
**Fire safety engineering — General
principles —**

**Part 2:
Example of a dry-cleaning store**

*Ingénierie de la sécurité incendie — Principes généraux —
Partie 2: Exemple d'application à un pressing*

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Foreword

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

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

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A list of all parts in the ISO 23932 series can be found on the ISO website.

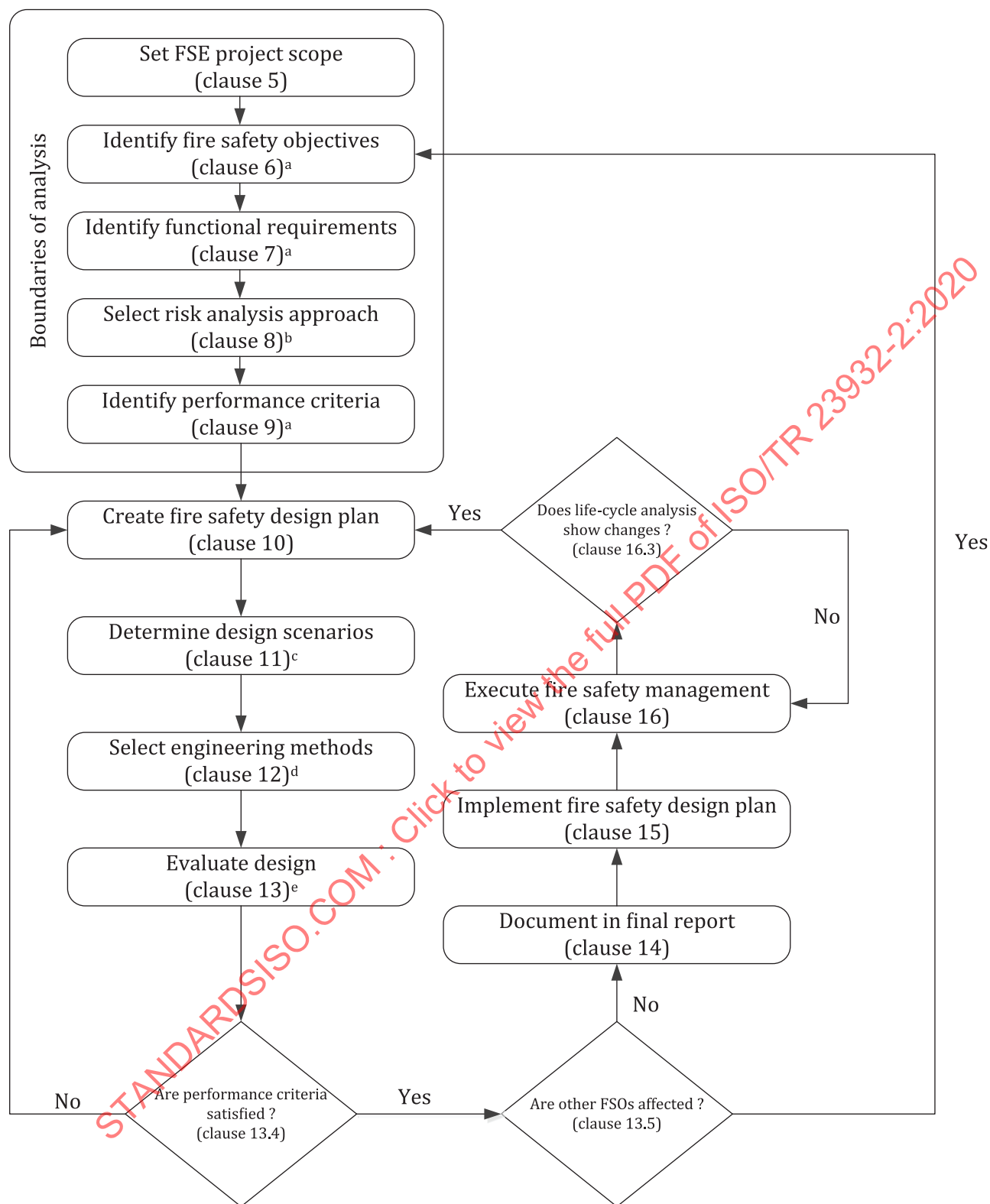
Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document gives a complete example to illustrate ISO 23932-1.

The following chart is an outline of the fire safety engineering (FSE) process (design, implementation and maintenance) of a built environment, as described in ISO 23932-1.





Key

^a See also ISO/TR 16576 (Examples).

^b See also ISO 16732-1, ISO 16733-1, ISO/TS 29761.

^c See also ISO 16732-1, ISO 16733-1, ISO/TS 29761.

^d See also ISO/TS 13447, ISO 16730-1, ISO/TR 16730-2 to 5 (Examples), ISO 16734, ISO 16735, ISO 16736, ISO 16737, ISO/TR 16738, ISO 24678-6.

^e See also ISO/TR 16738, ISO 16733-1.

NOTE Documents linked to large parts of the FSE process: ISO 16732-1, ISO 16733-1, ISO 24679-1, ISO/TS 29761, ISO/TR 16732-2 to 3 (Examples), ISO/TR 24679-2 to 4 and 6 (Examples).

Figure 1 — Flow chart illustrating the fire safety engineering process (design, implementation and maintenance) as per ISO 23932-1:2018, Figure 1

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Fire safety engineering — General principles —

Part 2: Example of a dry-cleaning store

1 Scope

This document provides a complete example to illustrate ISO 23932-1.

The example is a dry-cleaning store, for which the fire safety objective is life safety, for both people located inside or outside the shop, in the event of a fire within the shop.

NOTE Generally, an FSE study is not needed for such a small shop. However, this example was chosen to demonstrate the application of ISO 23932-1 in detail while keeping the documentation provided sufficiently brief.

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 13943, *Fire safety — Vocabulary*

ISO 23932-1, *Fire safety engineering — General principles — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 and ISO 23932-1 apply.

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

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

4 Objective

The objective of this case study is to demonstrate, by way of an example, how a fire safety engineering (FSE) process (as illustrated in the chart in Figure 1) can be applied to a simple building.

5 Example of FSE process applied to a dry-cleaning store

5.1 Scope of the project concerning FSE process (ISO 23932-1:2018, Clause 5)

The project is the construction of a small shop for dry-cleaning activity.

This dry-cleaning shop is open 6 days a week, between 8 am and 7 pm. The staff consists of 5 people (the manager, three laundry employees, one surface technician).

Its activity involves the usual activities of dry-cleaners, namely:

- receiving clothes (to be washed) at a counter (direct connection in business with customers);

- sorting clothing in packaging containers;
- brushing and stain removal of clothes;
- use of a washing and drying machine (front-opening window);
- ironing clothes;
- handling and packaging of the clothes under cover;
- storing clothes before and after washing;
- receiving and storing products used in dry-cleaning;
- delivery of clothing to the customer.

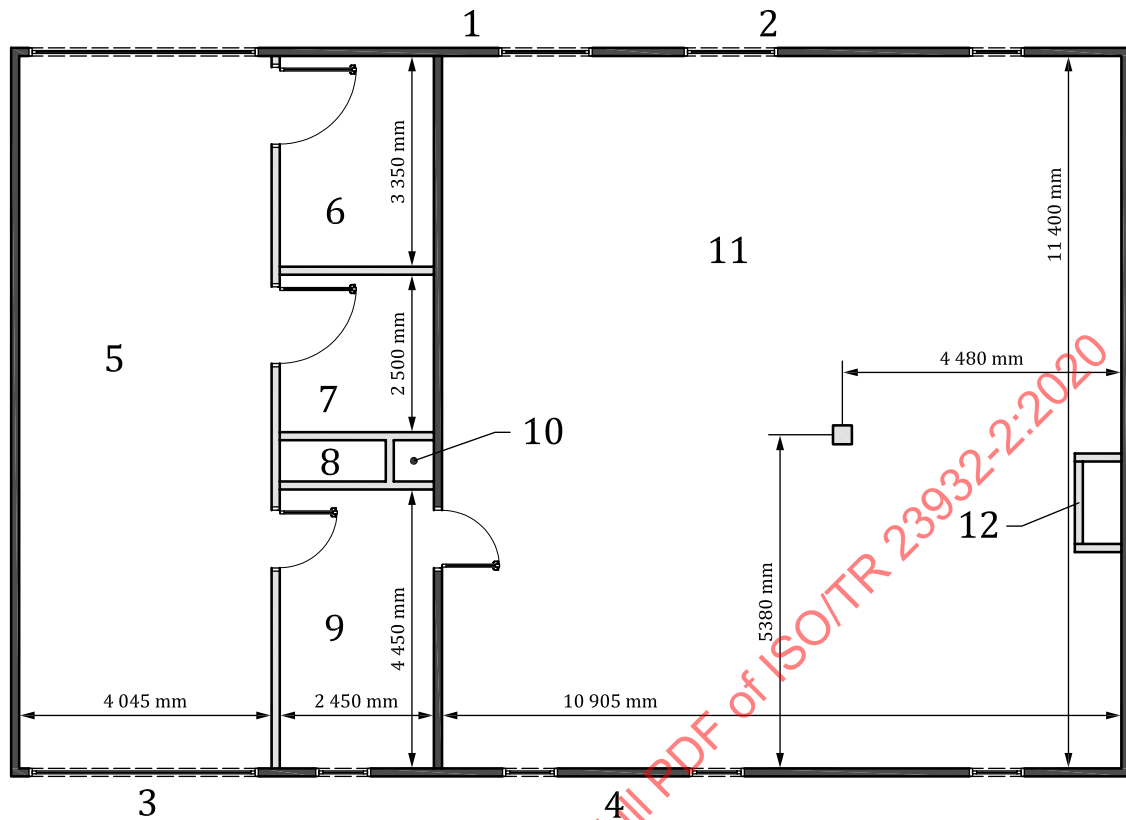
With the further complementary activities:

- accounting and administration for a small business;
- cleaning and maintenance of the facility.

The building is an old building consisting of 2 stories, with the north and south facades equipped with windows and overlooking either the street or an interior courtyard. The east and west facades are common with neighbouring buildings. An entry on the west side of the property leads to the stairwell and apartments upstairs. A trash storage room and a bike storage room are adjacent to the shop with shared access from the courtyard (see [Figure 2](#)). The building is equipped with a garbage chute accessed from the upper floor.

The courtyard serves as a car park for residents of the building and employees. It is bounded by walls about 2 m high, which separate it from other courtyards of neighbouring buildings.

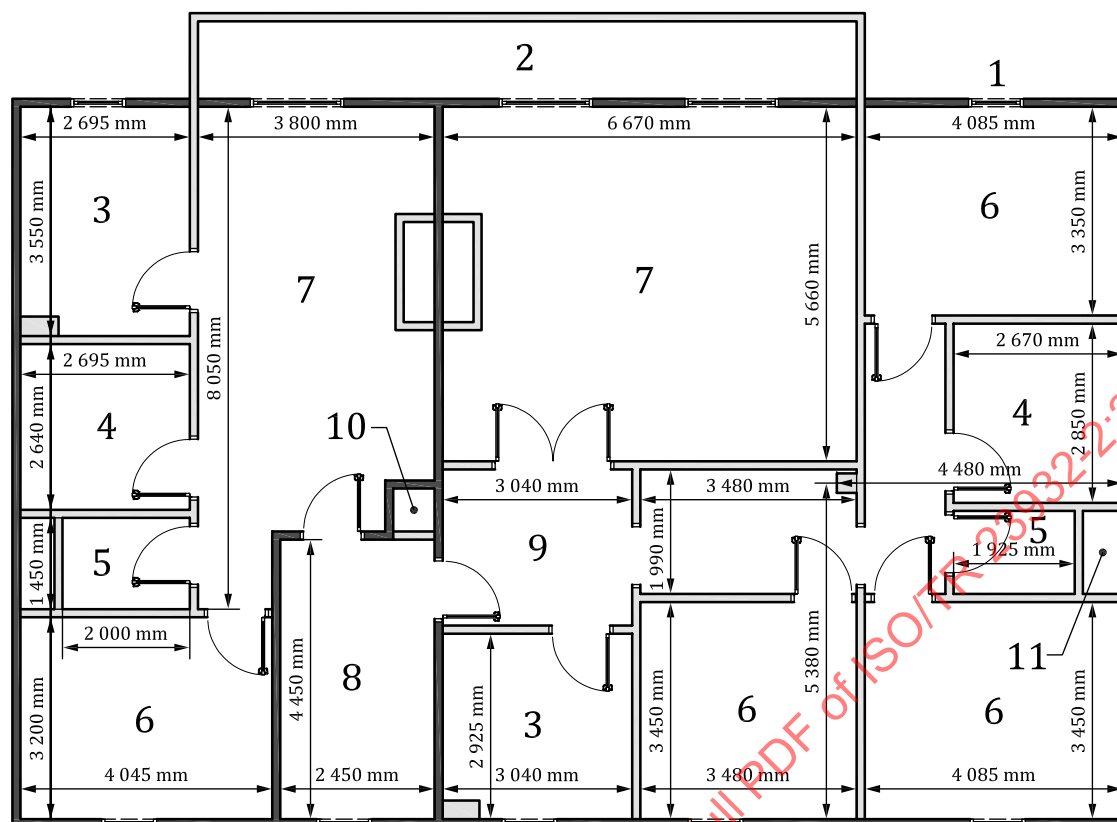
On each floor there are two apartments. One type T2, composed of a bedroom, a living room, a bathroom, a kitchen and a separate toilet. The other type T4 is composed of three bedrooms, a large living room, a kitchen, a bathroom, a toilet, an entrance and a hallway with storage cupboards (see [Figure 3](#)). Note the presence of a balcony at the first-floor level overlooking the street. There are five windows per floor and per facade. At the balcony level, there are French windows. Each apartment has a fireplace.



Key

- 1 street side
- 2 north facade
- 3 south facade
- 4 courtyard side
- 5 access to the courtyard
- 6 room for bicycles
- 7 room for trashcan
- 8 switchboard
- 9 staircase
- 10 garbage chute
- 11 location of the dry-cleaning shop
- 12 service shaft

Figure 2 — Ground floor (dry-cleaning shop) plan



Key

- 1 north facade
- 2 balcony
- 3 kitchen
- 4 bath room
- 5 restroom
- 6 bedroom
- 7 living room
- 8 staircase
- 9 entrance
- 10 garbage chute
- 11 service shaft

Figure 3 — Upper floor (flats) plan

The building has the following characteristics:

- a) floor:
 - full reinforced concrete slab 18 cm thick;
- b) concrete load-bearing walls 20 cm thick:
 - delimiting the outline of the building;
 - separating the local trash room and the staircase of the shop;
 - separating the two apartments on each floor;

- c) internal partitions:
 - solid brick walls 6 cm thick;
- d) wood frame windows;
- e) solid wood doors.

The property is located in a large city, on the ground floor of a residential building in a one-way street, with parking authorized vehicles on both sides. The environment consists of the following elements, which are assumed to not change in the future:

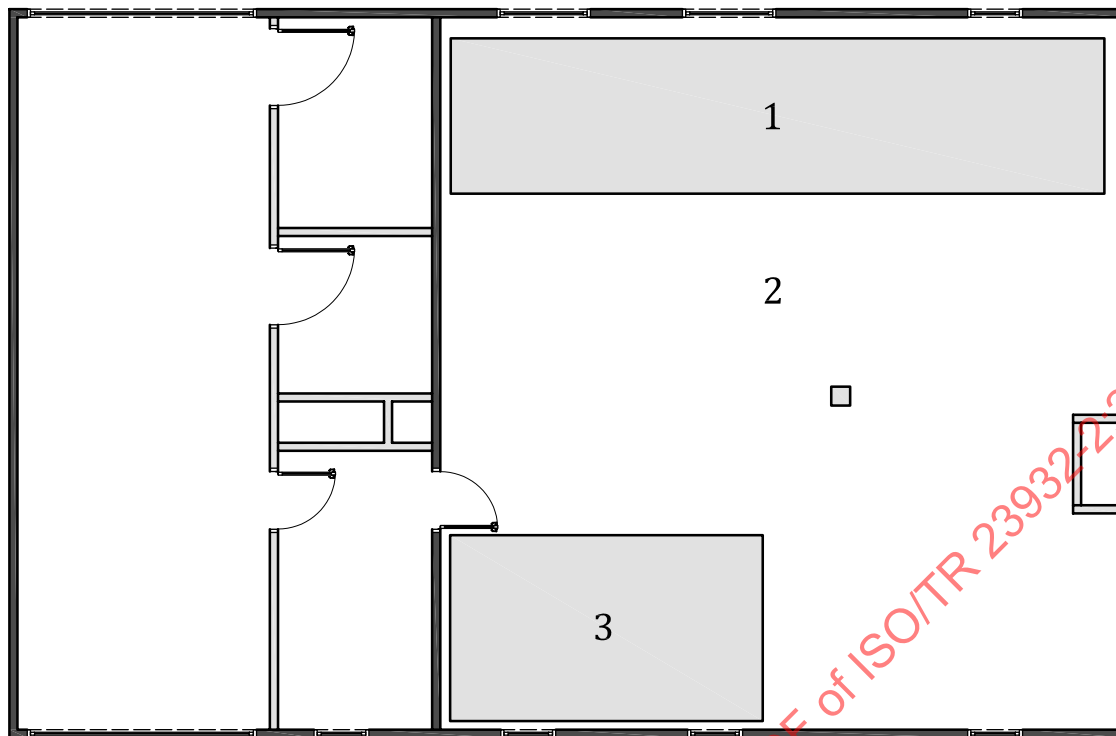
- east side, the presence of an adjacent residential building composed of two apartments on two floors and a tobacco/press shop on the ground floor. Access to the courtyard for cars separates the establishment from the tobacco/press shop;
- west side, the presence of an adjoining apartment building composed of four apartments over two floors and a neighbourhood grocery store on the ground floor. The staircase leading to the houses of the neighbouring building separates the dry-cleaning shop from the grocery store;
- north side, the presence of a clinic on the other side of the street (vis-à-vis). It is separated by a wall about 2,50 m high overlooking a car park and a garden. The main building is located 20 m away from the street;
- south side, the presence of a courtyard used as car park and gardens of neighbouring buildings.

The shop is located on the ground floor of the building whose construction predates 1986. With a total area of 120 m², there are three distinct areas (see [Figure 4](#)):

- the "commercial" area where the reception area is located for customers and where products used by the laundry are received;
- the "dry" area itself that covers the main activities (sorting, washing, ironing, storage, etc.);
- the "administrative" area made up of a desk and archive cupboards.

The ceiling height is 2,50 m, for ground dimensions of 11,40 m × 10,90 m. The shop features a glass facade overlooking the street and windows overlooking the internal courtyard to provide light.

A door provides access to the building lobby that serves the non-enclosed stairwell. The electric-meter, gas-meter and water supply-meter of the shop are located in a wall cupboard in the stairwell.



Key

- 1 commercial area
- 2 dry-cleaning shop
- 3 office room

Figure 4 — Three different areas within the shop

It is assumed that the shop is designed to fulfil national regulations and fire safety standards related to the city where the building is located. These regulations are mainly:

- a labour code;
- a decree of 25 June 1980 and of 22 June 1990 approving the general provisions of the safety regulation against the risks of fire and panic in establishments open to the public.

These regulations have the following main objectives:

- the protection of the health and life of the occupants of the establishment;
- the protection of surrounding people;
- the building owner is forced to ensure that the building design minimizes the risk to workers;
- the user is obliged to ensure that the workspaces are arranged so that their use ensures worker safety.

The chemical products used in the activities of dry cleaners contain volatile organic compounds (VOCs), harmful to health. For example, perchlorethylene has been classified R40 (suspected carcinogen). Regulations concerning installation classified for the protection of the environment have made some constructive provisions and mandatory safety measures from a defined threshold of such a hazardous product.

The organization of this project revolves around:

- 1) the client who will be the future operator. They are responsible for:
 - the choice of voluntary security objectives to complement the "regulatory" objectives;

- the project financing and choices made thereunder;
- 2) a project management team (design office + architect), which coordinates the various stakeholders' trades. They are responsible for:
 - the choice of skills and trades required for the project;
 - the budget and integration requirements from the FSE study;
 - satisfying the regulatory requirements and the meeting required time-frames;
- 3) the engineering design office responsible for the FSE study. They are the guarantor of the application of the methodology and have a duty to advise on the different phases of the FSE. They are responsible for:
 - the choice of engineering tools to set up and the competence of the users;
 - the coherence between the input data and the results given by the FSE study;
 - the feasibility of the design solution with respect to the regulatory requirements.
- 4) the insurer, who can make his/her point of view to the operator on the development strategy of the work safety regarding contractual requirements; and
- 5) the relevant safety committee, which has to validate the preliminary study report and then the FSE study, leading to the operating license.

To meet fire safety objectives as prescribed in the national regulation and standards, prescriptive requirements are implemented except those in direct relation with the current FSE study which deal with:

- the smoke generation and propagation within the shop;
- the tenability of people;
- and, regarding safety of neighbours:
 - smoke propagation within the stairwell leading to the upper floor of the building;
 - assessing the risk level of fire spread by the facade;
 - fire resistance of the upper floor of the shop.

Regarding protection of environment, there are specific regulatory requirements according a decree of 2 May 2002 on the general requirements applicable to facilities classified for the protection of the environment subject to declaration under heading No. 2345 on the use of solvents for dry-cleaning and treatment of textiles or clothing. These prescriptive requirements are fulfilled.

5.2 Identification of fire safety objectives (ISO 23932-1:2018, Clause 6)

5.2.1 Safety of life

Selected fire safety objectives are the protection of health and life of:

- occupants, namely the employees of the company and the public;
- neighbours;
- fire fighters.

5.2.2 Conservation of property

The property conservation objective regarding the shop is not a selected objective of this document. However, safety of movable and immovable property of third parties is an objective to fulfil.

5.3 Identification of functional requirements (ISO 23932-1:2018, Clause 7)

According to fire safety objectives mentioned within [5.2](#), the associated functional requirements are the following.

5.3.1 Occupant protection

The objective is to avoid endangering people in the establishment, i.e. customers, employees and potential suppliers.

In case of occurrence of a fire, the general provisions should allow an evacuation of the facility without the occupants having to suffer the effects of the fire. Tenability conditions should not vary abruptly before the evacuation of the facility.

This requirement is especially supplemented by the following sub-requirements:

- visibility for distinguishing evacuation signage;
- fire development compatible with the fire evacuation of people.

5.3.2 Protection of neighbours

Neighbours should not be impacted by the effects of the fire. Those present in the apartments located above the shop must be able to stay in corridors and flats, while having satisfactory tenability conditions for the whole duration of the fire scenario.

5.3.3 Protection of fire fighters

The fire fighters must be able to conduct reconnaissance in establishing and evacuating bystanders and residents who may be impacted by the fire.

5.3.4 Property protection

The fire at the facility should not spread to neighbouring structures (buildings located on both sides), nor to the apartments above. It must not cause irreversible damage to them, for the duration of all fire scenarios.

5.4 Selection of risk analysis approach (ISO 23932-1:2018, Clause 8)

The current performance-based fire safety design uses an absolute approach with deterministic analysis. The deterministic analysis involves the evaluation of worst credible case scenarios, i.e. scenarios that represent a severe but not unlikely challenge for the shop. It is based on the estimation of the seriousness of the consequences of each design scenario, which is compared with threshold values expressed within [5.5](#).

5.5 Identification of performance criteria (ISO 23932-1:2018, Clause 9)

5.5.1 Protection of occupants of the shop

To satisfy the objective of protection of occupants and associated functional requirements, performance criteria are as follows (before the end of the evacuation).

- The temperature at 1,80 m above the floor does not exceed 60 °C in the "commercial" area.
- The distance of visibility at 1,80 m from the ground is not less than 5 m in the "commercial" area.
- Radiative flux incident, to people in the "commercial" area, is not greater than 2,5 kW/m².

5.5.2 Protection of neighbours

The criteria achieved are:

a) regarding the apartments:

- temperature of the unexposed side of the top floor of the shop is less than 60 °C on average;
- there is no drop of visibility due to the presence of smoke (which also covers the risk of toxicity);
- no broken glass at the windows of the first floor of the external facade of the building;
- absence of collapse from the top floor of the shop (throughout the duration of the fire);

b) as regards the corridors and stairwell:

- the temperature is less than 60 °C;
- visibility is not less than 10 m.

5.5.3 Protection of fire fighters

The performance criteria for the protection of fire fighters during their intervention in the shop are:

- no falling objects and materials on fire fighters;
- no potential obstacles in the traffic lanes in the shop.

NOTE The criteria for the protection of neighbours for the evacuation of persons present in the apartments also address the protection of fire fighters.

5.5.4 Property protection

The criteria associated with the protection of goods and neighbouring properties are:

- the top floor of the shop should not undergo deformation which may lead to the collapse;
- temperature rise is not greater than 140 °C on the unexposed side of the peripheral walls of the shop;
- no broken glass at the windows of the first floor of the external facade of the building.

5.6 Fire safety design plan (ISO 23932-1:2018, Clause 10)

The proposed design solution is based primarily on prevention measures to reduce the occurrence and intensity of the feared event (to prevent fire spread to the whole shop). The risk management strategy is directed towards reducing the likelihood of a fire starting and development of a fire (with the elimination or reduction of fuels and sources of ignition) and the setting up of devices to limit the spread of the fire.

The action of the fire fighters was not taken into account for elaborating the design solution.

5.6.1 Development of the proposed solution

5.6.1.1 Prevention

Preventive measures aimed at reducing the hazard potential:

- limitation of flammable products in daily amounts in the activity area;
- permanent ventilation of premises, monitoring the ambient temperature;

- restriction of the quantity of goods stored to that necessary for one month of activity (not long-term storage);
- no light fixtures above the storage area. They are installed above the passageways;
- electrical system complying to the required standards and inspected every year;
- no multi-sockets in offices, the installation of wall outlets to be of sufficient number;
- regular maintenance of the machines.

Preventive measures aimed at limiting the fire development:

- physical separation of the office from the rest of the facility including use of door closers;
- physical separation of the reserve from the rest of the facility including use of door closers;
- work organization: separation of activities;
- physical separation of the preparation area of the clothes (laundry to be washed) and the zone of the machines;
- physical separation of the area of the zone of the machines and the clothes storage area;
- physical separation of the ironing zone and linen (clothes) storage area;
- physical separation of the customer reception area from the rest of the establishment;
- use of non-flammable materials for construction products (e.g. floor, walls and ceiling).

Preventive measures aimed at reducing the kinetics of the fire:

- flammable products in permanently closed containers;
- physical separation of flammable products in a closed cupboard;
- installation of closed cupboards for archives in the office;
- installation of an emergency exit opposite the main entrance of the establishment.

5.6.1.2 Protection

Passive means of protection:

- current perimeter masonry walls 20 cm thick;
- closing access to the stairwell with the replacement of the door by a wall;
- current upper floor slab with a thickness of 18 cm.

NOTE 1 The relevance of the effectiveness of passive means of protection has been verified through the proposed fire scenarios. In particular, the following have been audited:

- the sufficiency of tightness (integrity) to the smoke and flames and the heat insulation of the facade of the building and inner peripheral partition walls to satisfy the fixed objectives;
- the security option of closing the stairwell. This audit was conducted via a smoke propagation study scenario in this staircase, taking the hypothesis that the current door remains open;
- the sufficiency of tightness (integrity) to the smoke and flames and the thermal insulation of the top floor of the facility to meet the objectives set.

Means of active protection:

- installation of two fire extinguishers of 6 litres; with annual service and maintenance;

- installation of two Autonomous Alarms Smoke Detectors (DAAF in French); annual service and maintenance of detectors;
- emergency lighting over the exit.

NOTE 2 The scenarios studied do not take into account the use of extinguishing means. On the other hand, water extinguishers are adapted for the control of fire initiated in textile materials and can thus contribute to reduce the risk of development of a fire.

5.6.1.3 Forecast

Measures for emergency actions:

- Egress plan / shop map.
- Staff training in risk prevention at the workplace and the use of emergency resources.
- Reminder of emergency numbers near the phone.

5.6.2 Description of the management of fire safety

The manager is responsible for fire safety of its establishment. As such, they will take care of:

- training of staff and external stakeholders within the shop;
- servicing and maintenance of equipment;
- compliance with preventive and protective measures considered in this document.

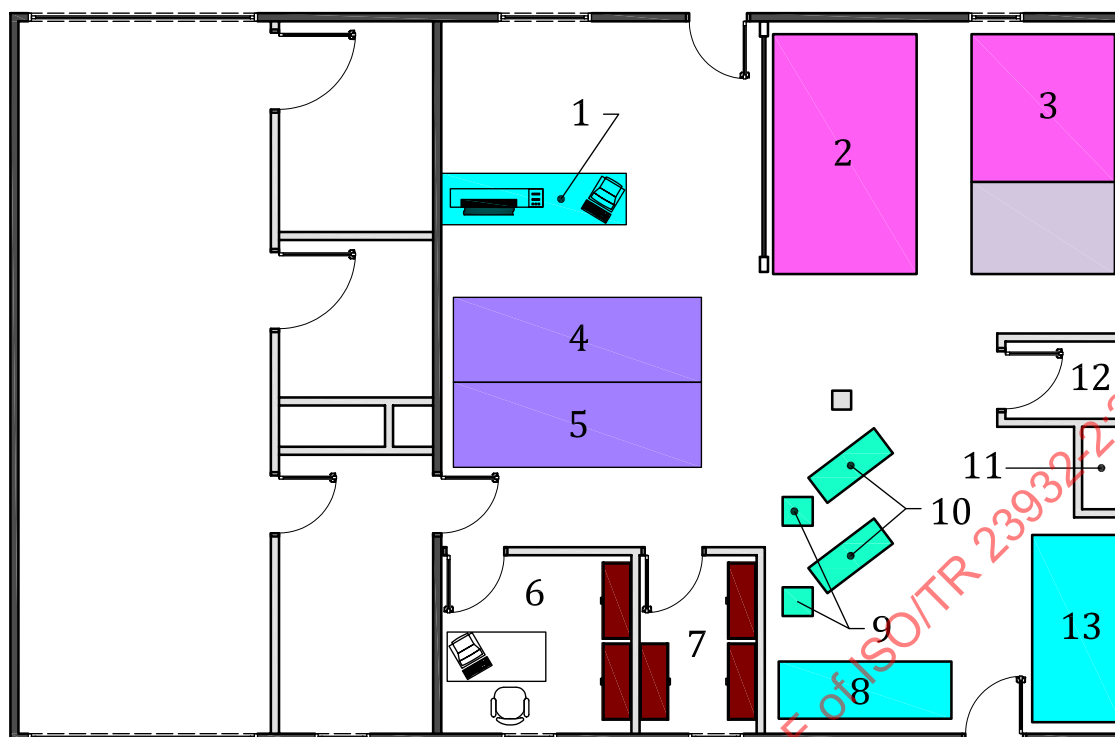
Verification will be transcribed in a specific specification to be followed over the life of the shop, archived and protected from any disaster in the facility.

5.6.3 Design proposal

At this stage of the design, the number and type of machines used are not yet defined. The plan takes into account the possible maximum capacity based on the size of the machines, namely (dimensions according to data width, depth and height, in mm):

- 2 dry-cleaning machines (unit capacity 19 kg): $1\ 960 \times 1\ 430 \times 2\ 150$;
- 2 washing machines (unit capacity 55 kg): $1\ 450 \times 1\ 400 \times 1\ 750$;
- 3 machine dryers (unit capacity 25 kg): $950 \times 1\ 400 \times 1\ 900$;
- 2 ironing boards: $1\ 610 \times 520 \times 885$;
- 2 steam generators: $450 \times 410 \times 830$;
- 1 manual wrapper: $1\ 450 \times 700 \times 900$;
- 1 ironing machine: $2\ 490 \times 1\ 070 \times 550$.

[Figure 5](#) shows the draft layout of the shop.



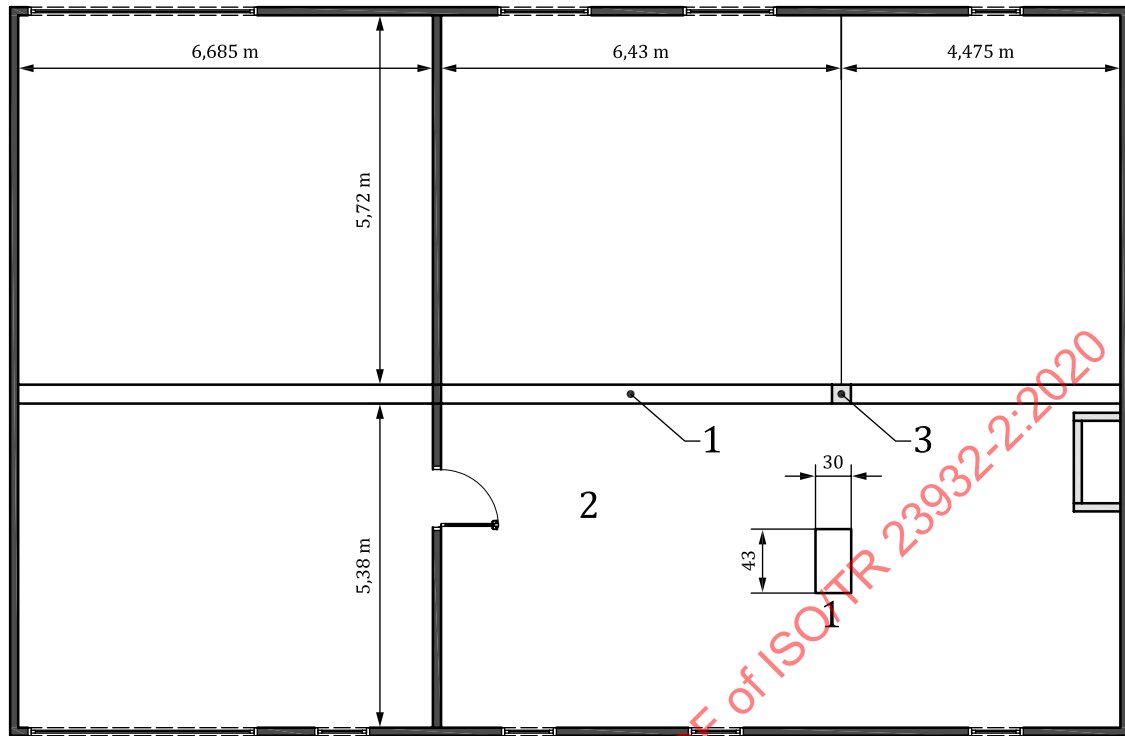
Key

- 1 packaging machine
- 2 storage of the received washing
- 3 storage of clean linens on hangers
- 4 washing machines
- 5 dryers
- 6 office
- 7 storage room
- 8 ironing machine
- 9 steam generator
- 10 ironing board
- 11 service shaft
- 12 restroom
- 13 dry-cleaning machine

Figure 5 — Design proposal of the shop

The materials used for the ground floor (tiles), the ceiling and walls (paint) will be low or non-combustible. Any ventilation ducts at the ceiling level are metallic materials, insulated with appropriate mineral wool (especially for the evacuation of steam).

The top floor of the local pressing is composed of two continuous slabs, each resting on the external walls and on a central beam. This continuous beam consists of three sections, supported both on the external walls and on a central column (see [Figure 6](#)).



Key

- 1 beam
- 2 concrete slab, thickness = 18 cm
- 3 column

Figure 6 — Plan structure elements of the top floor of the shop

Regarding the design of the slab, the loading is: $G = 6,72 \text{ kPa}$ and $Q = 1,5 \text{ kPa}$. The thickness is 18 cm. The lower reinforcements parallel to the y axis are made of steel diameter $\Phi 12 \text{ mm}$ spaced every 15 cm ($7,53 \text{ cm}^2 / \text{m}$) and the steel reinforcement parallel $\times \Phi 8 \text{ mm}$ diameter spaced every 20 cm ($2,5 \text{ cm}^2 / \text{m}$). An upper steel lattice of $\Phi 8 \text{ mm}$ steel diameter, spaced 20 cm in both directions is set up to 3,5 cm from the upper side.

At the beam level, the upper reinforcement bars $\Phi 12 \text{ mm}$ diameter spaced every 20 cm ($5,65 \text{ cm}^2 / \text{m}$) are put in place. The concrete cover of rebars is 2 cm and it could be increased up to 3,5 cm if needed for fire resistance.

For the design of the continuous beam, the loading is $G = 40,85 \text{ kN/m}$ and $Q = 8,7 \text{ kN/m}$. Their spans are 6,43 m and 4,575 m length. The beam section height is 43 cm and its width 30 cm. Concerning the span of 6,43 m: lower reinforcing bars are made of $6\Phi 16$ ($12,06 \text{ cm}^2$), above the support frames of $4\Phi 20$ ($12,57 \text{ cm}^2$) and $2\Phi 16$ ($4,02 \text{ cm}^2$) and top reinforcement on support based on the post $4\Phi 20$ ($12,57 \text{ cm}^2$). Concerning the span of 4,575 m: lower reinforcing bars are made of $4\Phi 16$ ($8,04 \text{ cm}^2$), top reinforcement on the support $4\Phi 20$ ($12,57 \text{ cm}^2$) and top reinforcement on $2\Phi 12$ riverside support ($2,26 \text{ cm}^2$). The concrete coverage of rebars is 2 cm, which could be increased up to 4 cm if needed for fire resistance.

For the design of the central column, the loading is $G = 938,36 \text{ kN}$ and $Q = 174,25 \text{ k}$. The cross-section is $0,30 \times 0,30 \text{ cm}^2$. There are eight reinforcement bars with a diameter $\Phi 20 \text{ mm}$ ($25,13 \text{ cm}^2$). The concrete coverage of rebars is 2 cm, which could be increased up to 3,5 cm if needed for fire resistance.

5.7 Fire and behavioural scenarios (ISO 23932-1:2018, Clause 11)

5.7.1 Hazard identification

Internal identified hazards are:

- products and materials, e.g. textiles, chemical products (stain removal, dry cleaners (tetrachloroethylene);
- tools and equipment, e.g. dry-cleaning machines, washing machines, dryers, irons, press or ironing boards, dry steam generator (press machine), or various electrical equipment (computers, cash register, radio, lights, etc.), covers packaging machine (packer);
- process, e.g. receiving, sorting, handling, machine loading and unloading unit, packaging and placed under cover, maintenance of machinery.

According to a survey conducted by the French BARPI in 2008 (http://barpipdf.geniecube.info/liste_etude_pressing.pdf), seven cases were identified between 1991 and 2000 where fire occurred in premises having such activities. The vast majority of events are related to leakage of tetrachloroethylene or perchloroethylene. These products are indexed as toxic and dangerous when inhaled.

5.7.2 Fire scenarios

The spirit of ISO 16733-1 and its nine-step systematic procedure for identifying the design fire scenarios was followed. However, due to the size of the shop and the limited number of occupants, some of the steps were merged.

The risk analysis is based on a relative comparison of the scenarios to determine those which have an impact on the fixed objectives. The purpose of this step is to provide a few scenarios that will be used for the evaluation of the design solution.

Fire spread can occur due to:

- flame contact: the flame licks over fuel and causes its inflammation. The flame contact is limited to the immediately accessible area by the flame zone;
- convection: hot gases heat the fuel relay which comes up to the ignition temperature. Propagation by convection is limited to the upper part of the volume;
- radiation: flame emittance causes heating of the surrounding combustible materials until the ignition temperature. All fuels visible by flames are affected by the radiation.

The transfer by conduction and transport of sparks is not studied because it is considered negligible compared to other fire transfer modes.

The consideration of combustible materials is limited to combustible fuels present in relatively large amounts in the facility (i.e. textiles, machinery, furniture). Fuels present in small amounts and having no impact on the development of fire (e.g. plastic electrical outlets) are excluded.

The identification of a single ignition source (e.g. electrical, thermal) is sufficient to consider the potential fire hazard. Possible preventive measures are taken into account in assessing the risk of fire initiation. For example, if all fuels are protected in fire cupboards, and potential ignition sources are external, the starting fire is not considered. Conversely, the presence of electrical equipment of any kind is considered sufficient to cause a start of a fire (e.g. lighting).

The factors having an influence on the evolution (worsening or limiting) of the fire are:

- ease of ignition of fuels, regarding their nature, their state of division, their physical characteristics (e.g. ignition temperatures, dimensions);
- their ability to participate in the fire (calorific value, burn rate, fuel availability).

For safety objectives of this project, the presence of a secondary fire source close to the main fire source will be studied. The study considers the generalized ignition is possible if no action is taken on the initial outbreak of fire.

5.7.2.1 Identification of potential fire scenarios

The proposed design solution requires many of the sources of ignition hazard potential to be separated by construction or distance. [Table 1](#) lists the event initiators identified according to the location in the facility.

Table 1 — Potential initial events

Location	Ignition source	Combustibles	Existing measure	Predictable event
Commercial area	Power Supplies (computer, phone, etc.)	Paper, computer	—	Start a fire on the counter
	Packing machine	Polyethylene film	—	Start a fire in the packing machine
	Lighting	—	Lighting within corridor	—
Storage area clean linen	Lighting	Clothing, various textiles	Lighting within corridor	—
Storage area received linen	Lighting	Clothing, various textiles	Lighting within corridor	—
Washing machine and dryer zone	Electrical incident	Linen, fuel elements of the machine	—	Start fire in a washing machine / dryer
	Lighting	Linen	Lighting within corridor	—
Dry-cleaning machine area	Electrical incident	Linen, fuel elements of the machine Toxic product: perchlorethylene	—	Start fire in a dry-cleaning machine: toxic release
	Lighting	Linen	Lighting within corridor	—
Iron machine area	Electrical incident	Linen, fuel elements of the machine	—	Start fire in the machine
	Lighting	Linen	Lighting within corridor	—
Steam generator and iron board area	Electrical incident on steam generator	Fuel elements of the machine	—	Start fire on the steam generator
	Heating element (iron)	Linen	—	Start fire on the ironing board
	Lighting	Linen	Lighting within corridor	—
Storage room	Lighting	Solvent products	Products in closed cupboards	—
Office	Electrical materials (computer, phone, etc.)	Various papers	—	Start a fire within the office
	Lighting	Materials of light fittings, diffusers, cable insulation	Lighting within corridor	—

According to these fire initiation events, the following fire scenarios are identified:

- fire on the counter or on the packaging machine: The assumption in this scenario is starting a fire located at the customer reception counter. The presence of sensitive and dispersed fuels (such as sheets of paper or plastic) is favourable to a plume fire spreading step by step;
- fire on a washing machine / dryer: The assumption in this scenario is starting a fire located at a washing machine or a dryer. It is therefore initially an electrical fire (short circuit) or thermal (heating of a textile);
- fire on a dry-cleaning machine: This scenario is very similar to a fire starting on a washing machine or a dryer. The main difference comes from the presence of highly toxic products used in the process: perchlorethylene. Although the product is non-combustible, the evaporation temperature of 121,2 °C is very low and the product can spread rapidly with the smoke;
- fire on the ironer: The ironer is a machine for ironing the clothes automatically. The process is hot, so the fire risk is higher than in the previous scenarios;
- fire on the generator or on the ironing board: This scenario implies again a hot process directly on textiles. The risk of spread is higher due to the presence of linen close to potential fire starts;
- fire in the office: This scenario is relatively common which could be due to, e.g. short circuits in small electrical equipment or the desk lamp, hazardous products left in the trash;
- fire in the linen storage area: Taking into account the prevention measures taken (distance from sources of ignition), this scenario is not relevant. However, this area has the largest heat load and will be taken into account in the fully engulfed fire scenario;
- fire in the storage room: Given prevention regulations considered (removal of ignition sources and confinement of fuels produced in closed cupboards), this scenario is not relevant;
- fully engulfed fire within the shop: All fire starting scenarios mentioned above can lead in time to spread of the fire to the whole shop. The fire will then spread to all marketable fuels and could impact neighbours, either by smoke and flames especially at the upper levels, or remotely at ground level, due to the radiated heat flux.

5.7.2.2 Selection of design fire scenarios

The following table shows the priority of scenarios that could challenge the safety objectives defined above and states the evaluation criteria.

The scenarios are:

- Scenario 1: Start of fire on the counter or on the packaging machine;
- Scenario 2: Start of fire on a washing machine / dryer;
- Scenario 3: Start of fire on a dry-cleaning machine;
- Scenario 4: Start of fire on the ironer;
- Scenario 5: Start of fire on the generator or on the ironing board;
- Scenario 6: Start of fire in the office;
- Scenario 7: Start of fire in the storage area;
- Scenario 8: Start of fire in the storage room;
- Scenario 9: Fully engulfed fire within the shop.

Given their origins, scenarios 1 to 5 can be grouped under scenario 3, the latter being considered the most unfavourable regarding safety objectives due to the presence of toxic products. Moreover,

scenarios 6, 7 and 8 are covered by scenario 9. This results in the following table for the relationship between criteria and scenarios.

Table 2 — Selection of design fire scenarios

Acceptance criteria to be checked	Fire scenario challenging fire safety objectives	Proposal for design fire scenario
Ambient temperature <60 °C in the "commercial" area	All	3
Visibility >5 m in the "commercial" area	1 to 5	3
Ambient temperature in the upper apartments <20 °C	All	3
No smoke in the apartments	All	3
Ambient temperature <40 °C in the hallways and the stairwell	All	3
Visibility >10 m in corridors and the stairwell	All	3
Absence of falling objects on fire fighters	—	—
Absence of obstacles in the traffic lanes in the store	—	—
No collapse of the first floor	9	9
Temperature under thresholds for unexposed side walls	All	3
No broken windows on the first floor of external facade	All	3

NOTE For the performance criteria dealing with the absence of falling objects on people and the absence of obstacles in store traffic lanes, only constructive provisions can be considered. The evaluation will therefore be on the relevance of such provisions to meet the safety objectives.

Consequently, risk analysis showed two scenarios that could jeopardize the fire safety objectives for the shop:

- 1) The first one is a starting fire in a dry-cleaning machine (Scenario 3). The heat supply may contribute to the evaporation of toxic products such as perchlorethylene. Two options will be investigated:
 - 3a door to the staircase is closed;
 - 3b door to the staircase is open.
- 2) The second one is the spread of a fire involving all the fuels (Scenario 9). The size of the fire could be enough to cause damage to the immediate environment of the shop.

5.7.3 Behavioural scenarios

The occupants of the shop are of three types:

- employees (3 persons permanently present). They have access to the entire property during working hours;
- service providers (for maintenance of such equipment). They have access to the entire property during short periods and defined in time;
- customers. They only have access to the "commercial" part of the establishment.

Given the activity of the shop and the accessible surface to the public, the shop will accommodate less than 15 people permanently (public + staff).

As regards the immediate vicinity, no assumptions are made regarding the characteristics of the population living in the building. This population may be of any type. Taking into account the provisions of the apartments, the study considers the presence of 6 people per floor.

5.8 Selection of engineering methods (ISO 23932-1:2018, Clause 12)

Tools to be used are quite different since the study will differ among the design fire scenarios due to their different objectives:

- the scenario with the fire starting on a dry-cleaning machine (Scenario 3) is designed to evaluate the safety of persons on the ground floor of the building, as well as the risk of fire spread from the outside and the smoke propagation within the upper floors.
- the second concerns a fully developed fire in the commercial area (Scenario 9) to assess the behaviour of structural elements and the risk to persons in the upstairs living areas.

Regarding the objective of protecting people within the shop, the scenario will be simulated with the CFD software. It makes it possible to determine the desired quantities (e.g. temperature, heat flow, viewing distance) at any point of the modelling domain. Use of this type of software also evaluates the risk of transmission through the facade and analyses fire behaviour of the fire timber door.

The safety of neighbours involves an analysis of the fire resistance of the loadbearing structure under a severe post flashover fire. To assess the stability of columns, beams and flooring, we can be satisfied with an average temperature of hot layer regarded as evenly distributed. In this second scenario, simpler two-zone model software will be used. Thermal analysis of the structural elements will be performed with purpose-designed finite element software for obtaining field temperatures in the elements. Finally, a mechanical analysis will be conducted to check the fire resistance of the structure.

5.9 Scenario-based evaluation of trial design (ISO 23932-1:2018, Clause 13)

5.9.1 Quantification of design fire scenarios

5.9.1.1 Input data

5.9.1.1.1 Input data for the first scenario (scenario 3):

The fuel can be impacted by a fire which starts on a dry-cleaning machine and which concerns firstly fuel elements of the machine itself (e.g. electrical, electronic components, rubber seals, paint sheet metal), and the other textile items put inside (e.g. various characteristics of clothing: wool, cotton, acrylic).

There are many kinds of textiles that can be involved:

- natural, animal (wool, silk) or vegetable (e.g. cotton, flax, hemp);
- artificial based worked cellulose (viscose, cellulose acetate), or non-cellulosic (latex, vinyl);
- synthetic, based on organic polymers (e.g. polyester, polyamide, polyethylene, polypropylene, polyacrylic, polyurethane).

Natural cellulosic materials ignite easily and burn rapidly. Artificial cellulose such as acetate tend to burn by melting, leaving a sticky residue which hardens after cooling. Natural materials of animal origin are more difficult to ignite and tend to crack and char.

As regards the synthetic materials, primarily two kinds of combustion can be considered. The chlorofibres group and aramid and polyamide imide tend to carbonize while polyamide 6.6 and 6, polyester and acrylic are easily ignited and burn by melting.

For most of the substances listed above, the calorific value is between 17 MJ / kg (some cotton, for example), and 30 MJ / kg (polyester). Densities range from 200 kg / m³ to 1 200 kg / m³.

To limit the assumptions about fuel and associated data (e.g. quantity, calorific value, pyrolysis rate), it is considered a single fuel, representing all the materials present in the shop. The choice was made to use the acrylic values on the basis of experimental data.

To be realistic while using upper bound, the assumptions of the fire scenario (for the main focus, i.e. the two dry-cleaning machines) are, for the primary source of fire:

- fuel quantity: 40 kg (which is the summation of the maximum load of a dry-cleaning machine, 19 kg, and the fuel load of the machine itself);
- calorific value of 21 MJ / kg (experimental data);
- density of 200 kg / m³ (experimental data);
- surface pyrolysis rate of 0,08 kg / m² / s (experimental data increased to reflect the scale effect).

Safety margins taken concern both the maximum intensity of fire (through the pyrolysis rate is increased) and fire duration (through the amount of fuel available in full development phase).

The surface pyrolysis rate is considered an upper bound in respect of most solid fuels (other than textiles) present in the establishment. For comparison, the pyrolysis rate of solid wood (office, desk tray, etc.) is of the order of 0,015 kg / m² / s, a ratio greater than 4.

The rise follows a curve in "alpha t²", the alpha coefficient being 0,011 7 kilowatts / s. The maximum power reached is limited by the burning fuel surface. This phase constant maximum power continues until 70 % of the available energy is burned. Then, the power is reduced through a fast decay such that 100 % of the remaining energy is discharged during a double duration of a combustion at full power.

Differentiation regarding the secondary sources of fire is based on two parameters: the amount of material (linked to the duration of the fire) and maximum power (assessed on the basis of a maximum burning surface).

The following table summarizes the input parameters of the secondary source of fire.

Table 3 — Input parameters of the secondary source of fire

Fire source	Iron machines	Ironing tables	Washing machines and dryers	Linen storage	Counter
Quantity of substance (kg)	2	5	100	1 000	5
Maximum power (kW)	420	840	1 680	16 800	840
Spread velocity	Slow	Medium	Slow	Fast	Slow

The power curves are presented in the next figures. Note that the scenarios:

- take into account sufficient air renewal to ensure complete combustion;
- are an envelope in terms of the power curve of a real fire and in view of the safety objectives to be assessed.

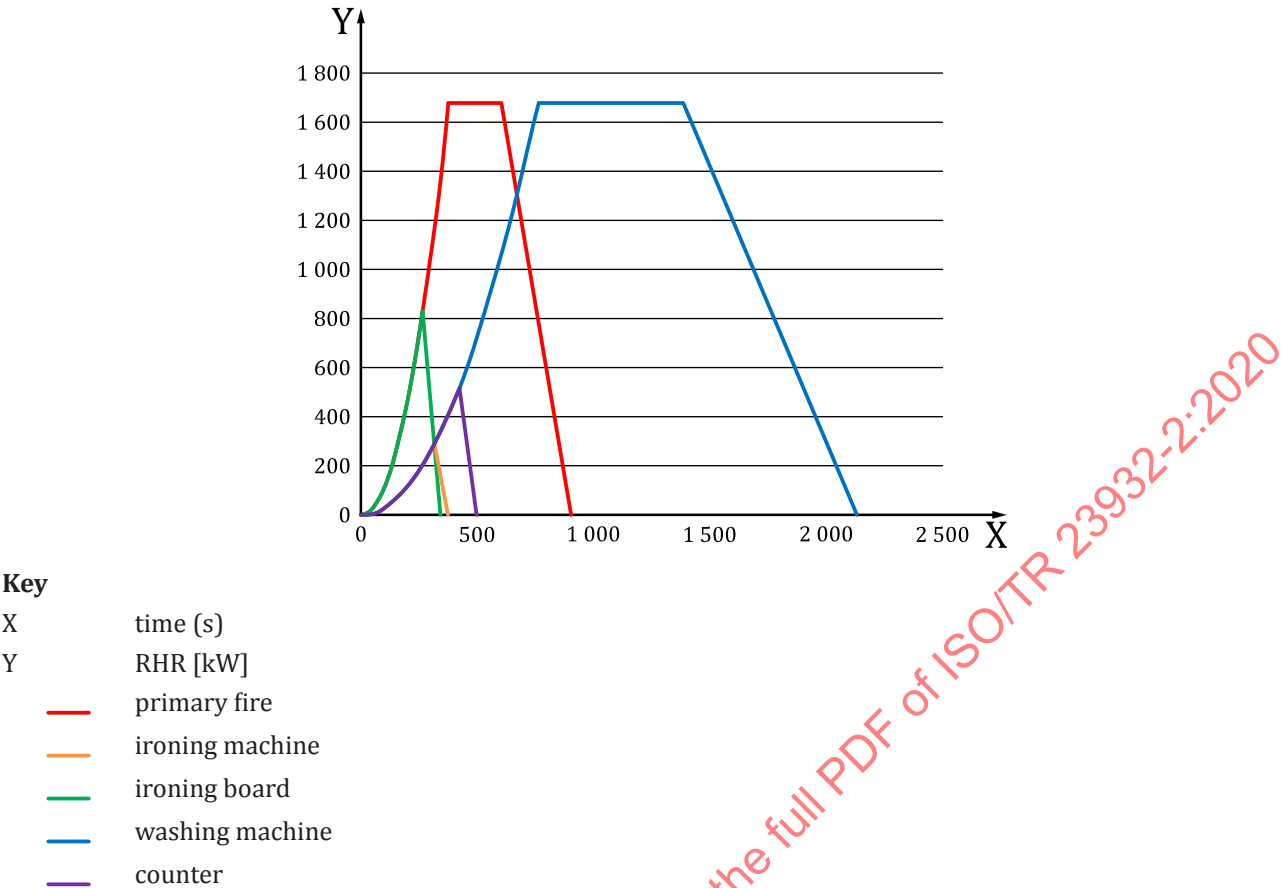


Figure 7 — Power curves of different fire sources

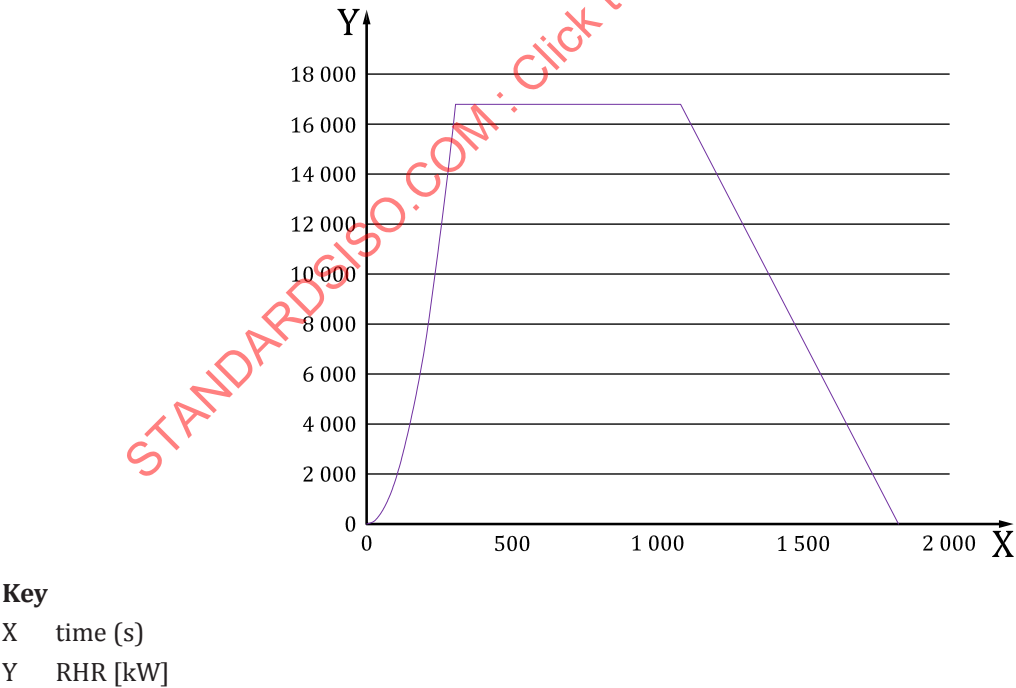


Figure 8 — Power curve for the linen storage

5.9.1.1.2 Input data for the second scenario (scenario 9):

This is a generalized fire to the whole laundry area. The power of the fire source of the linen storage represents the bulk of the contribution to the total power of the fire. To obtain an onerous thermal load, the power curve used as the initial focus will be that of the stored clothes, with, as in the first scenario, the possibility of spreading to other fuel elements of the room.

Simulations of the two scenarios are decoupled, based on the security objectives to be assessed.

5.9.1.2 Estimation of consequences

5.9.1.2.1 Scenario with fire starting on a dry-cleaning machine

5.9.1.2.1.1 Calculation parameters regarding fire development

The computational domain occupies a volume encompassing the ground floor and an exterior facade bounding volume to the first level, and a floor area of 141 m² (Figures 9 and 10).

The total number of elements: 475,200, with individual cells 10 cm × 10 cm × 10 cm.

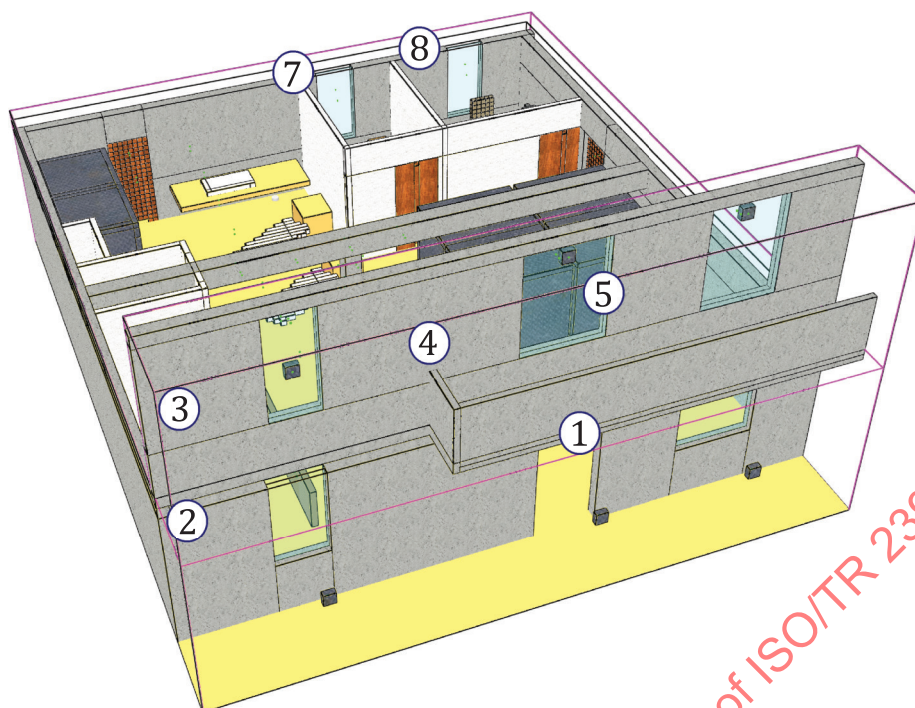
Boundary conditions as wall for external walls, floor and ceiling; with inert wall for floor and ceilings, and free elsewhere.

Modelling the fuel load, including internal obstacles of combustible material like wood (internal doors) and specific fuels (e.g. linen storage, dry-cleaning machines, ironing boards) which follow the power curves given in Figure 7. The flaming ignition of the burning equipment is subject to reaching a surface temperature of 200 °C.

The initiation of the fire is modelled by a hot spot located at the laundry close to a dry-cleaning machine (Figure 10).

The room ventilation is provided through the front door left open (2,2 m²) and a large gap under the non-fire door (0,4 m²) fitted to represent the vents and leaks by the frame of doors (Figure 9). Additional leads are possible depending on the thermal load, the apertures concerned are assigned the following behaviours:

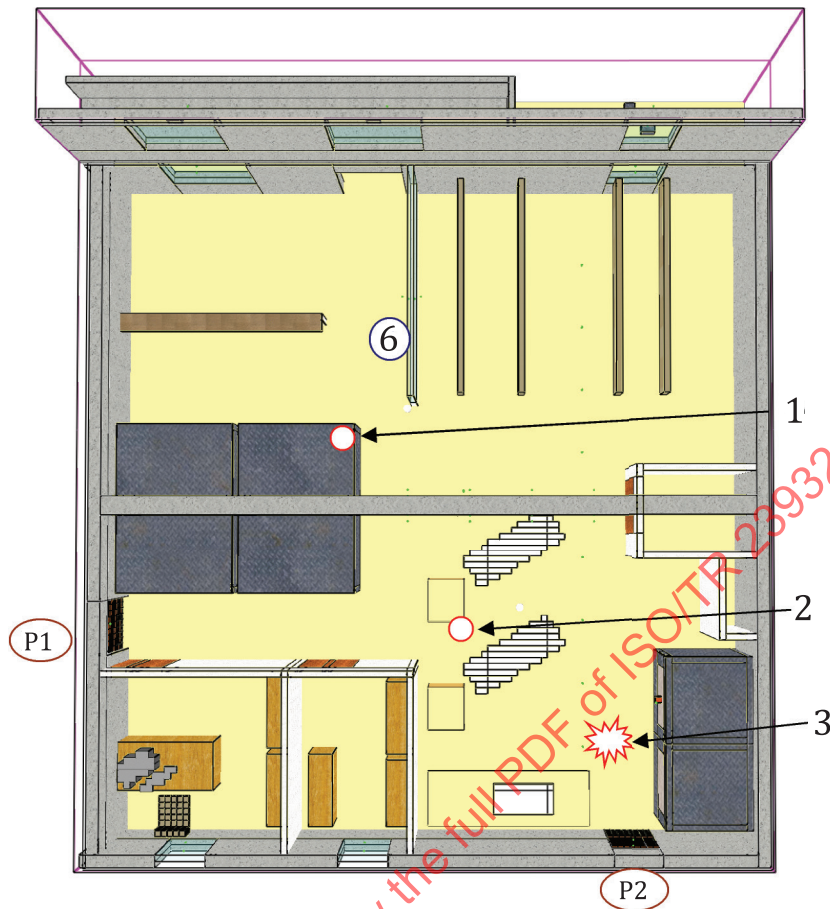
- non-fire-resistant internal timber doors;
- window glazing which is assumed to break when the glass temperature exceeds 220 °C;
- door 1 h fireproof timber (fire resistance 1H solicitation under ISO 834-1).



Key

- 1 front door open
- 2 to 8 locations of breakable glass

Figure 9 — Perspective view of the front door open



Key

- 1 DAAF 1, location of the optical sensors of smoke
- 2 DAAF 2, location of the optical sensors of smoke
- 3 fire origin/starting location
- 6 destructible glass partition

Figure 10 — Plan view of the ground floor, door EI60 (P1)

5.9.1.2.1.2 Fire development

Four separate regimes emerge in the course of the fire. (i) an initial growth phase with radiative heating of combustible products near the origin of the fire; (ii) a phase of growth slowed without further fire propagation to other combustible products, with a heat energy accumulation stored in the warm layer; (iii) a fast growth phase of the fire when the hot layer leads to the breakage of windows and rapid ignition of all fuel present in the room. In the storage area, this growth is followed by a corresponding plateau when the fire mobilizes most of the available fuel load; (iv) a phase of decrease of power or decay.

Full development during the third phase largely depends on the supply of fresh air following the breaking of glass. The breakthrough time of the individual windows is shown below. It is assumed that glass completely falls away from the opening following the breaking time.

Table 4 — Breakthrough time of the individual windows

Scenario 3	Glass breaking time
Window 6 (separating glass for storage)	24 min 30 s ($t_0 + 1469$ s)
Window 2 (facade close to storage)	25 min ($t_0 + 1520$ s)
Window 3 (1 st floor close to storage)	28 min ($t_0 + 1677$ s)
Window 1 (facade close to counter)	28 min 30 s ($t_0 + 1712$ s)
Window 4 (1st floor — centre of balcony)	None
Window 5 (1st floor)	None

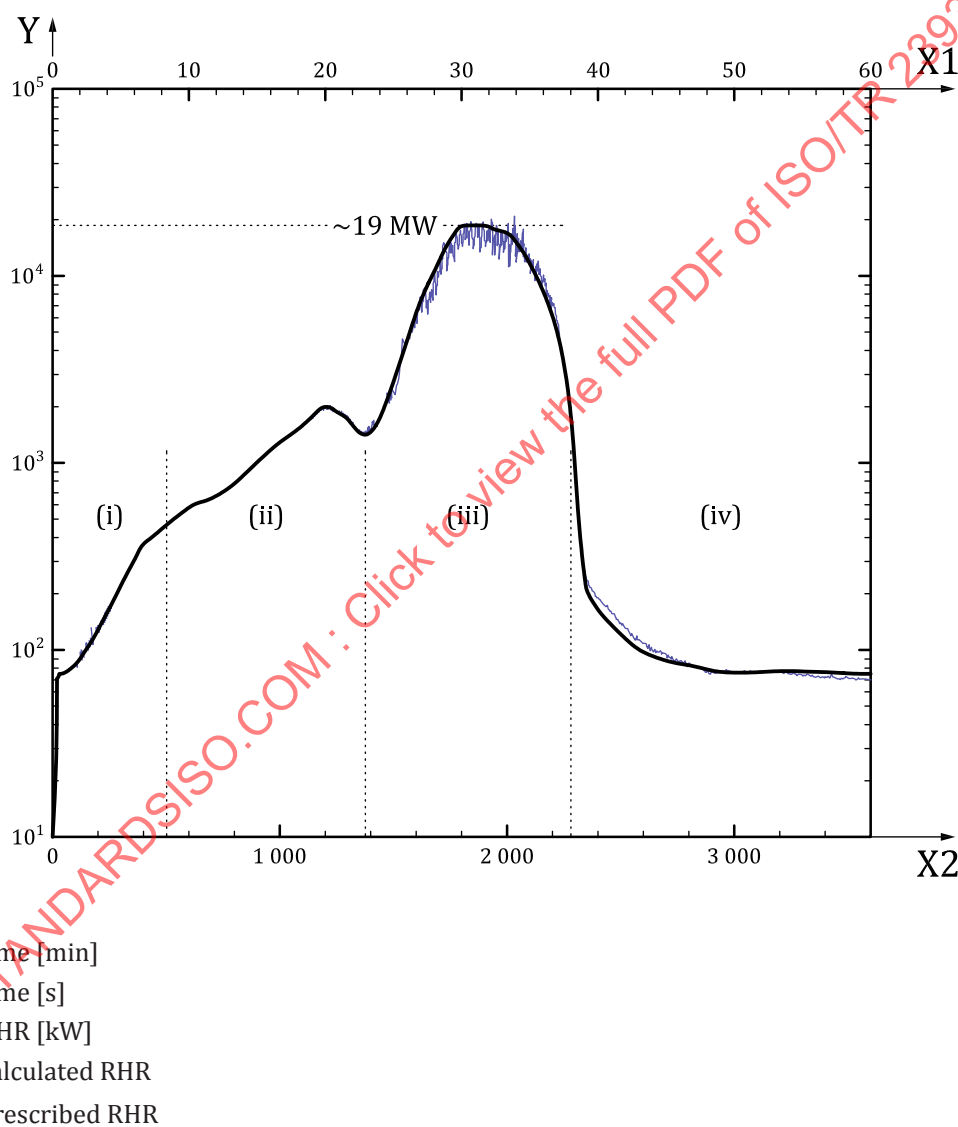
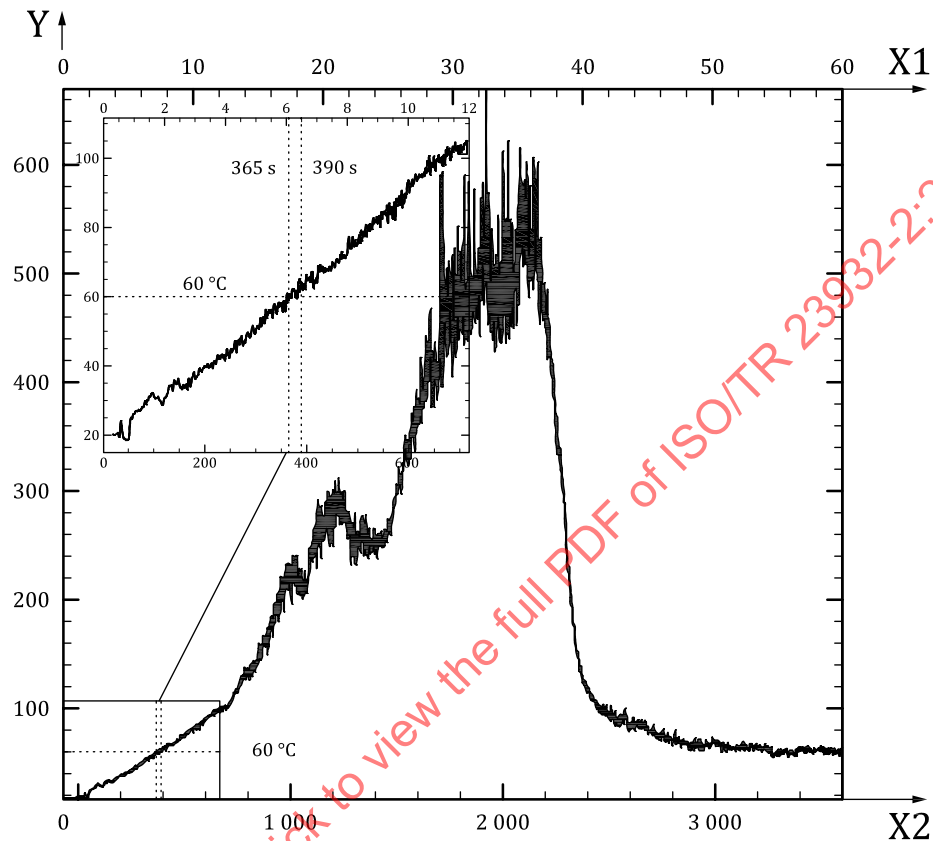


Figure 11 — Power of the fire

5.9.1.2.1.3 Safety of people within the shop

The temperature levels are compared to various thresholds of vulnerability. This allows the time until the tenability conditions are compromised to be determined. Beyond 300 s, the forced convection

lowers the hot layer to the most distant parts of the fire, near each of the doors of the premises. After a time of about 360 s, the warm layer drops below the critical threshold at the two doors of the room. In the middle of the room [Figure 12](#) shows the threshold being reached in the time between 365 s and 390 s after the start of the fire. The results at the shop emergency exit is more limiting so we can conclude that after 6 min the temperatures reached would compromise the egress conditions (see also [Figure 13](#)).



Key

X1 time [min]
 X2 time [s]
 Y temperature [°C]

Figure 12 — Temperatures and time to reach threshold of tenability ($T = 60\text{ °C}$, 1,80 m in the middle of the shop) between $t = t_0 + 365\text{ s}$ and $t = t_0 + 390\text{ s}$

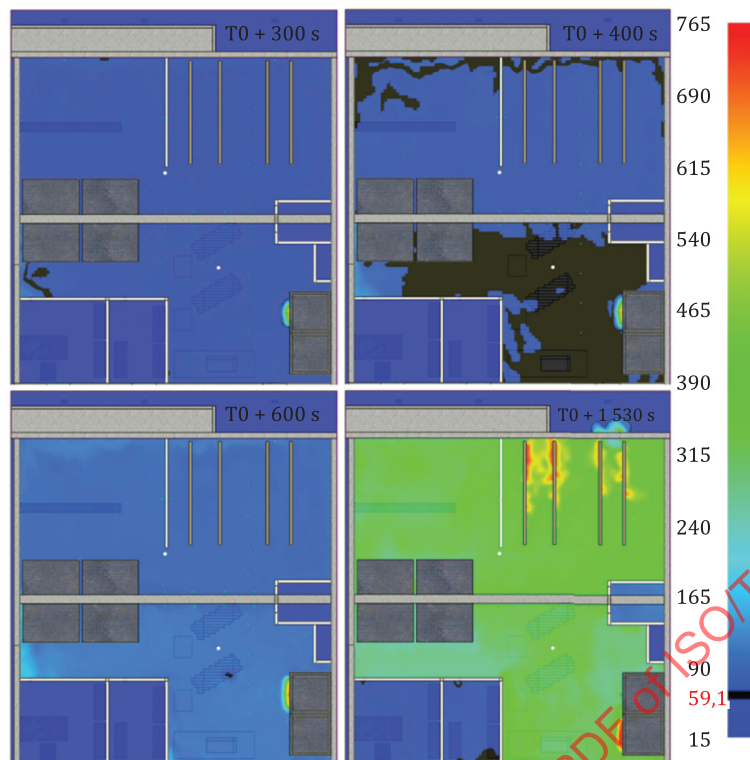


**Figure 13 — Top view, temperature mapping within the shop (staggered 15 °C to 765 °C)
isotherm representation at 60 °C in black**

Regarding visibility within the shop, given the small size of the room, conditions are here considered acceptable for more than 5 m visibility (see [Figure 14](#)). Evacuation conditions will be potentially compromised by smoke opacity about 4 min after the fire.

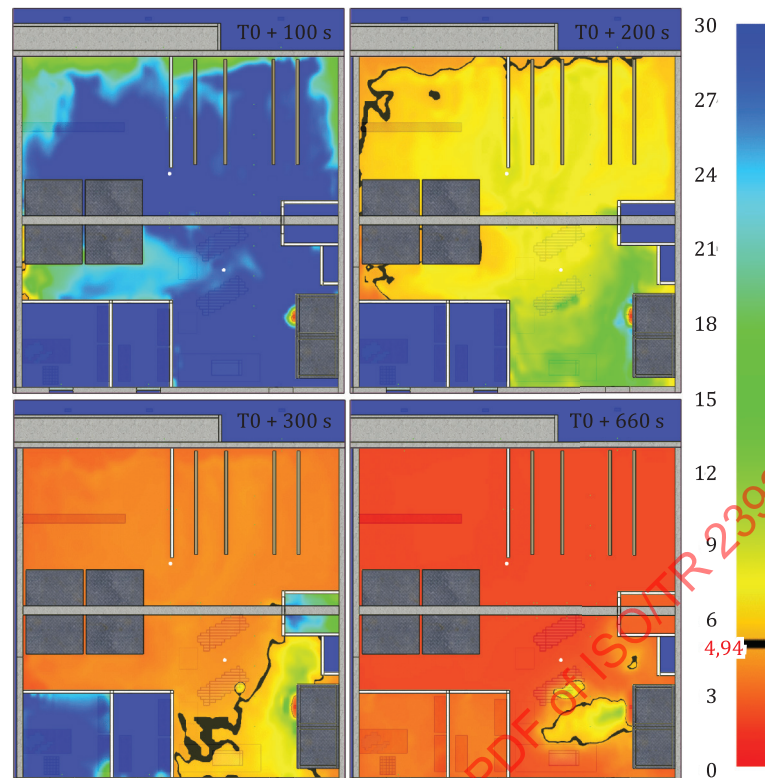


Figure 14 — Plan view of the shop — Mapping visibility conditions (scaled from 0 m to 30 m), representing the isovalue 5 m in black

A simple calculation of heat flow allows us to complete the analysis of the evacuation conditions. This calculation is based on the thermal radiation transfer equations. The commonly applied methodology is that of form factors. To simplify, we have considered the flame as a cylinder. The flame height is calculated via the Thomas^[17] formula and the emittance via the Mudan and Croce^[18] formulae.

The field of application is the usual fire in free field. The method can be applied to a generalized fire in a room or a building under the assumption of a collapsed roof.

In our case, the shop is small and confined, height and radiation have no real physical meaning since the flame is hidden by smoke, the effects of walls tend to lengthen its height, and the ventilation conditions greatly influence its emittance.

Nevertheless, the approach can be considered to be on the safe side because:

- flame height and diameter of the cylinder lead us to a flame surface similar to that of the calculation in FDS;
- emittance is overrated and does not take into account its decrease due to soot in smoke.

The following table gives the results of calculations based on the input data identical to those of models:

Table 5 — Results of calculations

Time min	Power (from FDS results) kW	Flame height m	Target distance to have heat flux of 2,5 kW/m ²
1	80	1,4	1 m to 2 m (result: 1,75 m)
4	150	1,8	2 m to 3 m (result: 2,5 m)
10	580	2,8	4 m to 5 m (result: 4,5 m)

Overall, this approach can be considered on the safe side.

By coupling with other study data, the balance calculation confirms the possibility of evacuation in the first 4 min of the studied scenario.

To summarize, previous findings can be considered as an upper bound approach that the time available for evacuation is 4 min from a visual alarm verification of the people in the reception area. Given the very small size of the area, the time available for evacuation of the public is acceptable, including for disabled people.

Regarding the staff, in the case of a single person in the administrative office this period is reduced to the time required to trigger the detection and warning (DAAF), which is about 50 s. Given the small size of the local delay of about 3 min available for evacuation of personnel on the ground floor is acceptable.

5.9.1.2.1.4 Fire behaviour of windows

The safety of neighbours implies a longer-term analysis of fire resistance of provisions such as regular and fire doors, as well as an analysis of the thermal stress of the structure (see scenario 9, more onerous).

The most significant risk vector regarding people located in the upper floor concerns the building's facade. The previous clause shows that after 25 min the window close to the storage of linen breaks and lets the flames escape. After 28 min, the window of the upper floor breaks, leading to the risk of fire spreading to the flat (see [Figure 15](#)). If the upstairs window is open, the risk of fire spread starts from the moment the window on the ground floor breaks at 25 min.

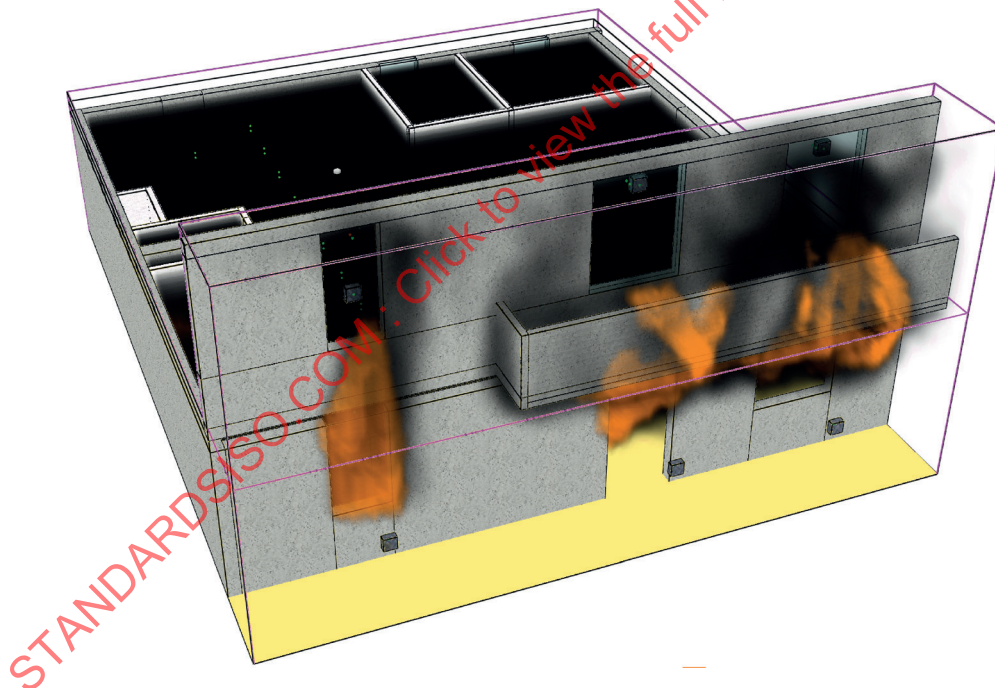


Figure 15 — Fire situation in façade after 34 min

NOTE After the second break window on the ground floor in the front upstairs windows, protected by the balcony, stand for the duration of the simulation (60 min), and the peak of intensity being passed, the balcony doors resist the entire duration of the fire ([Figure 16](#)).

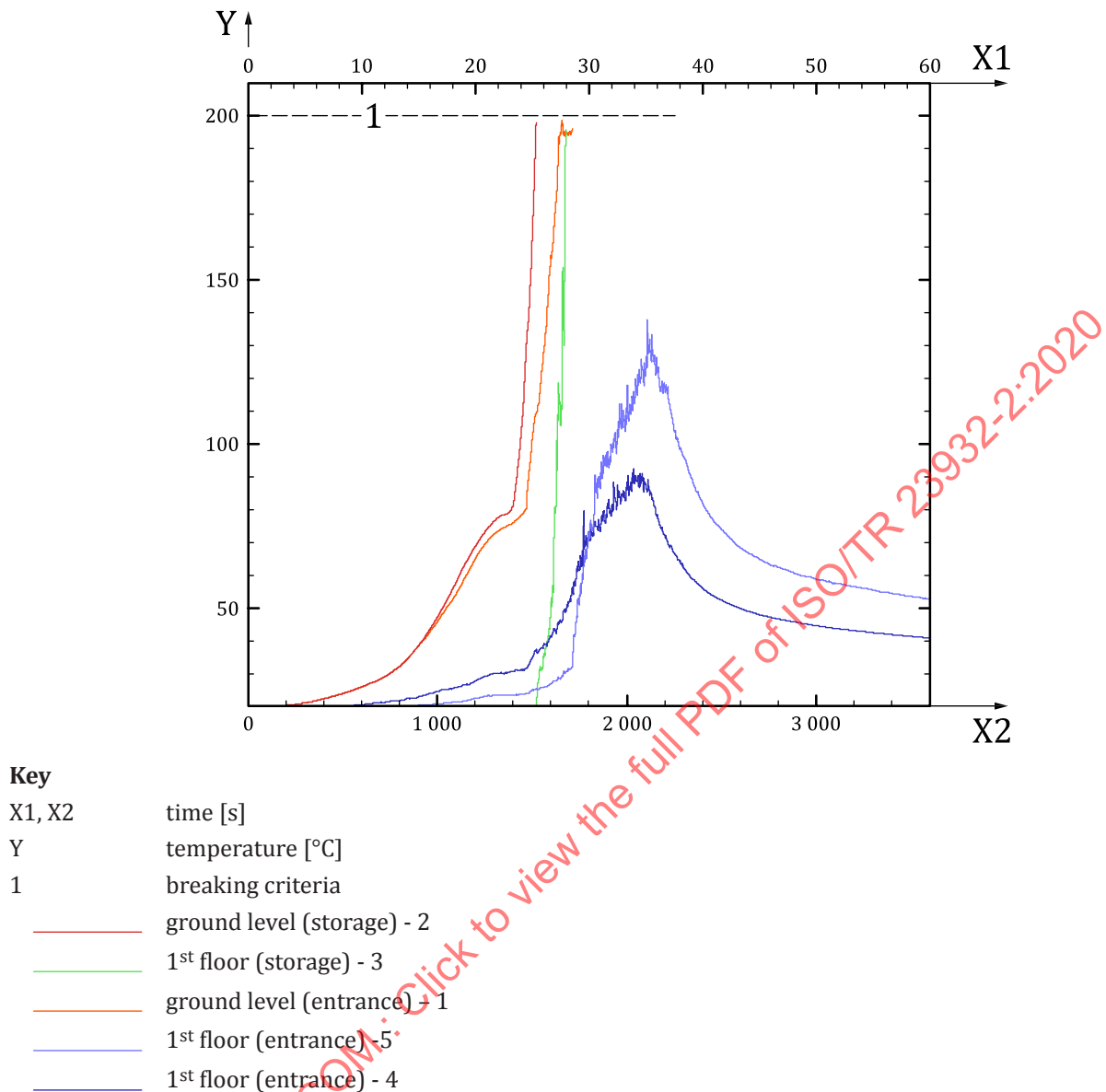


Figure 16 — Thermal load to windows, surface temperature. Window 2 (ground floor storage side facade), Window 3 (1st floor side storage), Window 1 (ground floor side facade), Window 5 remaining intact (floor balcony next to reception), Window 4 remaining intact (floor balcony in the centre)

5.9.1.2.1.5 Fire behaviour of doors

A door with an "ISO" fire resistance, which could stop the fire spread to sensitive areas (stairwell), is particularly analysed, as well as a similar regular door close to the fireplace.

Two different thermal effects are observable. At door 1 (near the fire start), the solicitation is primarily due to radiation flux since the radiated surface probe reports (see D3 in [Figure 17](#)) a measurement temperature much higher than the room sensor located in the same location. At door 2 (fire door), the opposite phenomenon is observed. The room sensor reports a temperature slightly higher than the measurement of the surface probe (see D8 in [Figure 17](#)), which means that the thermal solicitation is driven by convective-type because of the temperature of the hot layer. Maximum temperature, after 30 min, reaches 450 °C on the exposed face.

In both cases, extrapolated from standard tests results, the integrity criterion of doors is assumed during 60 min.

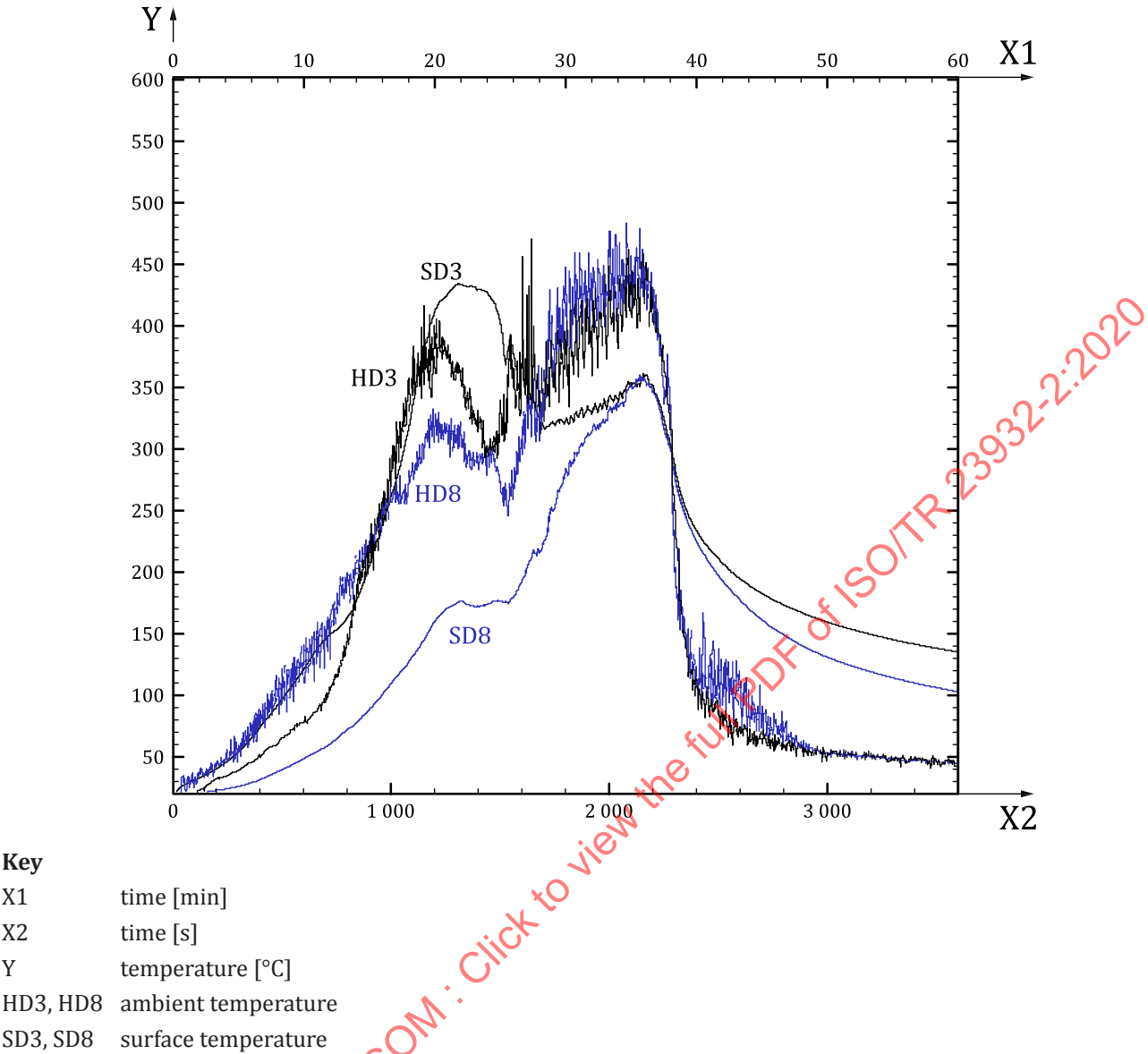
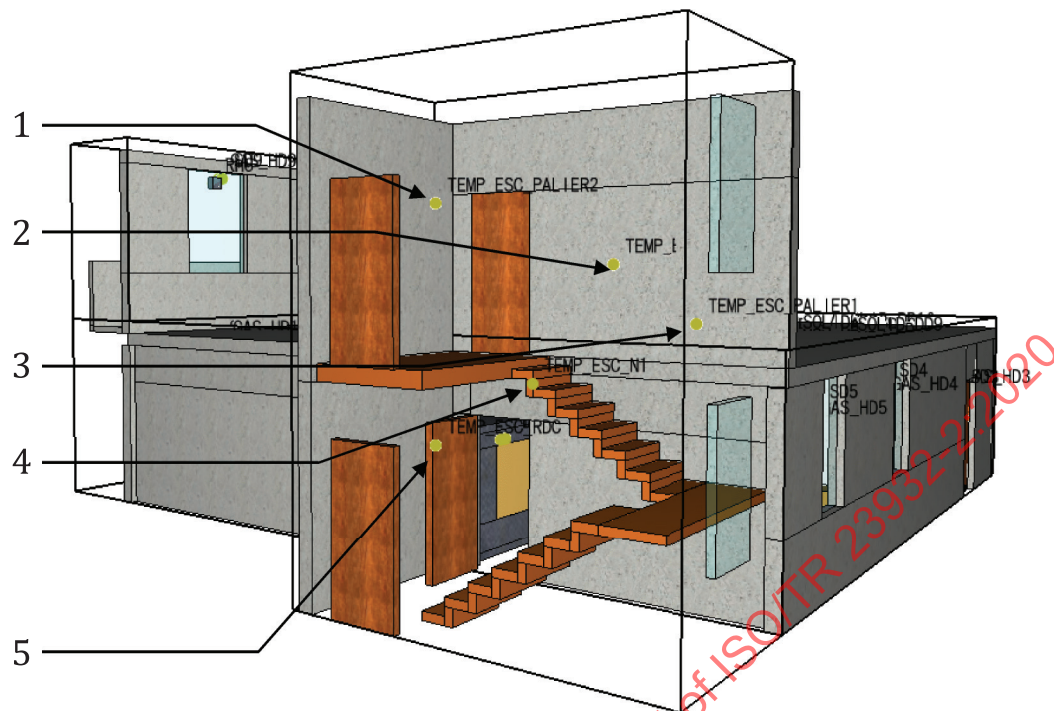


Figure 17 — Scenario 1 — Thermal solicitation of doors — Surface temperature and ambient temperature on the side exposed at 1,70 m height

5.9.1.2.1.6 Scenario 3b, with the door to the staircase open

Scenario 3b where the fire door to the staircase serving the upstairs apartments has been kept open was also investigated. The above assumptions have therefore been retained with additional geometry appended to the previous one, according to the representation of [Figure 18](#).

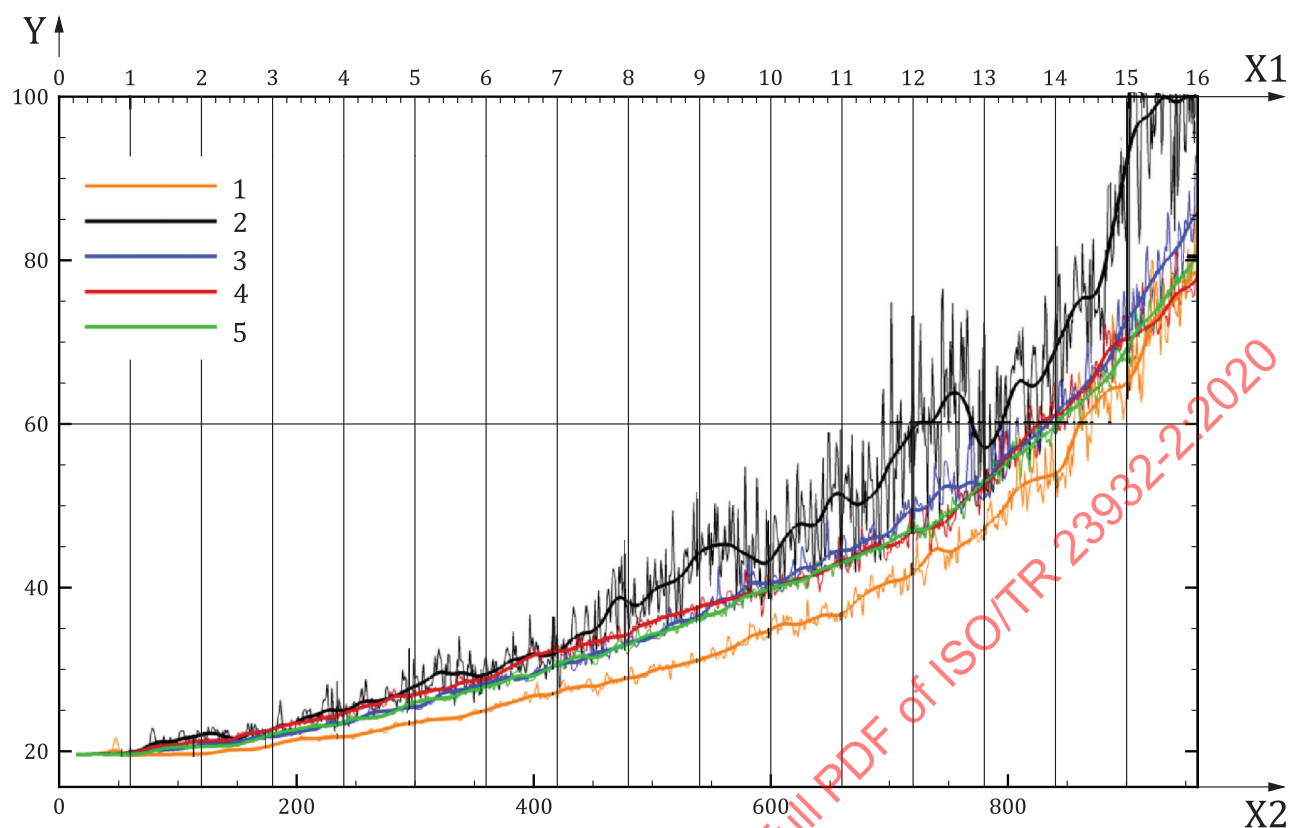
The temperature levels reached at the staircase are compared to the vulnerability threshold. [Table 6](#) shows that the egress conditions (at 1,80 m height) are compromised between 11 min and 12 min after the fire. The curves shown in [Figure 18](#) have been established to determine the limiting times. N1 curve corresponding to the temperatures reached in the middle of the first series of steps is very noisy, reflecting a significant flow of fumes to the place where the criterion is met first. Approximately one minute later conditions deteriorate in a quasi-simultaneous manner throughout the whole volume.

**Key**

- 1 stairway landing 2
- 2 N2
- 3 stairway landing 1
- 4 N1
- 5 ground floor

Figure 18 — Scenario 3b: smoking out to the stairwell through the fire door left open**Table 6**

Location for temperature at 1,80 m within the staircase	N1	N2	Stairway landing 1	Stairway landing 2	Ground floor
Time to reach the threshold of $T_{crit} = 60\text{ °C}$	between 11 min 30 s and 12 min	~ 13 min 45 s	~ 13 min 50 s	~ 14 min	~ 14 min 20 s



Key

X1 time [min]

X2 time [s]

Y temperature [°C]

1 staircase – ground level

2 staircase N1

3 staircase – 1st floor (stairway landing 1)

4 staircase N2

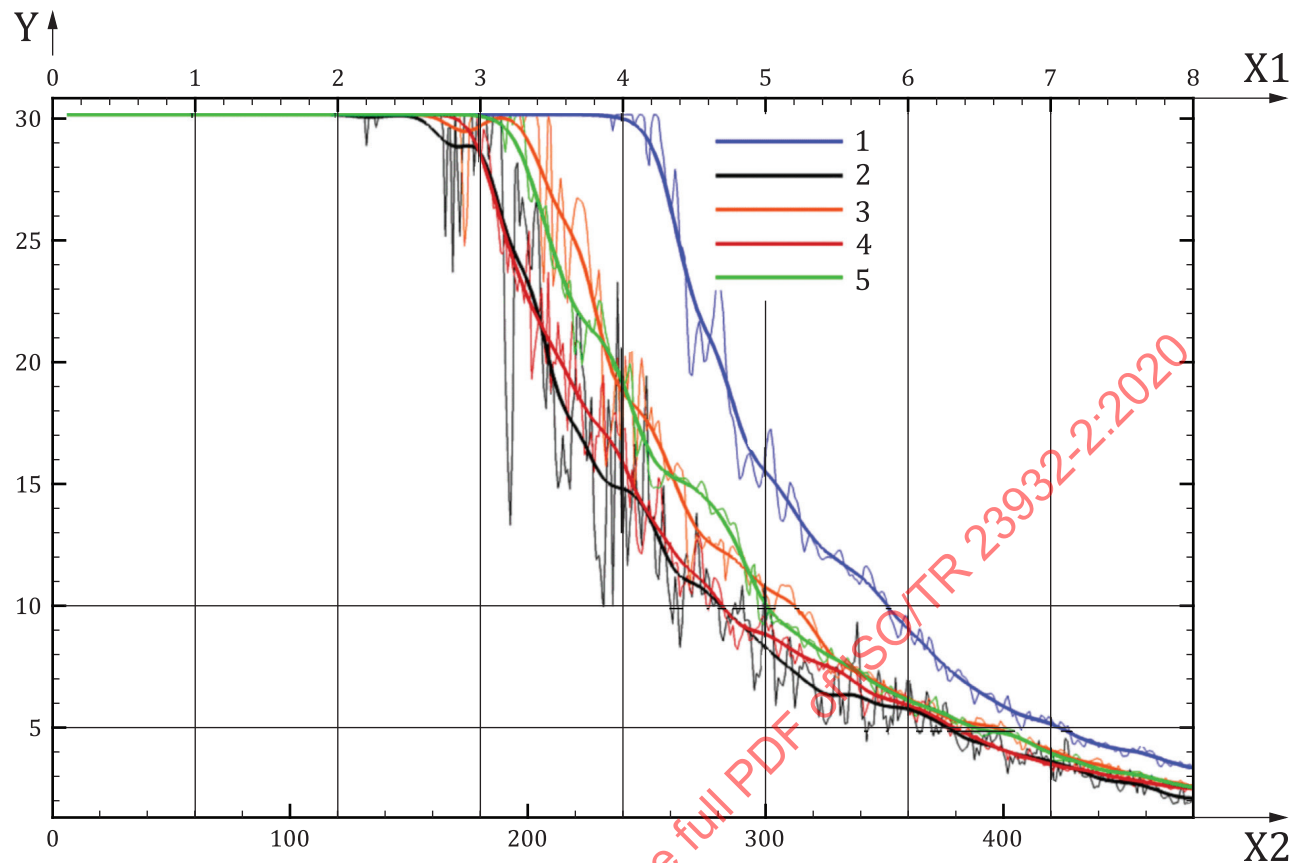
5 staircase – 2nd floor (stairway landing 2)

Figure 19 — Temperatures reached in the staircase, injury time tenability threshold $T = 60\text{ °C}$, 1,80 m high — Measured temperatures, smoothed values

The visibility levels reached the stairs are compared to the vulnerability threshold. The following table shows that the egress conditions are compromised about 6 min after the fire because then the visibility is below the threshold of 5 m. [Figure 19](#) shows that conditions degraded in terms of stratification are predictable before reaching the thresholds (see also [Figure 20](#)).

Table 7

Location for visibility at 1,80 m within the staircase	N1	N2	Stairway landing 1	Stairway landing 2	Ground floor
Time to reach visibility distance of 10 m	~ 4 min 40 s	~ 4 min 40 s	~ 5 min 10 s	~ 5 min	~ 5 min 50 s
Time to reach visibility distance of 5 m	~ 6 min 20 s	~ 6 min 20 s	~ 6 min 40 s	~ 6 min 40 s	~ 7 min 10 s



Key

- X1 time [min]
- X2 time [s]
- Y temperature [°C]
- 1 staircase – ground level
- 2 staircase N1
- 3 staircase – 1st floor (stairway landing 1)
- 4 staircase N2
- 5 staircase – 2nd floor (stairway landing 2)

Figure 20 – Conditions of visibility in the staircase, measured values, smoothed values