer section.

C.2.2 Requirements for oxygen monitoring systems

In general, oxygen monitoring systems comprise a gas measuring system and, if required, an additional sampler.

Oxygen monitoring systems shall detect oxygen concentration changes in time in order to prevent the generation of hazardous conditions.

The maximum increase in oxygen concentration over time within the total volume shall be determined by a risk assessment. Here, the normal operation and operational failures shall be considered.

For the determination of the total response time of the oxygen monitoring system the following parameters shall be considered:

— dead time of the sampler (for the minimum admissible flow rate of the gas sample);

— response time of the oxygen measuring system;

— time up to counter measures becoming effective.

For complex installations, the upstream installations shall also be considered.

NOTE 1 This implies knowledge of the dynamic behaviour of the dryer – including all control systems and units.

The sampler shall be designed in a way to minimise the dead time generated by the transport of measuring gas and to prevent formation of condensates.

NOTE 2 The dead time is influenced by the delivery rate of the pump of the measuring gas, length and cross section of the sample line and volumes of the filter.

The sampling system shall be appropriate for all flammable substances released during drying. A failure shall be indicated, if the flow rate of the gas sample falls below the minimum admissible value.

Annex D
(normative)

Calculation of the lower explosion limit at drying temperature

D.1 General

The lower explosion limit at the drying temperature $LEL_{\vartheta*}(\vartheta)$ can be calculated from the lower explosion limit LEL in g/m^3 at 20 °C. The temperature dependence of the gas volume (physical influence) and of the capability of being ignited (chemical influence) are both taken into account.

The following formulas are applicable for ideal gases, neglecting changes in pressure.

Definitions are as follows:

LEL	$g/m^3_{(S)}$	lower explosion limit at 20 °C and 1 013 mbar.
$LEL_{\vartheta*}$	g/m^3	lower explosion limit at 20 °C related to the gas temperature $\vartheta*$.
$LEL_{(\vartheta)}$	$g/m^3_{(S)}$	lower explosion limit at the temperature ϑ related to 20 °C
$LEL_{\vartheta*}(\vartheta)$	g/m^3	lower explosion limit at the temperature ϑ related to the gas temperature $\vartheta*$.
ϑ	°C	value of drying temperature.
$\vartheta*$	°C	value of gas temperature related to the concentration value in g/m^3. Standard values are $\vartheta* = \vartheta$, $\vartheta* = 20$ °C and $\vartheta* = 0$ °C.
Δ_{LEL}	%/100K	temperature dependence due to reaction kinetics of the LEL; if unknown: Δ_{LEL} = 20 %/100 K = 0,002/K.

D.2 Influence of temperature on the indicated value of concentration (physical influence)

The numerical value of the lower explosion limit at 20 °C changes with the gas temperature to which the indicated value of concentration refers. This physical influence shall be considered for measurement of concentration if the maximum admissible concentration of flammable substances according to Figure 1 does not depend on temperature (this is always the case, where the concentration limit of an admissible operating range runs horizontally in the diagram).

Conversion of the numerical value of the lower explosion limit at 20 °C to the gas temperature $\vartheta*$:

$$LEL_{\vartheta^*} = \frac{LEL \times 293}{273 + \vartheta^*} \quad (D.1)$$

$LEL_{\vartheta*}$ in g/m^3;

$\vartheta*$ in °C.

The concentration value indicated on a measuring instrument generally is based on the reference temperature $\vartheta*$. If necessary, the indicated measuring value shall be converted to the gas temperature ($\vartheta* = \vartheta$).

D.3 Influence of the temperature of mixture on the kinetics of reaction (chemical influence)

The following formula approximately describes the linear temperature dependency of the lower explosion limit as shown in Figure 1.

$$\text{LEL}(\vartheta) = \text{LEL} \times \left[1 - \Delta_{\text{LEL}} \times (\vartheta - 20)\right] \tag{D.2}$$

LEL(ϑ) in g/m^3;

ϑ in °C;

Δ_{LEL} in %/100 K.

D.4 Consideration of chemical and physical influences

For concentration monitoring the chemical and physical influences shall be considered if the maximum admissible concentration of flammable substances according to Figure 1 depends linearly on the temperature.

The lower explosion limit at drying temperature ϑ related to the gas temperature ϑ^* is calculated from

$$\text{LEL}_{\vartheta^*}(\vartheta) = \text{LEL} \times \left[1 - \Delta_{\text{LEL}} \times (\vartheta - 20)\right] \times \frac{293}{(273 + \vartheta^*)} \tag{D.3}$$

LEL_{ϑ^*} in g/m^3;

ϑ and ϑ^* in °C;

Δ_{LEL} in %/100 K.

The concentration value indicated on a measuring instrument is generally based on the reference temperature ϑ^*. If necessary, the indicated measuring value shall be converted to the gas temperature ($\vartheta^* = \vartheta$).

Annex E
(normative)

Explosion reliefs

Explosion reliefs shall be designed according to EN 14994.

NOTE EN 14994 is relevant only for dryers which withstand an explosion pressure of 10 kPa or more. NFPA 68 "Standard on Explosion Protection by Deflagration Venting" gives information on explosion relieves also for explosion pressures smaller than 10 kPa.

Furthermore EN 1127-1 shall be taken into account.

Annex F
(informative)

Sensors for measurement of the volume flow

F.1Pitot-static tubes

A pitot-static tube is a tube open at one side for measurement of total pressure of liquids and gases. Measurement of flow velocity is possible when equipped with a static pressure probe (Prandtl's tube, Pitot tube). Often differential pressure sensors or switches are used for data collection. Pitot-static tubes are prone to contamination and condensates and are suitable for high ambient pressures and temperatures.

The use of velocity measurements according to the principle of pitot-static tubes requires a pressure measurement with a pressure sensor or switch, or a differential pressure sensor or switch. Corresponding requirements for reliability and precision or reproducibility of the switch point are imposed on this element.

F.2Venturi nozzles

Flow measurements with a Venturi nozzle use the pressure difference between a wide and a narrow duct section. The differential pressure depends on the flow velocity and the density of the flowing fluid. Differential pressure sensors are used for the measurements. Venturi nozzles are not very prone to contamination and condensates.

F.3Wind vanes and plate anemometers

The upstream fluid flow forces a plate which is suspended in a pivoted way from its zero position. The variation in position is displayed by one or several switches. Compared to other methods, this one is not very precise and, depending on the decrease of signal, very prone to interferences. Deposits on the plate will lead to deviations in measuring results.

F.4Hot-wire anemometers

A heated wire is placed in an air flow, and thus the wire is cooled. The resulting heat loss allows drawing conclusions on the flow velocity. The measurement value depends on the temperature of the fluid. The heat flow is also impeded by contaminations, and this will result in measured value of flow velocity which is too low. Hot-wire anemometers do not have any movable parts. The air-flow meter of modern vehicle motors works according to the principle of hot-wire anemometers.

F.5Ultrasonic anemometers

Ultrasonic anemometers determine the flow velocity via the sound propagation time between two points. This allows very precise measurements and high sampling rates. Ultrasonic anemometers do not have any movable parts. An increase in complexity allows compensating for the temperature dependency of this measurement method.

F.6 Windmill anemometer

The flow speed is determined by the rotational speed of a propeller. The bearing friction can have inhibitive effects at low flow speeds. In case of protected bearings and depending on the measurement of rotational speed, windmill anemometers are not very susceptible to contamination.

Table F.1 — Suitability of the sensors for measurements of volume flow in dryers in which flammable substances are released

Type of sensor	Advantages	Disadvantages	Suitability
Pitot-static tube (Prandtl's pitot tube, Pitot-tube, Venturi nozzle	no moving parts broad field of applications	susceptible to contaminations and condensates	very good
Hot wire anemometer	no moving parts mass produced article	susceptible to contaminations complex operation	good
Ultrasonic anemometer	no moving parts high measurement frequency	not available for high temperatures	good
Windmill anemometer	relatively unsusceptible to contamination	not available for high temperatures	usable
Wind vane	Simple robust	not very precise susceptible to contamination	usable

Annex G
(normative)

Requirements for energy-efficiency and reduction of environmental impact

G.1 General

The safety requirements defined in this European Standard override the requirements defined for minimizing energy usage and environmental impact.

The significant aspects for minimizing energy usage and environmental impact of dryers have been identified based on CEN Guide 4:2008 as follows:

G.2 Acquisition

Insulation material shall be selected with regard to process temperature to optimize durability and lifetime of the dryer.

NOTE Insulation material is the typical limiting factor for heat-insulation properties over the dryer lifetime.

G.3 Production

No significant impact.

G.4 Use

G.4.1 General

Information shall be given on operational measures to minimize energy usage and environmental impact of the dryer. Typical measures are:

— minimize opening times of dryer;

— set process temperature to the minimum needed for drying/curing the coating material;

— avoid or minimize operation with no-load;

— provide information for use to minimize environmental impact & energy usage;

— provide information for use to minimize formation of condensation products in the dryer.

NOTE The formation of condensation products depends on the drying process and the coating material.

G.4.2 Energy usage

Minimize energy usage by design and construction

a) operation modes

1) stand-by (reduction of recirculated forced ventilation);

2) start up (optimize heating system capacity to start up time and capacity needed at normal use);

   3) normal use (heating system controlled with regard to required heat capacity);

b) minimize overall energy use by

   1) reduction of recirculated and exhaust air, especially when dryer is not processing goods;

   2) avoiding of thermal bridges;

   3) design of conveyor system with low mass carriers;

   4) design of dryer to minimize energy loss through openings

      — air locks with fans or gates;

      — input and output openings facing downward;

   5) Housing shall be isolated;

   6) Air ducting shall be

      — as short as possible;

      — designed to avoid pressure drop;

      — isolated if passing through colder environment;

   7) Heat recovery system;

   8) Design of forced ventilation system taking into account

      — fans characteristics;

      — heat transfer at heat exchanger;

      — heat distribution in the dryer.

G.4.3 Minimizing of emissions to air

Thermal and catalytic incinerators can be used.

NOTE Emission limit values to air are subject to national regulation (based on IED 2010/75/EC).

G.4.4 Minimizing of noise emissions

Sound absorber at exhaust duct reduces noise emissions to the environment.

See 5.5.

NOTE Noise emissions limit values to air are subject to national regulation.

G.5 End of Life

Isolation material shall be separable from construction materials.

NOTE Isolation material can be contaminated by condensates.

Annex H
(informative)

Guide for implementation of control system requirements for explosion protection for type A dryers

H.1 General

The safety functions described in Table 3 are based on a combination of monitoring devices according to Table 2 and protective measures.

The monitoring devices according to Table 2 comprise sensor technology for detection of physical parameters (e.g. differential pressure gauges with Pitot tubes for recording the exhaust volume flow). Depending on the complexity of the measurement task this part of the safety function may include electronic control components for evaluation, amplification, zero balancing, etc.. The design of the safety function should also provide appropriate measures regarding the diagnostic coverage according to EN ISO 13849-1 (e.g. cross monitoring with time and value tolerances when recording two redundant input signals).

According to EN ISO 13849-1, the protective measures according to Table 3 should be considered as outputs or actuating elements of the safety functions. Depending on the design, cutting-off the heating system can, for instance, be done by cutting off the gas supply. The input of flammable substances can, for instance, be done by interrupting the coating process and/or stopping the conveyor.

The effectiveness of the possible protective measures for various designs of dryers may vary considerably. It depends, for instance, on the thermal inertia of the heating system or on the input flammable substances per time unit. For a typical coil coating system the most effective measure, with respect to dynamics of the process and to maintain a safe state, is to stop the input of flammable substances. For a manually charged chamber dryer, the most effective measure is to cut-off the heating system. If a chamber dryer is, equipped with an additional exhaust fan for rapid cooling, the most effective measure is the activation of this fan to maximise the exhaust air flow. Figure H.1 shows a procedure for identification of the most effective measure.

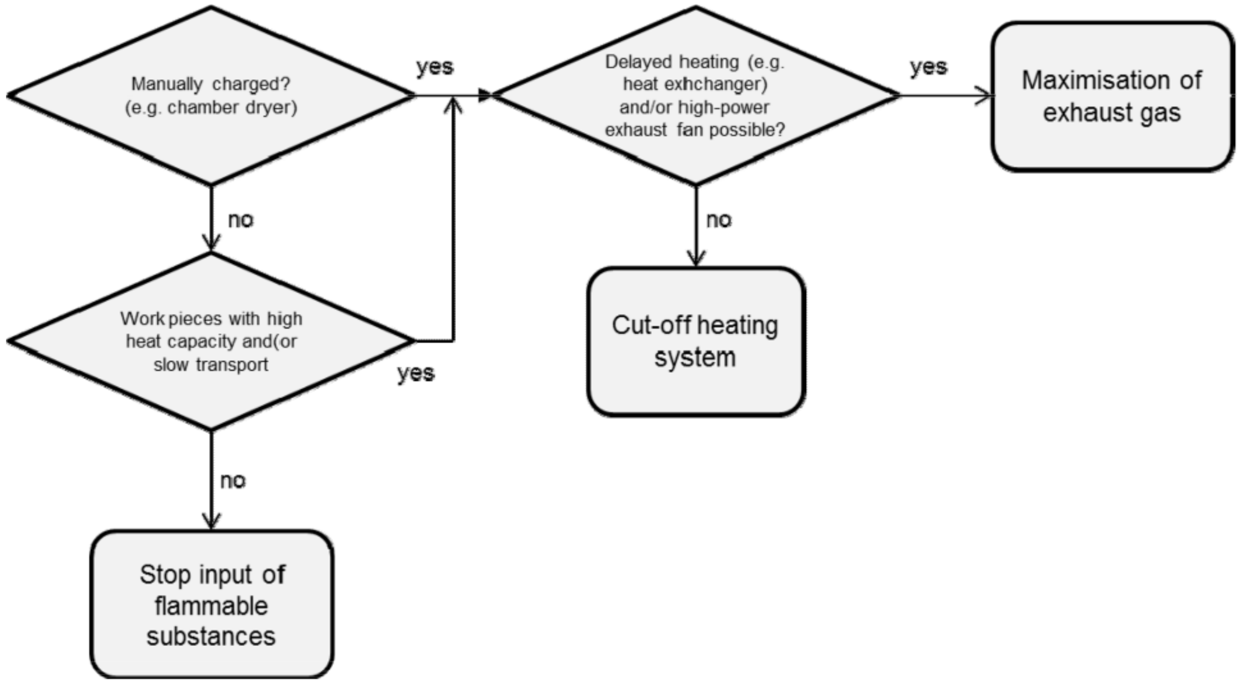


Figure H.1 — Possible procedure for selection of the most effective protective measure

H.2 Example for chamber dryer

This chamber dryer is designed to operate in range 1. The dryer is equipped with a monitoring device for the exhaust air flow. The most effective protective measure is to cut-off the heating system. According to Table 2 and Table 3 the safety functions (SF) are as follows:

SF1	Underrunning the minimum exhaust volume flow results in cutting-off the heating system	PLr = d
SF2	Overrunning the maximum drying temperature results in cutting-off the heating system	PLr = d

According to Table 2 and Table 3 both of these safety functions are appropriate, since the dryer is charged manually and thus the supply of flammable substances cannot be stopped by a control system. Moreover, the dryer is designed exclusively for a constant exhaust volume flow, and therefore the exhaust volume flow cannot be maximized on demand, but it is only possible to ensure the minimum exhaust volume flow.

In the block diagram (Figure H.2), light-grey boxes stand for elements involved in safety-related processes which are interconnected by bold lines. According to EN ISO 13849-1 white boxes are related to fault detection (diagnostic coverage) of the elements (grey boxes) interconnected by dashed lines.

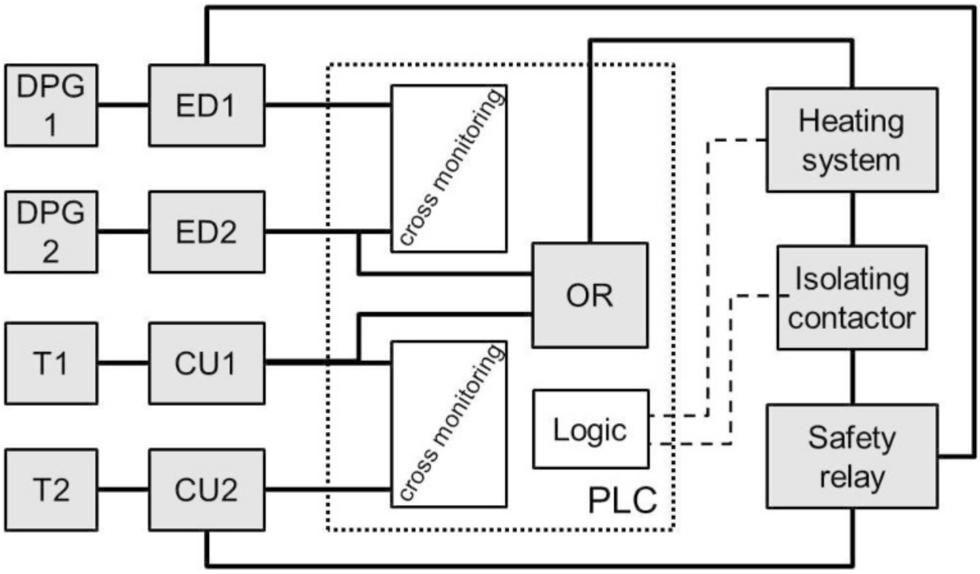


Figure H.2 — Safety block diagram for a simple chamber dryer, range 1, with exhaust gas monitoring

SF1 comprises two redundant differential pressure gauges (DPG1 and DPG2) and the corresponding evaluation devices (ED1 and ED2). ED1 is directly connected to a safety relay which triggers an isolating contactor, which in turn will separate the heating system from the electrical energy, if the minimum exhaust volume flow is underrun. For gas burners, for instance, this will generally result in a safe state. In order to allow detection of faults, an auxiliary contact of the isolating contactor is returned to the PLC.

ED2 is connected to the PLC which carries out a cross monitoring with the signal of ED1 on switching on the dryer and thus allowing detection of faults of both sensor channels. The PLC in turn activates the release of the heating system via a control output. This is done during the standard process control. Consequently faults are also detected by the process. It should be observed in especial that the corresponding software of the SPS complies with EN ISO 13849-1.

SF2 comprises two temperature sensors (T1 and T2, e.g. Pt100) and the downstream control units (CU1 and CU2). Here, CU2 is directly connected to the safety relay and CU1 is combined with the PLC. The cross monitoring of SF2 is similar to SF1. The PLC revokes the release for the heating system in case the programmed temperature limit of the heating system is overrun, which realizes a redundant cut-off path for separating the power supply by the isolating contactor.

H.3 Example for continuous flow dryer

The second example is a coil coating dryer operating in range 3. The system should be equipped with measures for monitoring the exhaust volume flow, monitoring of concentration and for prevention of ignition sources. The manufacturer identified the 'stop of supply of flammable substances' as most effective protective measure. According to Table 2, the prevention of ignition sources does not present a control or safety function. According to Table 2 and Table 3 the other safety functions are as follows:

SF1	Underrunning the minimum exhaust volume flow results in a stop of input of flammable substances	PLr = d
SF2	Underrunning the minimum exhaust volume flow results in cut-off of the heating system	PLr = c
SF3	Overrunning the maximum drying temperature results in a stop of input of flammable substances	PLr = d

SF4	Overrunning the maximum drying temperature results in cut-off of the heating system	PLr = c
SF5	Overrunning the maximum drying temperature results in maximizing the exhaust volume flow	PLr = c
SF6	Underrunning the minimum drying temperature results in a stop of input of flammable substances	PLr = d
SF7	Underrunning the minimum drying temperature results in maximizing the exhaust volume flow	PLr = c
SF8	Overrunning the maximum admissible concentration of flammable substances results in a stop of input of flammable substances	PLr = c
SF9	Overrunning the maximum admissible concentration of releasable flammable substances results in cutting off the heating	PLr = c
SF10	Overrunning the maximum admissible concentration of releasable flammable substances results in maximizing the exhaust volume flow	PLr = c

When illustrating these requirements in a safety-related block diagram Figure H.3 is obtained. The dark grey elements comply with a PL c (single-channel in category 1 or 2 according to EN ISO 13849-1):

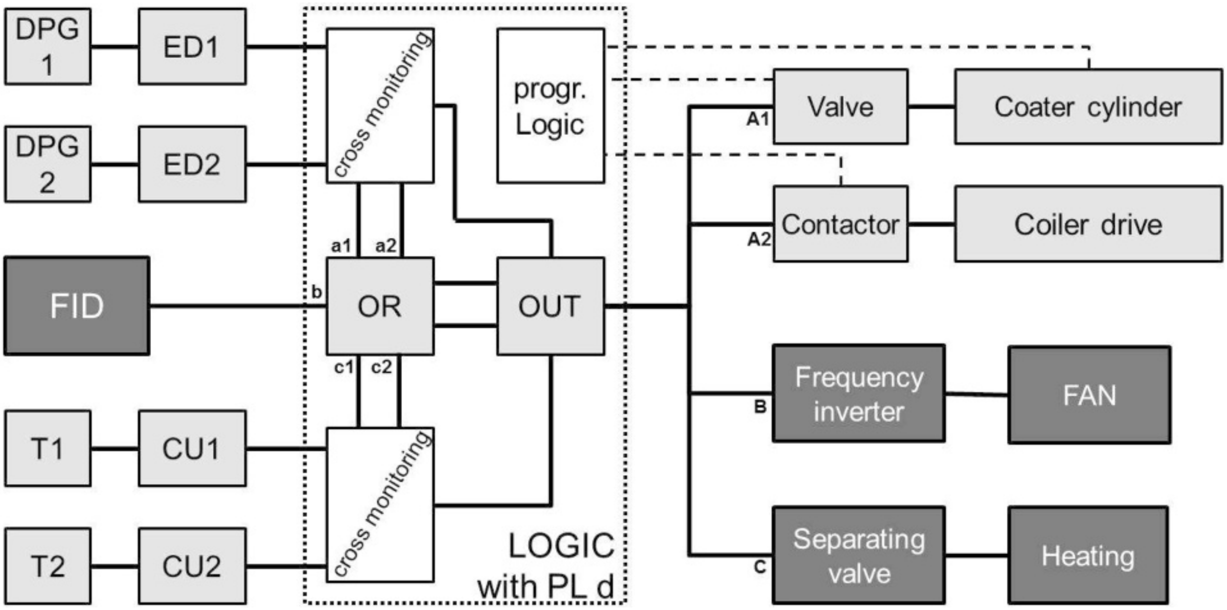


Figure H.3 — Safety block diagram for coil coating dryer, range 3, with monitoring of exhaust gas and concentration

The exhaust gas volume flow is monitored by two differential pressure gauges (DPG1 and DPG2) and two evaluation devices (ED1 and ED2) according to a PL d including cross monitoring. The concentration monitoring is implemented by a single flame ionisation detector (FID, well-tried component according to EN ISO 13849-1) and thus complies with a PL c. Finally the temperature monitoring (overrunning and underrunning) is realized by two redundant sensors (T1 and T2) and control units (CU1 and CU2) and thus complies with a PL d including cross monitoring.

The most effective protective measure is a stop of supply of flammable substances. The PL d is realised by a stop of the coating process (disengaging the coater via the hydraulic valve and the coater cylinder), and in the redundant channel by a stop of the coil. The other protective measures, that is maximization of exhaust gas (frequency inverter and a fan for adjustment of exhaust volume flow), as well as cut-off of the heating (gas separation valve and heating) comply with a PL c according to EN ISO 13849-1.

The PL d-logic (e.g. safety PLC or programmable safety control unit) is responsible for the logic combination of the inputs and outputs according to the following procedure:

— If the OR elements a1, a2, b, c1 or c2 reports a safety critical state, the two redundant outputs will be set to the OUT element.

— If the outputs of the OR element are set, one of the cross monitoring or the "progr. Logic“ (evaluation of the actuating elements - e.g. auxiliary contact of the contactor) reports a fault, the output of the OUT element is set.

— The output of the OUT element always set the whole chain A1, A2, B and C.

In doing so a combination of all the safety functions 1 to 10 listed above can be realised. Here, the PL of each of the safety function results from "weakest" element. The PL for SF2, for instance, cannot be higher than 'c', because it involves also the output C (cut-off of the heating) with a PL c.

NOTE With a programmed time element and a corresponding logic combination the hardware shown in Figure H.3 can also be responsible for the safety function "Purging" according to 5.9.2.5.2.

Annex ZA
(informative)
Relationship between this European Standard and the Essential Requirements of EU Directive 2006/42/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive Machinery 2006/42/EC.

Once this European Standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this European Standard confers, within the limits of the scope of this European Standard, a presumption of conformity with the relevant Essential Requirements (except Essential Requirement 2.1) of that Directive and associated EFTA regulations.

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this European Standard.

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