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Earth-moving machinery — Fire prevention guidance

Engins de terrassement — Lignes directrices pour la prévention des incendies

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Foreword

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This document was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*.

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

Earth-moving machinery — Fire prevention guidance

1 Scope

This document provides guidance on protective measures for consideration in fire risk reduction through machine design and operation and maintenance instructions for earth-moving machinery, as defined in ISO 6165, during their intended use.

NOTE The information in this document presumes that fire hazards for the normal applications anticipated for the machine family by the machine manufacturer have been analysed. This analysis can be done as part of the ISO 12100 machine risk assessment or as a separate fire hazard risk assessment conducted in accordance with ISO 12100 or ISO 19353:2019, 5.1, 5.2, 5.3 and 5.4.

This document also provides the basic concept of fire hazards and examples of typical fuel sources and ignition sources found in earth-moving machinery and earth-moving machinery applications.

This document does not cover all specific aspects of fire prevention for battery electric powertrains (e.g. fire prevention for batteries, battery management systems) due to the evolving development of such technology. However, the guidance in this document can still be beneficial. Additional guidance can also be found in the ISO 14990 series and ISO/DIS 23285.[1)]

This document does not cover the additional risks for machines operating in potentially explosive atmospheres.

2 Normative references

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

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

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
explosive atmosphere
atmospheres containing substances or gases at concentrations that will burn or explode if ignited

[SOURCE: ISO/TR 19591:2018, 3.112]

3.2
fire prevention
measures to prevent the outbreak of a fire and/or to limit its effects

[SOURCE: ISO 8421-1:1987, 1.21]

1) Under preparation. Stage at the time of publication: ISO/DIS 23285:2024

3.3
ignition energy
energy necessary to initiate combustion

[SOURCE: ISO 19353:2019, 3.8]

3.4
ignition source
source of energy that initiates combustion

[SOURCE: ISO 13943:2023, 3.244]

3.5
combustible
capable of burning

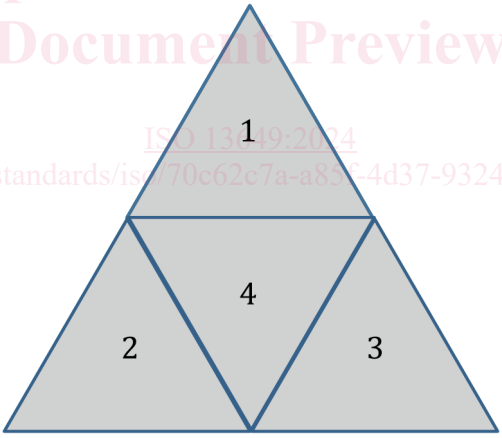
[SOURCE: ISO 8421-1:1987, 1.9]

3.6
firewall
wall or partition designed to inhibit or prevent the spread of fire

4 Fire hazards

4.1 General

A fire hazard exists if combustible materials (fuel), oxidizer (oxygen) and ignition energy (heat) are available in sufficient quantities at the same place and at the same time. A fire is an interaction of these three components in the form of an uninhibited chemical chain reaction. See Figure 1.



Key
1 heat (see 4.3)
2 oxygen
3 fuel (see 4.2)
4 uninhibited chemical chain reaction

Figure 1 — Fire tetrahedron

A fire can be prevented or suppressed by controlling or removing one or more of the components of the fire tetrahedron.

4.2 Fuel sources

4.2.1 General

Fuel is any substance that can undergo combustion. Fuel sources can occur as solids, liquids or gases. Fuel sources can arise from the material processed, used or released by the machinery, from materials in the vicinity of the machinery, or from materials used in the construction of the machinery.

The ease of combustion of fuel sources is affected by the size, shape and deposition of the materials. For example, small pieces of a material loosely collected together can be more easily ignited than a large piece of that material. Also, the combination of materials can have an influence on the ignitability and the burning behaviour. Where relevant properties of fuel sources are not well understood, appropriate testing or analysis should be conducted.

4.2.2 Machine components

Materials used in the construction of machine components can be fuel sources. See Annex A for examples of machine components that can be fuel sources for earth-moving machinery.

4.2.3 Machine fluids, gases and other onboard substances

Fluids, gases and other onboard substances required for operation of the machine can be a fuel source. Leaks, spills and overflows of these fluids or gases can become the fuel source for a fire. See Annex A for examples of machine fluids, gases and other onboard substances that can be fuel sources for earth-moving machinery.

4.2.4 Environmental debris

Combustible materials from the working environment which accumulate on or in the machine can be a fuel source. The amount of accumulation can be affected by weather conditions, type of debris, machine design, missing machine components, operational and maintenance practices, and other factors. The ease of combustion of these materials is affected by the size, shape, and deposition of the materials. See Annex A for examples of environmental debris that can be fuel sources for earth-moving machinery.

4.3 Oxidizers

An oxidizing agent is a chemical substance that, while not necessarily combustible by itself, can rapidly increase the rate of burning of other substances, or result in spontaneous combustion when combined with other substances. The most common oxidizer is oxygen in the atmosphere. But there are other oxidizers that support combustion, e.g. ammonium nitrate (NH_4NO_3) and potassium nitrate (KNO_3).

4.4 Ignition sources

4.4.1 General

Ignition sources for an onboard fire typically fall into three categories:

— thermal energy;

— electrical energy;

— mechanical energy.

These ignition sources can come from the machine itself and from sources external to the machine.

4.4.2 Thermal energy ignition sources

Thermal energy is the energy contained within a system that is responsible for its temperature. The transfer of heat from these systems can be a thermal energy ignition source. See Annex B for examples of thermal energy ignition sources for earth-moving machinery.

4.4.3 Electrical energy ignition sources

Electrical energy is the movement of electrons from one point to another. Heat created by unconstrained movement of electrons can be an electrical energy ignition source. See Annex B for examples of electrical energy ignition sources for earth-moving machinery.

4.4.4 Mechanical energy ignition sources

Mechanical energy is the energy created by friction of one component moving over another. The heat created by this friction can be a mechanical energy ignition source. See Annex B for examples of mechanical energy ignition sources for earth-moving machinery.

5 Strategy for risk assessment and risk reduction

The risk assessment and risk reduction process for fire prevention comprises a series of logical steps that allow systematic examination of fire hazards according to the procedures outlined in ISO 12100. This process includes the following sequential phases:

a) fire risk analysis, comprising:

   1) determination of the limits of the machinery;

   2) identification of fire hazards;

      NOTE Machine and application incident history can be used as sources of information to help identify fire hazards.

   3) risk estimation;

b) risk evaluation;

c) risk reduction, if deemed necessary.

If risk reduction is required, then appropriate protective measures should be selected and applied. Clause 6 provides design guidance for fire risk reduction specific to earth-moving machinery.

The risk assessment and risk reduction process for machinery should consider the entire lifecycle of the machine, including the following:

1) design, including but not limited to, the following:

   — operator egress;

   — considerations for fire suppression system;

   — access ports for firefighting to fire risk areas on the machine (e.g. engine compartment).

2) installation, assembly, and commissioning;

3) operation;

4) maintenance;

5) decommissioning and dismantling.

The fire risk assessment and risk reduction is repeated as an iterative process until the risk of a fire occurrence has been adequately reduced.

Care should be taken to ensure that the protective measures applied do not create or increase other risks.

See ISO 12100 or ISO 19353 for guidance on the risk assessment and risk reduction process.

Special use or severe applications (e.g. transporting hot materials) can require a separate risk assessment by the site management specific to that machine application.

6 Design guidance for fire risk reduction

6.1 General

Design measures for eliminating or reducing the potential risk of fire should include consideration for ignition sources, fuel sources, segregation of fuel and ignition sources, and minimizing the effects of fire.

6.2 Ignition sources

6.2.1 Mechanical and thermal ignition sources

Design considerations for mechanical or thermal ignition sources should include, but not be limited to, the following:

a) Eliminate or minimize, as practical, exposed hot surfaces, for example:

   — reduce surface temperatures with airflow;

   — insulate or double-wall exhaust components;

   — liquid cool components.

b) Eliminate or minimize, as practical, the risk of overheating of machine components and systems (e.g. engines, transmissions, brakes, hydraulic systems, retarding grids, electrical motors). Where the potential exists for overheating in the presence of a fuel source; either monitoring or controls, or both, should be considered.

Simulation or surface temperature measurement can be carried out to understand machine surface temperatures.

NOTE Surfaces above 250 °C are generally considered to support a higher likelihood of combustion with typical fuel sources (e.g. diesel fuel, hydraulic oil) on board earth-moving machinery.

6.2.2 Electrical ignition sources

Design considerations for electrical ignition sources should include, but not be limited to, the following:

a) Eliminate or minimize, as practical, the risk of incorrect electrical connections. Electrical wires and cables used to connect components in electric circuits should be marked and identified. ISO 9247, ISO 23285 or ISO 14990-1 can be used as guidance.

b) Ensure electrical wires and cables, including wire and cable covering, are applicable for the intended application. Considerations should include voltage, load, temperature, chemical resistance, contaminant ingress (e.g. moisture, dust) and flammability rating.

c) Eliminate or minimize, as practical, the risk of overloading electrical circuits. Electrical circuits should be protected by fuses, circuit breakers, or current limiting devices unless specifically designed to be unprotected (e.g. starter motor, pre-heater). The circuit protection for the electrical equipment should be as close as practical to the source. Protection devices should be sized to protect the conductors. If a harness is split (separated into multiple wires), then the protection device should also be placed

immediately after the point of the split, unless protection device amperage rating prior to the split is sufficiently low to protect the wire sizes after the split.

d) Eliminate or minimize, as practical, the risk of electrical shorting. Electrical wiring and cables should:

   1) be routed and supported or clamped in a manner to prevent chafing, crushing or rubbing on sharp edges or rough surfaces and to minimize damage from vibration. Reusable or permanent clamps are preferred to assure proper support and routing are followed and repeatable after repairs. If cable ties are used, consideration should be given to:

      i) the appropriate numbers and placement along the length of the wiring harness to prevent relative movement or rubbing;

      ii) provision of adequate instructions and clear identification of the tie off positions to which cable ties are to be secured, so that they are tensioned and oriented correctly, including if replaced in the field;

      iii) whether the specific cable ties used are suitable for the operating environment (e.g. temperature, vibration, chemical exposure, UV exposure);

      iv) appropriate methods and tooling for cutting the excess length (i.e. length after the pawl) on the cable tie, to prevent sharp edges along the cut face from damaging adjacent components.

   2) use cable glands or bulkhead fittings where wiring enters an enclosure;

   3) accommodate the relative motion between machine components (e.g. lift arm to loader frame, frame articulation joint), if applicable;

   4) be routed to prevent contact with hot surfaces;

   5) use insulated cable connections where not connected to the frame (e.g. positive SLI battery cable).

e) Eliminate or minimize, as practical, the risk of batteries shorting to ground. Secure batteries to protect against damage.

f) Eliminate or minimize, as practical, the risk of shorting due to damage from external elements during operation (e.g. debris falling from bucket, rocks thrown from tyres during travel). External electrical components should be protected.

g) See ISO 23285, ISO 14990-1, ISO 6469-1, and ISO 6469-3 for additional guidance when using lithium-ion and other batteries of similar technology, either as part of the machine or added accessories. Lithium-ion batteries have ignition, burning temperature, and burning environment characteristics that are unique from other potential electrical fire hazards. See IEC 62619 for guidance on requirements and tests for the safe operation of lithium-ion batteries.

6.3 Fuel sources

Design considerations for eliminating or minimizing, as practical, fuel sources should include, but not be limited to, the following:

a) Eliminate or minimize, as practical, combustible and flammable materials in the construction of the machine or use materials with reduced combustibility and flammability.

   1) Use cab and canopy components (e.g. upholstery, insulation, plastic coverings) and insulation materials used on other parts of the machine with a burning rate in accordance with ISO 20474-1:2017, 4.19.1.