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INNOVATIVE AND EFFECTIVE APPROACHES TO THE PREVENTION AND INTERVENTION OF INDUSTRIAL FIRES

Editör :
Kasım YILMAZ

SERÜVEN
YAYINEVİ

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She is a founding member of The Slovenian Fire Protection Association (SZPV), established in 1993. She was employed as SZPV Secretary General in 2009. In 2013 she founded her own company (SIS Mateja Gris s.p.) and continued working with SZPV and other partners in the field of fire safety. In 2017 she started to work on EU-funded projects (Interreg SI-AT and Erasmus+). Currently, she is managing two Erasmus+ projects (Skilled to be a Fire Expert and IndFires), participating in preparing national technical guidelines on accessibility for disabled people, and lecturing. She is an editor of the magazine Požar (Fire), UDK (614.84), and ISSN (1318-7651).

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He is a management specialist and senior fire officer**.** As a management specialist, Borut Lončarevič managed many business projects and led different departments. When driving the investment project in a new factory, he combined his business skills with his knowledge of firefighting skills in the field of fire safety. As an employee, he repeatedly managed crises in the company during storms, water spills, and defects.

He is a long-time operational firefighter who performs tasks at the highest level of the Fire Association of Slovenia as a command member. He is the president of the Commission for industrial firefighting and the regional fire chief. As the operational manager and coordinator, he participated in many large-scale interventions, such as the fire at the Fibram factory, the secondary and primary schools in Kočevje, and the chemical company Melamin. He also participated in the operational organization of the fires in the Karst, the natural disaster in Ukva, Italy, and the hailstorm in Bela Krajina.

He is also a long-time lecturer and instructor of firefighting content at the level of Firefighters' Associations and also at the Firefighter's School in Slovenia. He cooperates with the Fire Association of Slovenia, the Institute for Corporate Safety ICS and the Slovenian Association for Fire Safety with professional articles.

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PREFACE

Industrialization activities aim to increase the wealth and welfare levels of societies. The industry and the rapidly developing technology, brings socially specific risks idiosyncratic to them. Industrial accidents, explosions and fires are among these risks. Industrial accidents, depending on the nature of the activities and facilities, are events that have the potential to have consequences that will adversely affect large population and the environment. 1976 Italy Seveso Disaster, 1984 India Bhopal Disaster, 1986 Chernobyl Disaster are shown as examples of industrial accidents as technological disasters. Other than these large-scale accidents, smaller-scale accidents, fires and explosions in industrial areas cause loss of life and property, and carry the risk of causing negative social and environmental effects.

In order to prevent disasters and emergencies, we have to make strategic plans, ensure continuity in training and preparation studies, establish an effective response capacity by determining emergency response procedures, and learn from disasters. Especially developing countries should pay attention to carry out industrialization activities in a planned and safe manner. This care includes many factors such as choosing the right location of industrial facilities, facility architecture, technology used, training of personnel, establishing relevant legislation and training personnel.

Industrial fire safety is a field that requires multidisciplinary and coordinated research and development studies. Many different disciplines, from engineering and architecture to law, from health services to fire services, should take a role and assume responsibility in the field of industrial fire safety.

With this perspective, in 2020, the EU Erasmus+ project INDFIRES was prepared with the participation of academics from Turkey, Denmark, Italy, Slovenia and Poland, and professionals working in the field of disaster and emergency management. This book is the result of two years of work. In the book, there are issues related to industrial fire status reports, legal regulations, industrial fire causes, hazardous materials, fire safety management principles, industrial fire risk assessment and emergency planning principles, fire detection and warning systems and industrial fire response principles in the project partner countries. The aim of the book is to contribute to the literature in the field of industrial fire safety and to a clearer understanding of the general picture.

I would like to express my gratitude to each of our chapter writers and project researchers, who have great experience in the fields of architecture, engineering, disaster and emergency management, heavy industry, fire safety and risk analysis, for their valuable contributions. I would also like to thank the managers and employees of Seruven Publishing House for their support and contributions during the printing, editing and publication stages of the book.

It is our greatest wish that this work will contribute to the studies carried out in the field of industrial fire safety.

Kind regards…

06.11.2022

Kasım YILMAZ

Editor

Chapter 1.

INDFIRES PROJECT AND SITUATIONAL INDUSTRIAL FIRE REPORTS OF PARTNER COUNTRIES

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1. Aim and Scope of INDFIRES Project

This project, titled "Innovative and Effective Approaches to the Prevention and Intervention of Industrial Fires (IndFires)," has been prepared by a professional team composed of different institutions from several countries. The Project was funded by the Turkish National Agency. The focus point of the project is industrial fires.

Industry, which is the key driving force of innovation and productivity, has always been the keystone of economic welfare; and protecting industrial leadership of Europe by solving the problems that occurred in the industrial field in the fastest way has taken place among the European Union strategies. (State of the Union 2017 – Industrial Policy Strategy: Investing in a smart, innovative and sustainable industry, EUROPEAN COMMISSION, Brussels, 13.9.2017).

Industrialization is one of the most critical factors in the development of societies. Looking at the developed countries today, we see that they stand out with their industries, and because of their industrial capabilities, they are effective in global markets. Today, enterprises of the countries give direction to the national and international economy. However, industrialization brings several problems. One of them is the risk of technological disasters like industrial fires.

The risk of industrial fires has become the nightmare of industrialized societies. When we look into the industrial fires that happened in history, we can see they create great damage in terms of life, properties, and the environment. Below are examples of fires that occurred in Turkiye and the European region:

- Wood factory fire in Mönchengladbach in Ren Vestfalya state in the north of Germany. (12.06.2019)
- Fire in the chemical factory belonging to Lubrizol company in Rouen, northwest France. (26.09.2019)
- Industrial warehouse fire in the Villeurbanne region in Lyon, France. (08.10.2019)
- Fire in the chemical factory in the Fuente del Jarro industrial complex, Paterna, near Valencia, Spain. (08.02.2017)
- Fire in a factory of EPS and XPS insulation boards, Podskrajnik, Slovenia.
- Fire in Gebze, Turkey (13.06.2019)
- Factory fire in Kocaeli, Turkey (21.12.2019)

- Industrial fire in Bursa, Turkey (17.10.2018)
- Fire in Ivedik Organized Industrial Zone, Ankara, Turkey. (16.05.2019)
- Industrial fire in Ereğli, Konya, Turkey (27.10.2019)
- Factory fire in Manisa Industrial Zone, Manisa, Turkey (06.02.2020)
- Factory fire in Adana, Turkey (14.02.2020)
- Industrial Fire in Gaziantep, Turkey (14.02.2020)

Damages caused by industrial fires may be devastating. Industrial fires may cause significant damage to the economy of the country as well as to the environment. They may need different systems and techniques compared to ordinary fires regarding interventions and fire prevention. Fire Safety Management for industrial fires, including intervention techniques, equipment, competencies, and skills, must be organized in detail in a multi-disciplined way. Fire safety management of industrial fires is an exceptional subject. This project aims to contribute to industrial fire safety studies by researching the most innovative and effective methods and techniques for industrial fire safety.

Photo 1. *Fire at an industrial facility in Safranbolu on 23rd of March 2022, Karabuk/Turkiye*

Industrial fires are one of the critical factors threatening the safety of lives, goods, and the environment. Therefore quite a few countries have been carrying out studies in terms of implementation and legislation. For instance, a fire in a factory in SEVESO, Italy, producing Triphenyl Chlorophenol (TCP) due to an explosion caused a great deal of economic and environmental damage. Following this event, SEVESO Directive (82/501/EEC) for the industrial accidents and fires has been accepted. Damages caused by industrial fires are too much compared to regular fires. Therefore, the issue of industrial fires is considered a subject that requires a unique study. Successful Industrial Fire Safety Management should include using and following modern equipment and technology, strategic plan, and coordination. Educational institutions, fire departments, public institutions, industrial enterprises, NGOs, and other stakeholders must collaborate to increase the efficiency of industrial fire safety.

When we examine the industrial fires in Türkiye, we see that 152 factories burned in 2019 only in Istanbul. (For more information see https://www.milliyet.com.tr/gundem/istanbul-da-1-yilda-152-fabrikayandi-2804750). As a product of the Indfires Project, this book can be used as a training module and resource. The professional multi-disciplined academic resources are crucial for increasing efficiency, training, and fire safety applications. However, in many countries, including member countries and our country, it was observed that there are insufficient resources for Fire Safety Management for industrial fires (EQF Level 8). For this reason, as a product of the Indfires Project, partners from different countries with their fire safety specialties contributed to preparing this book. The institutions that participated in this Project from several countries are listed below:

1. Karabuk University (Türkiye)
2. Karabük Emergency Disaster Provincial Directorate (Türkiye)
3. Kardemir Co. (Türkiye)
4. Safranbolu Municipality (Türkiye)
5. FireAid (Denmark)
6. Slovenian Fire Protection Association- SZPV (Slovenia)
7. Gdansk University of Technology (Poland)
8. University of Camerino-UNICAM (Italy)

The project team held international meetings in Italy, Poland, Slovenia, and Turkiye to observe the activities of industrial fires and transfer innovation and share their experiences for two years. This module has nine chapters, and the project team has written each chapter according to their specialties.

2. Situational Industrial Fire Reports of Partner Countries

2.1. Denmark

The following report presents an inventory and current situation analysis report for Denmark. The report was prepared considering information from Danish Emergency Management Agency (DEMA) and the database "statistikbanken." Also, current law and standardization information are presented in the report.

Denmark, officially the Kingdom of Denmark, is a country in Scandinavia and a sovereign state located in the southernmost of the Scandinavian nations, southwest of Sweden and south of Norway, and borders Germany to the south. Greenland and the Faroe Islands are also part of the Danish state as parts of the kingdom with autonomy within the Kingdom of Denmark (Denmark's relationship with the kingdom is called the Commonwealth). Several seas surround Denmark: the North Sea (North Sea), the Skagerrak, and the Kattegat on the west, north, and east sides of Jutland, the Kattegat, and the Baltic Sea north and south of the Danish islands. Denmark consists of the peninsula Jutland and 443 named islands and islets, with the largest islands being Zealand and Fyn. The country is characterized by flat, arable land and sandy coast, low altitude, and a temperate climate. Denmark has a total area of 43,094 km^2, of which the water area is 700 km^2; the entire region, including Greenland and the Faroe Islands, is 2,210,573 km^2.

The population is 5,8 million inhabitants (2019) ex. Greenland and the Faroe Islands The Danish workforce numbers around 2.85 million people. 79.8% of the employees work in the service sector, while 17.6% are associated with the industry or the construction sector. Agriculture, once the country's primary occupation, is nowadays a less crucial economic factor for employment: Only over 2% (63,000 people) are employed in agriculture and horticulture, while 5,000 people or 0.2% work in forestry and 2,300 people (0.1%) in the fisheries sector (November 2017).

The cultivated area in Denmark accounted for 63% of the country's total area in 2018, which is the highest cultivation intensity in the world. Fisheries account for about 3% of total exports of goods.

2.1.1. Definition and the Content of the Industrial Fires

Industrial fires strongly influence industry and the development of each country. Therefore, very important is fire prevention and intervention in this field. Factors influencing the quality of fire prevention are appropriate country and industrial law, appropriate standardization of materials used for construction and fire prevention, proper requirements and procedures and practices for the design, and relevant audit of ready construction. The following report presents inventory and current status analyses in the industry's fire prevention field.

2.1.2. Statistical approach

The first information one needs to obtain is the statistical data regarding industrial fires. Data presented in this report were obtained from Danish Emergency Management Agency (DEMA) and the national online data program ODIN. The queries sent to DEMA required information about industrial fires from 2010-2020. Detailed information regarding industrial fires consisted of number of fatalities and injuries, the cause of the fire, the type of industry, and the fire size. Unfortunately, such detailed information was not provided, as agencies do not collect such data. Related data are presented in Table 1.

Additional data regarding industrial fires in a more detailed manner can be obtained from the questionnaires. Nevertheless, due to the COVID situation, the process of getting answers is elongated.

As seen in the table, the number of industrial fires in the last four years in Denmark is on a steady level. In the last four years, The number of fires ranged from 3839 to 3917, which is around 9,5 % of the total number of fires in Denmark. There is no death (regarding industrial fires) registered in the danish database, and it has not been possible to get the numbers of injuries in industrial fires.

A steady and relatively low number of industrial fires could result from various factors, such as the types of industry which dominate in Denmark. Examples are light industry production, distribution, laboratories (mostly shipyards), light production, storage, and transportation. The requirements for the design of industrial buildings and vigorous enforcement and cyclic controls of law. Not fulfilling the law requirements could lead to not opening the facility or stopping production.

Table 1. *Statistics on fire events.*

Information	Amount										
Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
No. of fires in industrial places	n/d	n/d	328	307	276	2015	3839	3846	4003	3917	n/d
No. of fatalities in industrial places	0	0	0	0	0	0	0	0	0	0	n/d

No. of injured in industrial places	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Total no. of fires in Denmark	n/d	n/d	38103	40583	39882	40979	41990	40850	42494	39775	n/d

2.1.3. Industrial fires in law and standardization

The most important act in Denmark that describes fire prevention for all types of buildings is Bygningsreglementet (Buildings Code-https://bygningsreglementet.dk). This Act informs that each construction and its elements should be designed so that a part of appropriate bearing capacity and durability should provide adequate fire safety. More detailed information is presented in executive documents (Ordinances of specific ministries).

Also, technical regulations for different industrial buildings describe the design requirement for the building. Each document presents rules regarding the construction design following appropriate fire prevention measures. Other ordinances and laws are presently used in Denmark, which regulates fire prevention equipment and its usage, the training of fire prevention employees, the scope and deadlines for fire prevention controls, the scope of fire prevention audits, and so on. Additionally, also European and international standards are applied in Denmark. Most standards regulate the properties of materials used in construction and the properties of equipment used in fire prevention.

2.2. Poland

The following report presents Poland's inventory and current situation analysis reports. The report was prepared considering information from Polish Government and Fire Prevention Agencies. Also, current law and standardization information are presented in the report.

Introduction

Industrial fires strongly influence industry and the development of each country. Therefore, very important is fire prevention and intervention in this field. Factors that affect the quality of fire prevention are appropriate country and industrial law, appropriate standardization of materials used for construction and fire prevention, proper requirements and procedures and practices for the design, and relevant audit of ready construction. The following report presents inventory analysis and current status analysis in the industry's fire prevention field.

2.2.1. Statistical approach

The first information one needs to obtain is the statistical data regarding industrial fires.Data presented in this report were obtained from the national fire prevention agency andthe Statistics Poland webpage. The queries sent to both agencies required informationabout industrial fires from 2010-2020. Detailed information regarding industrial fires included: the number of fatalities and injured, the cause of the fire, the type of industry, size of the fire. Data obtained from both agencies are presented in Table 2.

As seen in Table 2, the number of industrial fires in Poland in the last ten years has been steady. In the last ten years, the number of fires ranged from 2068 to 2506, which isaround 1% of the total number of fires in Poland. Also, the number of fatalities and injured inindustrial fires is low and steady – respectively from 4 to 12 per year and from 104 to 178 per year. A stable and relatively low number of industrial fires could result from various factors.

Table 2. *Statistical data regarding industrial fires in Poland.*

Information	Amount										
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
No. of fires in industrial places	2211	2453	2360	2068	2232	2425	2306	2254	2506	2415	2327
No. of fatalities in industrial places	5	4	8	4	7	10	8	5	10	6	12
No. of injured in industrial places	132	115	129	133	146	178	148	161	156	110	104
Total no. of fires in Poland	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	183 735	225 601	n/d

2.2.2. Information obtained from the questionnaires

Up till the end of May, only single answers were returned from the industrial sites, and more are expected to arrive in a short time. After obtaining all of the questionnaires presented, information will be accordingly updated. Nevertheless, some statements can beformulated concerning all industrial partners.

The person responsible for fire safety is of higher education and with at least withfew years of experience. Usually, it is either a dedicated employee or the head of the industry's building.

In all cases, fire safety and supervision are done by an external company, and in most cases, additional prevention methods than the minimum required by law are utilized. Additional measures result mainly from the localization or specialization of the respective industry.

Most companies have not reported any fires in the last five years. If so, no fatalities or injured were reported. The most common cause of the fire was: electrical malfunction or welding operations.

All companies are insured against fires.

2.2.3. Industrial Fires in Law And Standardization

The main act in Poland which describes fire prevention for all types of buildings is the Construction Law (Prawo budowlane - *Ustawa z dnia 7 lipca 1994r, tekst jed- nolity - Dz. U. z 2020r. poz. 1333, 2127, 2320; z 2021 r. poz. 11, 234, 282*). More detailed information is presented in executive documents. In case of constructions there are two main documents which regulates fire prevention measures are: ordinance for buildings and their location (*Warunki techniczne, jakim powinny odpowiadać budynki i ich usytuowanie - obwieszczenie Ministra Inwestycji i Rozwoju z dnia 8 kwietnia 2019 r., Dz. U. 2019, poz. 1065*) and ordinance for bases and stations for liquid fuel and pipelines for transport of petroleum and their location (*Warunki techniczne,jakim powinny odpowiadać bazy i stacje paliw płynnych, rurociągi przesyłowe dalekosiężne służącedo transportu ropy naftowej i produktów naftowych i ich usytowanie - Dz. U. z 2014 r. poz. 1853*). Each of these documents presents regulation regarding design of construction in accord- ance with appropriate fire prevention measures. Other ordinances and laws are presentlyused in Poland which regulates: fire prevention equipment and its usage, the organizationand financing of the fire prevention squads, the trainings of fire prevention employees, the scope and deadlines for fire prevention controls, the scope of fire prevention audits, and so on). Additionally, also both country and European standards are applied in Po- land. Most of the standards regulates the properties of materials used in construction andproperties of equipment used in fire prevention. The related documents with the dates of their implementation or updates are presented in the following chapters.

It should be noted that in the general division of the types of buildings, the industrial constructions are described as PM – production and storage building, without further division into specific industrial types. PMs are not divided into distinct classes as typical buildings for housing purposes. They are divided according to fire density loading. The good practices report will present detailed information regarding the design of the PM buildings.

2.3. Slovenia

The following report presents an inventory analysis and current situation analysis report on firesafety in industrial premises in Slovenia, based on information on fire statistics in the last ten years, current fire safety regulations, information provided by people responsible for fire protection in Slovenian companies and information on fire brigades.

Introduction

Fires on industrial premises can dramatically impact national income, the environment, and loss of lives. In the Slovenian economy, industry is vital, with a %32 contribution to the total national GDP (The World Factbook, 2017).

Note: Most important industries in Slovenia are ferrous metallurgy and aluminum products, lead and zinc smelting, electronics, trucks, automobiles, electric power equipment, wood products,textiles, chemicals, and machine tools (The World Factbook, 2017).

In Slovenia, there is no accurate data on financial losses due to fires, not in general and not for the industry sector. Statistical information on fires, presented in this report, is gathered inSPIN (SPIN, 2022), an application managed by the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief, a constituent body of the Ministry of Defence. There is data on insurance activity, including fire insurance, presented yearly in the Statistical insurance bulletin issued by Slovenian Insurance Association (Statistical Insurance Bulletin, 2021), but information from this source is not helpful for this inquiry because it is designed for a different purpose.

Despite the lack of data on fires and fire losses, based on which fire safety measures could and should be planned, fire prevention and intervention are taken seriously in Slovenia in general and in the industry sector. Fire safety is regulated by the Fire Protection Act (Fire Protection Act, 1994), which represents the cover regulation under the authority of the Ministry of Defence. In the planning and construction of buildings, fire safety is regulated asone of the essential requirements in the Building Act (Building Act, 2017) under the Ministry of the Environment and Spatial Planning authority. All construction products, as well as their fire characteristics, have to comply with EU construction product regulation, in Sloveniaregulated with Construction Products Act (Construction Products Act, 2013). The Ministry of Economic Development and Technology is responsible for this area. The fire service's tasks, organization, and status are regulated by the Fire Service Act (Fire Service Act, 1993) under the authority of the Ministry of Defence. Thescope of the laws mentioned above is described in this report.

2.3.1. Fire Statistics on Industrial Fires In Slovenia

In Slovenia, between 4,000 and 6,000 fires occur every year. The numbers of all fires, industrial fires, and share of industrial fires in the last ten years are shown in Table 3.

Information from fires is provided by authorized fire officers, who are obligated to make an input of facts they are familiar with for every incident and make a conclusion at the end. Some information need not to be written, such as fire damage, cause of the fire,etc., because fire officers are probably not familiar with it, and misestimation could causeproblems later on.

Table 3. *Statistical data regarding industrial fires from 2010 to 2020.*

Information	Amount										
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**[1]
Total no. of fires in Slovenia	3,987	5,499	6,347	4,456	3,884	4,756	4,691	5,992	4,128	4,381	4,445
No. of fires in industrial premises	161	273	260	303	283	263	329	358	359	359	175

[1] For 2020, not all reports may be completed yet.

Numbers presented in Table 3 were taken from the national database SPIN (SPIN, 2022), an application for gathering data on fires and other accidents, managed by the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief, a constituent body of the Ministry of Defence.

As seen in Table 3, the number of fires fluctuates all the time but has not changed drastically over the years. The number of industrial fires in the last ten years varies from 161 to 359, which is approx. 6% of all fires.

The number of fatalities or injured is not managed in SPIN (SPIN, 2022) in a way to be helpfulfor this analysis.

2.3.2. Fire Safety Regulation

The primary fire safety regulation in Slovenia is Fire Protection Act. It regulates the fire protection system: organization of planning, implementation, control, and financing of fire protection activities and measures, like fire safety education and training, spatial planning, construction of buildings with a certain level of fire safety, reducing the risk of fire at certain activities, which can easily cause fire, especially in industry, traffic, and natural environment. The Ministry of Defense is responsible for the information system, collecting and saving fire and explosion records. Firefighting companies and fire protection personnel do their jobs under the authority of the Defense Ministry. State authorities, local community bodies, companies, and individuals must keep evidence and data about fires and explosions, the total damage, the qualifications of the fire safety personnel, equipment, devices, and other means of fire protection. The basic fire safety document of each company is Fire Safety Order. The content of this document is prescribed according to the fire hazard, size, number of occupants of buildings, etc.

According to Building Act, fire safety is regulated as one of the essential requirements for the planning and construction of buildings. Building Act is under the Ministry of the Environment and Spatial Planning. Rules on Fire Safety in Buildings (Regulations on Fire Safety in Buildings, 2004, presenting the second level of building regulations, regulate basic measures for fire protection in buildings:

- Prevention of the spread of fire to neighboring buildings;
- Maintaining the load-bearing capacity of the structure for a certain periodduring the fire and prevention of the rapid spread of fire in facilities;
- Provision of evacuation routes, fire and alarm systems;
- Provision of devices and water supply for firefighting, access routes, and area for fire-fighters and their vehicles in case of emergency.

Buildings can be designed in a prescriptive way (in accordance with Technical Guide-line TSG-1-001: 2019 Fire Safety in Buildings (Technical Guideline, 2019) or with measures from other norms, using fire safety engineering techniques. In Technical Guideline TSG-1-001: 2019, measures for fire protection in industrial buildings are described: minimum distanceto relevant boundary according to the fire load, fire resistance of loadbearing construc- tions, use of materials and products with specific combustibility class on facades, roofs, linings, fire resistance and other characteristics of doors and lifts relevant to fire safety, equipment of rooms with special electrical installation, smoke control measures, safety power supply for safety installations and appliances, travel distances to an emergency exit, water supply for fire suppression, number and position of access roads and other areas for firefighters and their vehicles.

Before construction, a fire safety study is required for almost any, but except for single-family ones with low firehazards, a responsible designer of any profession can provide Basic Fire Safety Design as far they are a member of The Chamber of Architecture and Spatial Planning ofSlovenia or The Slovenian Chamber of Engineers. For larger buildings, with many occupants, with higher fire hazards, etc., Fire Safety Study has to be done by a Responsible Designer with authorization from The Slovenian Chamber of Engineers fire safety design. The law needs no double check of the Fire Safety Study, so the responsibility lies on the designer and can be a heavy burden.

The fire characteristics of installed construction products have to comply with EU construction product regulation, in Slovenia regulated with Construction Products Act. The Ministry of Economic Development and Technology is responsible for this area.

Tasks, organization, and status of fire services are regulated by Fire Service Act, under the authority of the Ministry of Defence. Firefighting is declared a mandatory public service, which has to be ensured by municipalities and the state. It is also reportedhumanitarian activity in the public interest. Firefighting, protection, rescue in other operational tasks performed by the fire brigades are free of charge for the affected and endangered. Fire brigades can be:

- Professional,
- Voluntary and
- Industrial, as part of companies, institutes, and other organizations.

Fire brigades shall perform their tasks under the rules of the professionand the rules of the voluntary fire service (Rules of the Voluntary Fire Service, 2016).

An essential part of the national services of protection against natural and other disasters is provided by firefighters. Professional firefighters represent a solid professional coreof the Slovenian firefighters' community. Their activities occur in professional territorial units, airports, major industrial premises, and voluntary fire brigades with an experienced nature.

The rules for the voluntary fire service regulate individual issues for the operation ofvolunteer firefighters in detail, such as membership in voluntary fire brigades, management of voluntary fire brigades, rights and duties of operational firefighters, training of volunteer firefighters, use of labels and ranks, organization of firefighting tasks, protection of firefighting and rescue equipment, and rules for competitions of volunteer firefighters.

2.3.3. Information Obtained From The Questionnaires

An overview of the situation of fire safety in Slovenian industrial companies from the point of view of persons responsible for fire protection in Slovenian companies was prepared based on the small-scale survey using the questionnaire designed by the international project team. The questionnaire was not tailored for national-specific circumstances, for example, the size of the country or number of citizens, the level of industrial development or gross national income, national fire regulation and organization of fire safety in practice, type of organization of fire services, etc.

The conclusions of the query, explained in detail in another report and still in revision atthe moment, are that the level of fire safety seems to be satisfactory, but improvements are possible.

2.3.4. Information on Fire Brigades

Slovenia has 20,273 km^2 and approx. 2,110,000 inhabitants. Ljubljana, the capital, has approx. 300,000 inhabitants, Maribor, the second largest city, has approx. 110,000. There are 14 towns with approx. from 10,000 to 50,000 inhabitants, while others are smaller (Slovenia Statistical Office, 2022). There are approx. 50,000 active volunteer firefighters in Slovenia (Safety Aspect of Operational Firefighters, 2020). The percentage of voluntary firefighters per capita is one of the largest in the world. There are approx. 1,340 voluntary fire brigades of different scales all over the country; some are very advanced, and some are only keeping the tradition of local society alive. The density of the location of volunteer fire brigades is highest in the northeast of the country (Figure 1).

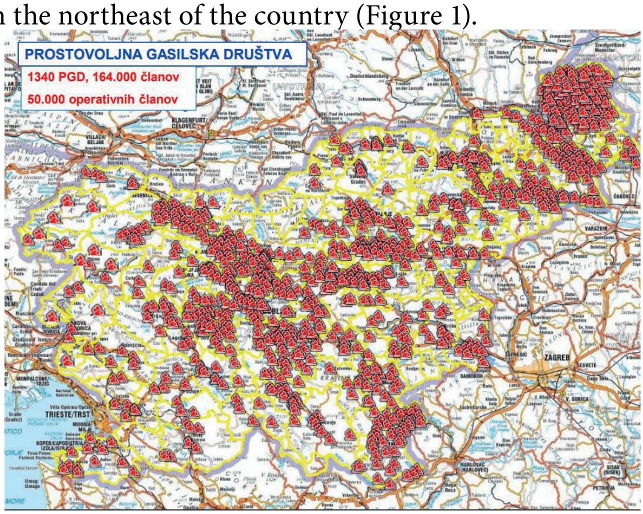


Figure 1. *Location of 1,340 voluntary fire brigades in Slovenia. (Safety Aspect of Operational Firefighters, 2020).*

Approximately one hundred fire brigades are categorized as industrial. There are also approx. 700 professional firefighters work at 15 professional fire brigades (see Figure 2), and almost the same number of professional firefighters workin industrial fire brigades.

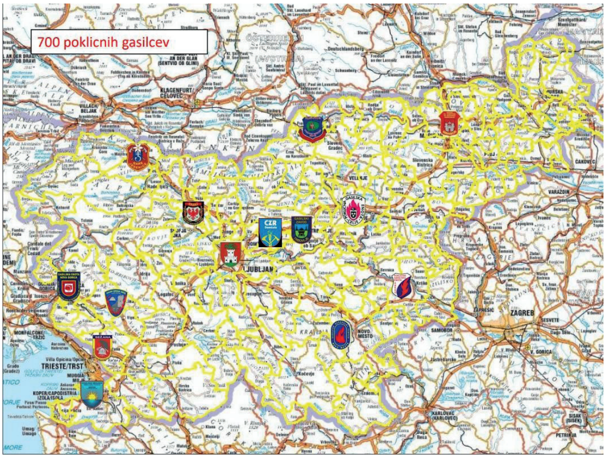


Figure 2. *Location of 15 professional fire brigades in Slovenia, (Safety Aspect of Operational Firefighters, 2020).*

According to the Fire Service Act, companies, institutes, and other organizations with high fire hazards, explosion risks, and those performing other special dangerous activities must establish an industrial fire brigade. The type and the size of the industrial fire brigades are determined in accordance with the organization's criteria and equipment of fire brigades, prescribed in an annex of The Decree on the Organization Equipment and Training of Protection and Aid Forces (Regulation for Rescue Organization, 2007). One criterion is the obligatorypresence of firefighters per shift (Table 4).

Table 4. *Minimum requirements for the presence of firefighters per shift of industrial fire brigades (Regulations for Rescue Organizations, 2007).*

Obligatory presence of firefighters	**Number of firefighters per shift**		**Number of firefighters outside working hours[1]**	
Category of Industrial Fire Brigade	**Professional firefighter**	**Non-professional firefighter**	**Professional firefighter**	**Non-professional firefighter**
I. category	/	3	/	/
II. category	/	5	/	1
III. category	2	1	1	1
IV. category	4	5	4	5

1 *The term "outside working hours" also includes Saturdays, Sundays, and holidays.*

The founder of the industrial fire brigade has to provide funds for the operation of the fire brigade.

Observations and conclusions

In general, fire safety in Slovenia is in good condition, based on the tradition of fire prevention. Practices of larger industrial companies from socialistic times of the former stateYugoslavia of having departments with safety at work & fire safety engineers and industrial fire brigades seem to fade in times of modern economic approaches. Fire safety is often organized with hired specialized companies to meet the minimum legal requirements. In industry, in many cases, industrial fire brigades are seen as a cost and are abandoned or reduced in numbers of firefighters and equipment.

In practice, the dispersion of competencies between ministries is a problem because coordination becomes difficult, mainly because of a lack of interest in improving the situation or vision defined; primarily because of new challenges facing society today: theaging of the population, the growing of vulnerable community, dangerous reduction in es- cape times, new technologies with additional fire hazards of buildings, etc. Firefighters are well educated and equipped but have limitations of being humans only.

2.4. Turkiye

Definition and the Content of the Industrial Fires

Industrial buildings are the buildings and structures where operations such as processing, assembling, mixing, cleaning, washing, packaging, storage, distribution, and repairs are done and factories where all kinds of products are produced under Article 14 of the Regulation on Protection of Buildings from Fire in Turkey (BYKHY). It is defined that "all kinds of factories, sawmills, laundries, textile production plants, energy-producing plants, food processing establishments, supply and discharge systems, dry cleaning systems, mineral processing facilities, refineries, and similar places are under this coverage." The concept has been widely described in the Regulation, and the article is ended as ...and similar places" leaving a position to interpret which buildings will be industrial. (BYKHY, 2021). When the Regulation is considered, it is possible to describe the fires that could occur in the facilities mentioned above as industrial fires.

The statistics and the evaluation of the industrial fires that occurred in the USA between the years 2011-2015 were reported under the heading "Fires at Industry and Production Plants" by the American National Fire Fighting Association.

In this report, industrial fires are accepted as fires at facilities and areas that are defined in the two sub-headings. The first one is the industrial facilities and the second is the production plants sub-heading. What is meant by industrial and production facilities is the facilities or lands related to those defined below:

- Production or production processing plant
- Related to distribution systems such as electricity, gas, water
- Related to agricultural production
- Related to energy production
- Laboratories
- Mines and stone quarries
- Facilities and land where forest products are produced

Fires in these facilities are grouped as structural fires (building fires), vehicle fires, outdoor fires, and non-classified fires in this report. (Campbell, 2018)

As a result, fires occur in factories where production or product processing is realized, in energy production and distribution facilities, such as mine and refineries, storage, and lands belonging to these facilities as industrial fires.

2.4.1. Industrial Fires as Major Accidents

Major fires are considered technology-induced disasters (Kadıoğlu and Özdamar, 2008). Technology-based disasters can happen due to wrong implementations, ignorance, carelessness, and natural disasters such as earthquakes or tsunamis (Akın, 2012). Technology-based disasters and accidents can cause quite a few environmental impacts. As seen in Figure 3, more than seven million people were affected by technology-based accidents that occurred in Europe between 1998 and 2002, and there was at least a 60 billion Euro loss (European Environment Agency, 2003).

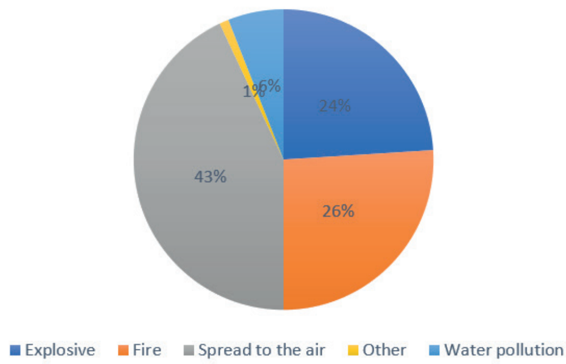


Figure 3. *Technological disasters in Europe occurred between 1980-2002 (ESA, 2003).*

Rapid industrialization and production increased the storage of hazardous materials in large quantities. This result has increased the risk of major industrial accidents, loss of life and property, and environmental pollution.

Awareness that happened following the significant accidents such as fires, explosions, and leakage that occurred in industrial plants and whose effects were extensive, regulations called SEVESO Directives were issued by the European Union (EU) to prevent such accidents. Within this respect, after the chemical leakage in Seveso, Italy, in 1976, Seveso Directive I 82/501/EC was issued. After this, 452 people were killed due to the explosion and the subsequent fire in a liquefied oil processing factory in Mexico City, the USA, in 1984; 72,500 people were killed because of gas leakage in a chemical factory in Bhopal, India. As a result, 96/82/EU Seveso Directive II, the Directive on Control of Major Accident Risks Including Dangerous Goods, was issued in 1996. The 2012/18/EU (Seveso III) Directive is in force now.

According to the Directives, with established systematic structure EU member countries it is aimed to inform the public about the safety precautions and emergencies as well as the prevention of major accidents, to limit their adverse effects, creating an accident prevention policy and the effective implementation of inspection and reporting processes,

In our country, the Regulation on Prevention and Mitigation of Major Industrial Accidents was renewed on March 2, 2019, and was in force after being published in Official Gazette No 30702. As of 2014, in our country, there is a total of 825 Seveso institutions, 369 of which are high-level and 456 of which are low-level (Economic Development Foundation, 2019). Kardemir Inc. in Karabük is high-level, and AYGAZ Filling Plants are low-level Seveso institutions. The Ministry of Environment and Urbanization and Labour and Social Security realize the inspection of the institutions under the regulation. Between 1900 and 2014, 133 technological disasters were reported in our country, 5912 people were killed in these accidents, and there was a 278 million dollar economic loss (AFAD, 2014).

Following the data from the eMARS Reporting System (Major Accidents Reporting System) created by the rules of the EU Seveso Directives between the years 2000-2012 in the EU region, 102 of the 321 accidents occurred in the general chemical substance production sector and 77 of them happened in the petrochemicals/refineries sector. Fire and explosions or chemical leaks can cause severe consequences in major industrial accidents. Chemical leaks can affect other living creatures besides human deaths and injuries and cause environmental pollution. 30 % of all accidents between 2000-2012 were fires, 28 % were explosions and 42 % were chemical leaks (Yavuz, 2016).

Another worldwide database about natural and technological disasters is the EMDAT database (Emergency Database) based in Belgium. This database covers the disasters from 1900 till today.

For a disaster to be included in the EM-DAT database, it should meet at least one of the following criteria:

- Ten or more deaths,
- 100 or more affected people,
- Emergency declaration,
- International call for help.

According to the EM-DAT database, 14 of the 17 reported industrial accidents reported from Turkey between 1979-2007 were the events reported as fire or explosion. However, not all of these accidents occurred in industrial plants. Ten of the listed accidents were related to industrial activity, most of which was firedamp explosions in the mines (Girgin and Yetiş, 2007).

In the EM-DAT database, disasters are divided into two sections natural and technological. Technological disasters are classified as industrial, transportation, and other technological accidents, as seen in Table 5. Depending on the situation, fires and explosions can be reported under the headings either number one or three (Çelik et al., 2020).

Table 5. *Classification of technological accidents according to EM-DAT database.*

Technological Accidents		
Industrial Accidents	**Transport Accidents**	**Other Accidents**
Fire	Seaway Accidents	Fall
Chemical Leakage	Airline Accidents	Explosion
Fall	Railway Accidents	Fire
Explosion	Motorway Accidents	Other
Gas Leakage		
Poisson		
Radiation		
Oil Leakage		
Other		

Technological disasters in Turkey between 2000-2020 were searched by Çelik et al. (2020) by taking the EM-DAT database as a base. According to the research, there were 102 technological disasters during this period. 2480 people were killed in these disasters, and 1961 people were affected. 1825 of the dead were killed in transportation accidents, and 476 were killed in industrial accidents. 419 of those killed in industrial accidents lost their lives in explosions, and 19 in fires. The total number of those who lost their lives in fires and explosions outside industrial fields was 75 (Table 6. Çelik et al., 2020).

Table 6. *Technological accidents in Turkey occurred between 2000-2020.*

Type of Technological Accident	Number of Accident		Casualties		Number of Incidences	
	Number	%	Number	%	Number	%
Transport Accidents	81	79,4	1825	73,6	1279	65,2
Industrial Accidents	12	11,8	476	19,2	256	13,1
Other Disasters	9	8,8	179	7,2	426	21,7
Total	102	100	2480	100	1961	100

One of the most critical accidents was the Soma mine accident (2014) which was reported as an explosion followed by a fire.

2.4.2. Hazards Caused by Industrial Fires and Fire Risks/Safety in Industrial Plants

People lose their lives, quite a few get injured, and significant direct and indirect financial losses are experienced because of industrial fires. Moreover, due to fires and explosions, environmental disasters may occur. The amount of particulate matter spilled in large-scale industrial fires in the air emitted to the environment can significantly increase and pose a severe risk to public health. Therefore, it must control the air quality after large-scale industrial fires. (Griffiths et al., 2018)

It is possible to see dense settlements in the immediate vicinity of industrial plants. In case of large-scale fires and explosions in industrial plants with this type of positioning, the large-scale evacuation of the plant and the surrounding residential area should be evaluated immediately with intervention. Informing the local people about the risks and the action plan in a possible event makes effective evacuation practices possible (Asgari, 2006)

In industrial fires, including storehouse fires, the amount of fuel per unit area is generally relatively high. According to the fuel and storage type, these kinds of fires spread intensive smoke and poisonous substances.

Because of the population density in the vicinity of industrial establishments, there may be a rapid spread of fire and, therefore, a need for large-scale evacuations due to industrial fires that may cause environmental pollution and the spread of carcinogenic substances. Moreover, during industrial fires, many professional firefighters are needed because of the magnitude and risks of these fires. Sandwich panels frequently used in industrial plants cause fire to progress rapidly because of their light plastic material. Moreover, the fire proceeding up to the roof threatens neighboring areas and increases the risk of building collapse (Ingason, Tuovinen & Lönnermark, 2010).

Industrial establishments storing flammable and combustible liquids due to their production processes have specific fire and explosion risks. Flammable and combustible liquids are classified following the Regulation on Protection of Buildings from Fire and (the National Fire Protection Association) NFPA 30 standard. According to this standard, hazard classes of flammable and combustible liquids are shown in Table 7 (Akın, 2009).

Table 7. *Hazard classification of flammable and combustible liquids.*

Class	**Flash Point**	**Boiling Point**
Flammable Liquids (Class I)		
Class IA	< 22,8 °C	< 37,8 °C
Class IB	< 22,8 °C	> 37,8 °C
Class IC	> 22,8 °C and < 37,8 °C	All boiling points
Inflammable liquids		
Class II	> 37,8 °C and < 60 °C -	-
Class IIIA	> 60,0 °C and < 93 °C -	-
Class IIIB	> 93 °C -	-

Paints and thinners, which have various numbers, types,, and properties,, are in the hazard classification given above due to the compounds in their structure and their flammability features. Flammable and combustible liquids are subject to different storage amounts and types by taking the hazard classes to which they belont. There are detailed provisions related to the storage amount and types of flammable and combustible liquids in the Regulation on Protection of Buildings from Fire (Akın 2009).

Fire and explosion are a significant sources of danger for those who work in especially paint/printing, petro-chemical, leather, textile, medicine, and other chemical industries in terms of workplace safety. "Regulation on the Protection of Employees from the Dangers of Explosive Environments," "Regulation on Equipment and Protective Systems Used in Potentially Explosive Atmospheres," and relevant standards include detailed provisions on the issues like protection from the dangers of such places, classification of hazardous regions, and selection of the equipment to be used in these areas. Places with explosion risk are classified as shown in Table 8. This classification is based on the frequency of occurrence and the duration of the period in which this setting continues (Mevlevioğlu, Kadırgan & Çiftçioğlu, 2019).

Table 8. *Classification of regions with explosion danger.*

Region class	**Explanation**
Region 0	Places where the explosive environment consisting of a mixture of flammable substances in the form of gas, steam, and fog with air occurs continuously or for a long time or frequently.
Region 1	Places where the explosive environment consisting of a mixture of flammable substances in the form of gas, steam, and fog with air are likely to occur occasionally under normal operating conditions.
Region 2	Places where the explosive environment consists of the mixture of flammable substances in the form of gas, steam, and fog with air is unlikely to occur occasionally under normal operating conditions or places where the explosive environment is permanent for a very short time, even if there is such possibility.
Region 20	Places where the combustible dust in the air in the form of clouds could create an explosive environment continuously or for a long time or frequently.
Region 21	Places where the combustible dust in the air in the form of clouds may occasionally create an explosive environment under normal operating conditions
Region 22	Places where the combustible dust in the air in the form of cloud may unlikely create an explosive environment under normal operating conditions; however, even if there is such a possibility, this is only valid for a short time.

Most fire safety implementations have been developed from the lessons learned from big industrial fires. Among these safety implementations are flammability tests, construction of a fire-resist industrial buildings, advanced automatic extinguishing systems, effective fire evacuation systems, safe electrical equipment and materials, more sensitive fire detection systems.

Zalosh (2003), based on the tremendous industrial fires he studied, states that the following fire safety measurements should not be neglected:

- Fire barriers such as firewalls etc., should be built in ample facilities,
- The spreading of fire on the roof coatings should be tested,
- Functioning of the sprinkler system should be tested regularly,
- Extinguishing systems should be renewed and improved, keeping in mind that flammable materials may be stored in the storage areas.
- Smoke currents (movement) in the facility should be monitored and controlled.
- Electric wires should be fire resistant.
- Fire evacuation rules and potentials should be good enough.
- Advanced fire protection precautions should be implemented in the storehouses where flammable liquids are kept.
- Contaminated water should be prevented from mixing with the water sources (Zalosh, 2003).

2.4.3. Reasons for Industrial Fires and Sectoral Problems

According to research carried out in England, more than half of the industrial fires are caused by arson; and the property damage average per fire is calculated as approximately 400,000 pounds. The most common reasons for industrial fires after arson are as follows (Thomson, 2001):

- Electric devices,
- Machines,
- Smoking, matches,
- Repair works,
- Solder, welding, cutting, and other hot works,
- Heating devices,
- Cooking devices (cookware),
- Garbage and waste.

According to research on industrial fires in our country, only 40 % of the establishments can return to the market in which they used to function after fire events that result in "full damage." Besides physical damages, market, reputation, and brand losses are the ones that are hard to compensate. 75% of the industrial fires and explosions in our country in 2018 occurred in establishments operating in the textile, metal, wood, paper, and plastic sectors. The main reason for this is the abundance of easily flammable materials in such industries and the lack of fire awareness. The causes for the fires can be listed as follows:

- Electric installations (wiring),
- Hot works,
- Unqualified work power and staff carelessness,
- Mechanical problems,
- Negligence,
- Static electricity,
- Poor quality materials,
- Process-specific reasons,
- False fires.

Industrial fires can grow big and spread rapidly. Expanding of these fires and their adverse effects are related to the conditions listed below:

- Building structure features,
- Not taking organizational precautions,
- Inadequate, non-functioning, or non-existing fire extinguishing systems/equipment
- Irregular storage and placement conditions,
- Technical measures specific to the business line were not taken,
- Firefighter teams and equipment that are insufficient at the fire intervention (Inadequacy of firefighters and equipment to respond to fires)
- Failure to provide structural and spatial separations (compartmentation) (Nazlıer, 2019).

Chemical plants, LPG production places and storages, refineries, and fuel storages, industrial establishments, have specific risks. These are the leakage, explosion, and fire dangers. Using technologically old and insufficient materials and production processes in industrial institutions increases the fire risk. Thanks to construction plans within the framework of protective measurements, buildings should be constructed in the areas with the least disaster risk, and a suitable circulation method that will function perfectly in case of panic should be planned in industrial establishments (Güler and Çobanoğlu, 1997).

Fire safety precautions are grouped as organizational, active, and passive measures. Fire safety precautions are compulsory with the legislation in the newly built industrial facilities. Detection of fire, warning, and extinguishing systems may not function as envisaged in case of fire due to organizational mistakes or projecting and calculation errors, assembly errors, and maintenance/revision deficiencies. It is essential to carry out intervention plans and drills in coordination with the fire department to prevent fires, minimize the effects of fire, and also to create fire awareness. Lastly, risk transfer through fire insurance is also a kind of measurement against the devastating impact of industrial fires (Nazlıer, 2019).

Different fire extinguishing systems mentioned below are used according to the kind of fire that may break out and specific to work done in the industrial establishments (Şimşek ve Aydoğdu, 2020):

- FM-200 Gas extinguishing systems,
- Extinguishing systems with Carbon dioxide (CO2),
- Hood extinguishing systems,
- Water (sprinkler) extinguishing systems

Genç and Pekey (2014) searched the industrial fires that occurred in Kocaeli between the years 2005-2011. According to the research, the reasons for industrial fires cannot usually be determined by the fire brigade, and experts are consulted. Therefore, there is not healthy statistical data about the causes for fire in the archives of the fire brigade. 79,2 of the establishments were partially, and 11,4% of them were totally burned in the industrial fires that occurred within this period.

It was found that 37,6 % of the fires that broke out within the borders of Istanbul Metropolitan Municipality (IMM) between 2015-2019 mainly were caused by cigarettes, 23,7% of them by electricity, and 8% of them were started on purpose. In the same period, approximately 160 factory fires occurred in Istanbul every year. In 2019, there was a 14% increase compared to the beginning of the period. (IMM Statistics, 2020). The population of Istanbul in 2020 was 15.4 million. This figure constitutes approximately 18 % of the whole population of Turkey (TurkStat, 2021).

The sectors where chemicals are used during production can potentially have a higher fire risk. Following laws and regulations have been prepared to ensure the safety of life and property in such workplaces:

- Regulations issued to comply with the Occupational Health and Safety Law No. 6331 and the relevant European Union regulations,

- "Regulation on Health and Safety Measures in Working with Chemical Substances" published in the Official Gazette No. 28328.,
- "Regulation on Equipment and Protective Systems Used in Potentially Explosive Atmospheres" published in the Official Gazette No. 26392."
- "Regulation on Emergency Situations in Workplaces" published in the Official Gazette No.'
- Regulation on the Protection of Buildings from Fire,
- Regulation on Prevention and Mitigation of Major Industrial Accidents
- Electricity Internal Facilities Regulation
- Regulation on the Protection of Employees from the Dangers of Explosive Environments (30.04.2013)
- Occupational Health and Safety Risk Assessment Regulation dated 29/12/2012 and numbered 28512.

Regarding the deficiencies in the provision of industrial fire safety in Turkey, Yener (2019) states that the regulations brought by the Labour Law No. 4857 and the Occupational Health and Safety Law No. 6331 are not designed to prevent casualties as a result of fire/explosion and occupational accidents. In many cases the lawful responsibility falls on the shoulders of occupational safety experts. The cause of the fires cannot be appropriately determined. The environmental effects derived from fires and explosions are not adequately examined. The construction plans, technical compliance, regulation, and standard requirements are not controlled adequately by the public authorities (Yener, 2019).

2.4.4. Industrial Fire Statistics at the National and International Level

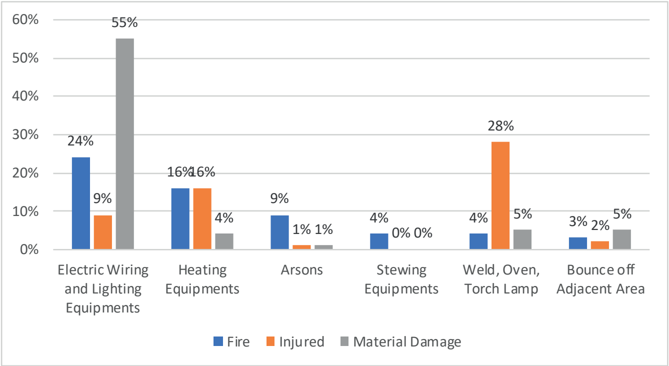
The statistics and the evaluation of the industrial fires that occurred in the USA between the years 2011-2015 were reported under the heading "Fires at Industry and Production Plants" by the American National Fire Fighting Association (NFPA). What is meant by industrial and production facilities is the facilities or lands related to the production or production processing plant, distribution systems such as electricity, gas, water, agricultural production, energy production, laboratories, mines and stone quarries, facilities, and land where forest products are produced. Fires that occurred in these facilities are grouped as structural fires (building fires), vehicle fires, outdoor fires, and non-classified fires in this report. Only industrial and production facility fires reported to local fire departments and intervened by them were included; on the other hand, those that were moderated by the federal government, state government, or the fire department of the industrial facilities were not included in this report.

According to the report, between 2011 and 2015, an average of 37910 fires occurred every year in the industrial and production facilities, including electricity, gas, water distribution, defense, agriculture, and mining sectors, and there was an average of 16 casualties and 273 injured per year in these fires. Moreover, an annual average of 1,2 billion dollars of direct financial loss occurred because of the fires. 71 % of the fires were outdoors, while 20 % were indoors, and 9 % were vehicle fires. 49 % of the casualties, 80 % of the injured, and 67 % of the direct financial loss occurred due to indoor fires. 65% of all industry and production facility fires happened in the production facilities (Table 9; Campbell, 2018).

Table 9. *The effects of the industry/production facility fires occurred in the USA between 2011-2015.*

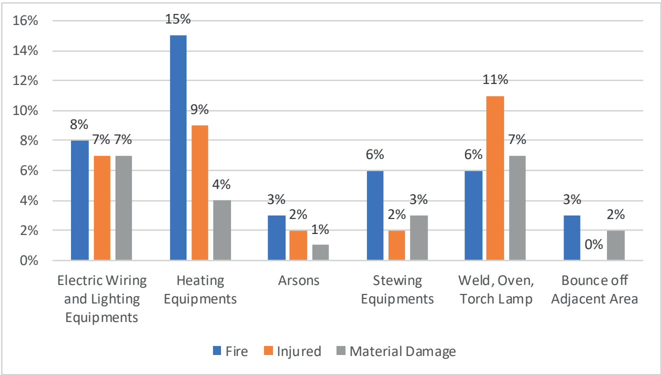
Type of the event	Number of the Fire-Ratio	Casualties	Injured	Direct Financial Loss (Million Dollars)
Outdoor fires and non-classified fires	26,730 (%71)	3 (%17)	38 (%14)	$265 (%22)
Outdoor fires, except for garbage fires or non-classified fires	23,210 (%61)	3 (%17)	37 (%14)	$262 (%22)
Outdoor garbage or waste fire	3,520 (%9)	0 (%0)	1 (%0)	$3 (%0)
Building fire	7,770 (%20)	8 (%49)	219 (%80)	$799 (%67)
Vehicle fire	3,410 (9%)	6 (34%)	17 (6%)	$125 (%11)
Total	37,910 (%100)	16 (%100)	273 (1%00)	$1,190 (%100)

The three main reasons for the fires in the industrial facilities in the analyzed period were electric installations and lightening equipment (24%), heating equipment (16%), and deliberate fires (9%) (Graph. 1; Campbell, 2018).



Graphic 1. *The causes for* **industrial facility fires** *occurred in the USA between 2011-2015.*

The three main reasons for the fires in the production facilities in the same period were in order heating equipment (15%), electric installations and lighting equipment (8%), welding, stove, and acetylene lamp (6%) (Graph. 2; Campbell, 2018). Heating and electrical equipment occupy the first two places as the cause of fire in both types of facility fires.



Graphic 2. *The causes for* **the production facility fires** *occurred in the USA between 2011-2015 (Annual average).*

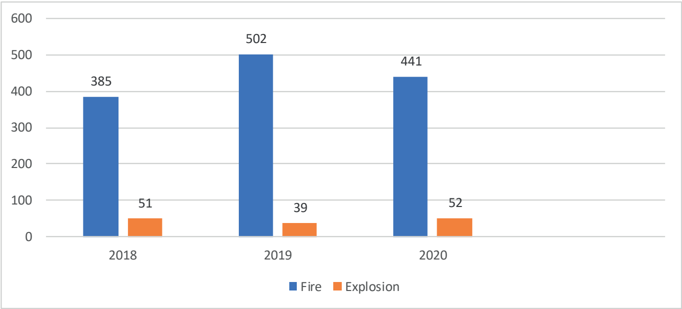
Fire statistics in Turkey are recorded locally by the fire departments suppressing the fire. In this regard, Municipality Fire Brigade Regulation has determined the statistical form to be kept. In this form, industrial fires are defined under the headings of "Workshops, plants, factories, etc. This form contains columns representing the damages, casualties, reasons, and explanations.

At the main management level, it is understood as a result of our research that Disaster and Emergency Provincial Directorates have received fire statistics from municipalities in some provinces and reported them to their administration centers. However, any central institution has no up-to-date fire statistics of Turkey.

It is seen that the most up-to-date source on industrial fire statistics is the annual industrial fires report prepared by the Istanbul Branch of the Chamber of Chemical Engineers (KMO) affiliated with the Turkish Chamber of Engineers and Architects (TMMOB). The Chamber of Chemical Engineers publishes industrial fire statistics regularly with a professional interest in the causes of industrial fires or solutions to safety measures.

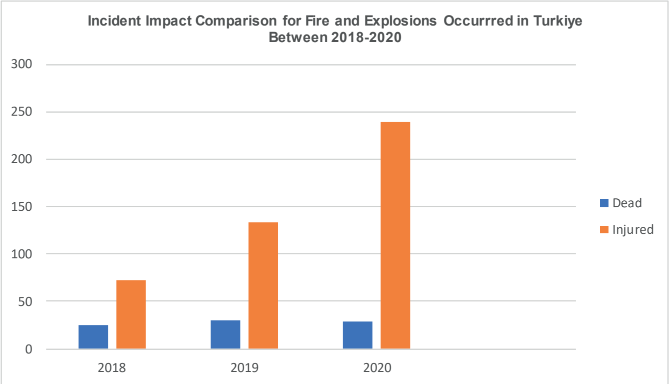
The Chamber of Chemical Engineers states that they consider all kinds of sources, including fire statistics of the metropolitan municipalities and media organs, while preparing these statistics. While preparing this report, the Chamber of Chemical Engineers's 2020 industrial fire and explosion report has been examined and taken as a reference.

According to the data, 441 industrial fires and 52 industrial explosions occurred in Turkey in 2020. At least 29 people were killed, and 239 were injured in these events. The "at least" expression is used because figures are not updated in case of death from the injured. At the sector level, the most fire and explosions occurred in the wood, paper, and furniture sector, with a 23 % ratio. 78% of the whole fires and explosions occurred in these five sectors. A comparison of fire and explosion events and their effects occurred between 2018-2020 is shown in Graphics 3 and 4 below: (KMO Report).



Graphic 3. *Comparison of industrial fire and explosions that occurred in Turkey between 2018-2020.*

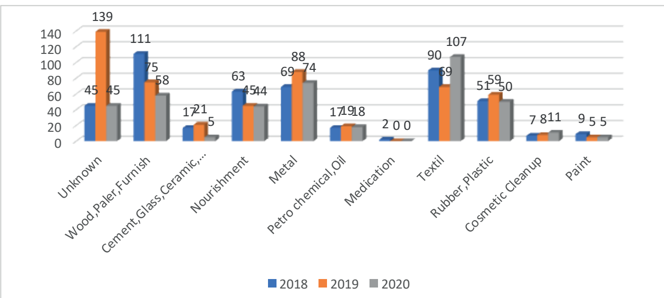
Incident/ impact comparison of industrial fires and explosions can be seen at Graphic 4. below.



Graphic 4. *Incident/impact comparison of industrial fire and explosions occurred in Turkey between 2018-2020.*

As technology advances, hazardous chemicals are used in production as raw materials in many sectors. Accidents that may occur during the storage, transportation, or disposal of these substances can cause severe loss of life and property. Some hazardous chemicals have explosive, oxidizing, or varying flammable properties. They may cause life-threatening danger or environmental pollution by burning or spreading. It is seen that industrial accidents usually occur in the form of fire, explosion, or chemical spread/leakage. Explosions may occur due to chemical or physical reasons. Explosions and fires may happen due to the cause or result of each other. As a result of the combustion reaction of the hazardous chemicals, suffocating and poisoning products may emerge. Arguably, fires are started deliberately in industrial facilities because of insurance fraud. However, it is wrong to interpret most fires and explosions this way unless proven. Lack of process and occupational safety draws attention to most industrial fires, accidents, and explosions (KMO Report, 2020).

The sectors that stood out in the industrial fires and explosions in 2018-2020 did not change. Textile in 2018, metal in 2019, and wood, paper, and furniture sectors in 2020 were the most incidents (Graph. 5, KMO Report, 2020).



Graphic 5. *According to sectors, the comparison of industrial fire and explosions occurred in Turkey between 2018-2020.*

The cause of 9 % of the fires and explosions occurred in 2020 was not determined. When examined based on establishments, it is seen that most fires and explosions occurred in furniture factories. It is understood that fires are common in waste collection facilities, regardless of the sector. A total of 33 fires were reported in waste collection facilities in 2020. As the places where fire breaks out, warehouses or silos in the facilities are the leading ones. In the fires, the source of which was found in Turkey, and the electrical spark was determined to be the most common reason for the fire to start. However, only the cause of 15 %of the entire industrial fires and explosions in Turkey in 2020 was identified. Besides electrical problems, fires mostly start due to mechanical sparks and overheating (KMO Report, 2020)

The most attention-grabbing event in 2020 was the explosion in the Coskunlar Firework factory in Hendek, Sakarya, on July 3, 2020. Seven workers were killed, and 127 workers were injured in this explosion. Moreover, three soldiers were martyred six days later, and eight were injured in the blast that occurred while transporting materials for controlled destruction.

For a detailed list of all industrial fires in 2020, the report titled "Industrial Fires and Explosions Report, 2020" of the Istanbul Chamber of Chemical Engineers can be examined. Table 10 below shares information about industrial fires reported to the Turkish national media in the three years between 2018-2020. Obtaining statistics on this subject through a mechanism must be determined jointly by municipalities, the Ministry of Interior, insurance companies, and relevant professional chambers, for appropriate fire safety policies to be determined soundly.

Table 10. *Significant national industrial fires reflected in the press between 2018-2020.*

No	Province	Sector/ business	Date	Dead	Injured	Financial loss	Info
1	Balikesir / Bandirma	Vegetable oil	13.12.2018	0	0	No data	Because of electricity
2	Gaziantep	Glue factory	11.1.2019	0	5	No data	None
3	Istanbul / Güngören	Beer factory	28.1.2019	0	0	No data	Started at the warehouse
4	Hatay / Iskenderun	Filter factory	16.2.2019	0	12	No data	
5	Diyarbakir	foam plate factory	15.3.2019	0	2	No data	
6	Istanbul / Hadimköy	Chemical factory	18.3.2019	0	1	No data	Started at 14:30, 85 vehicles intervened. there were a number of lpg tanks, hectane gas, solvent and 1200 tons of raw materials. 7000 m2 area burned in total.
7	Denizli / Pamukkale	Textile factory	27.4.2019	0	0	No data	Started at 03:30. after extinguished, it was found out that 18 industrial cylinders exploded
8	Adana	Recycle plant	9.5.2019	0	0	Totally burned	
9	Istanbul / Ikitelli-ss	Factory fire	11.5.2019	0	0	No data	
10	Kocaeli / Çayirova	Textile factory	6.6.2019	4	1	No data	Started in the logistics warehouse. it was found out that they had fire extinguishing systems, however valves were turned off.
11	Istanbul / Pendik	Plastic and ceramic factory	14.6.2019	0	2	No data	A facility quite close to the industrial and residential areas. a few years ago, there was a deadly fire event.
12	Istanbul / Büyükçekmece	Textile and plastic factory	22.6.2019	4	4	No data	4 firefighters were injured.
13	Istanbul / Hadimköy-ss	Plastic factory	26.6.2019	0	0	No data	

14	Istanbul / Kağithane	Textile factory	8.7.2019	0	0	No data	Occurred during the modification works
15	Istanbul / Başakşehir	Cosmetic material production factory	23.7.2019	0	0	No data	
16	Istanbul / Tuzla-osb	Leather -chemical materials	18.9.2019	0	0	No data	There were explosions during the fire. caused environmental effect concern.
17	Istanbul / Başakşehir- osb	Plastic factory	23.9.2019	0	0	No data	
18	Konya / Ereğli	Biscuit factory	27.10.2019	0	0	No data	
19	Istanbul / Arnavutköy	Chair production	2.11.2019	0	0	No data	
20	Istanbul / Küçükçekmece	Rubber production	16.11.2019	0	0	No data	
21	Sakarya / Erenler	Recycle plant	17.11.2019	0	0	No data	Started in the area with plastic and chemical waste
22	Istanbul / Tuzla	Ore processing	28.11.2019	0	0	No data	
23	Istanbul / Zeytinburnu	Weaving factory	31.12.2019	0	0	No data	Started at 04:00
24	Istanbul / Esenyurt	Textile factory	31.1.2020	0	0	No data	
25	Istanbul / Küçükçekmece	Paper factory	18.4.2020	0	0	No data	
26	Kocaeli / Dilovasi	Machine production	21.5.2020	0	0	No data	They are producing elevator weights.
27	Kahramanmaraş	Textile factory	21.6.2020	0	0	No data	
28	Manisa / Yunusemre -osb	Plastic factory	28.6.2020	0	4	No data	A firefighter was injured
29	Adana / Sabanci osb	Starch factory	28.6.2020	0	0	No data	
30	Sakarya / Hendek	Fireworks plant	8.7.2020	7	127	No data	Fire occurred after the explosion / there were 110 tons of explosives in the storehouse. the next day, the vehicle carrying explosives from the fire area for disposal exploded and 3 soldiers from the disposal team were

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CHAPTER 2.

INDUSTRIAL FIRE SAFETY REQUIREMENTS IN PARTNER COUNTRIES

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EU AND NATIONAL LEGISLATION AND STANDARDS IN PARTNER COUNTRIES

1. Poland

1.1. Fire Prevention Laws and Regulations

The main act in Poland which describes fire prevention for all types of buildings is the Construction Law (Prawo budowlane Ustawa z dnia 7 lipca 1994r, tekst jednolity - Dz. U.z 2020r. poz. 1333, 2127, 2320; z 2021 r. poz. 11, 234, 282) which states that each construction and its elements should be designed in such way that apart of appropriate bearing capacity and durability is should provide proper fire safety. More detailed information is presented in executive documents (Ordinances of specific ministries). In case of constructions there are two main documents which regulates fire prevention measures are: ordinance for buildings and their location (Warunki techniczne, jakim powinny odpowiadać budynki i ich usytuowanie - obwieszczenie Ministra Inwestycji i Rozwoju z dnia 8 kwietnia 2019 r., Dz. U. 2019, poz. 1065) and ordi-nance for bases and stations for liquid fuel and pipelines for transport of petroleum and their location (Warunki techniczne, jakim powinny odpowiadać bazy i stacje paliw płynnych, rurociągi przesyłowe dalekosiężne służące do transportu ropy naftowej i produktów naftowych i ich usytowanie - Dz. U. z 2014 r. poz. 1853). Each document explains regulations regarding construction design following appropriate fire prevention measures. Other ordinances and laws are presently used in Poland which regulate: fire prevention equipment and its usage, the organization and financing of the fire prevention squads, the training of fire prevention employees, the scope and deadlines for fire prevention controls, the content of fire prevention audits, and so on. Additionally, also both country and European standards are applied in Poland. Most of the standards regulate the properties of materials used in construction and the properties of equipment used in fire prevention. The related documents with the dates of their implementation or updates are presented in the following chapters.

It should be noted that, in general, division of the types of buildings, the industrial constructions are described as PM – production and storage buildings, without further division into specific industrial types. PMs are not divided into specific classes as typical buildings for housing purposes. They are divided, taking into consideration fire density loading. All the regulations are available for download from the government site: https://isap.sejm.gov.pl/. All of the regulations and ordinances are available in Polish.

Following laws and ordinances are currently used in Poland (on the base of [3] and own studies):

1. Construction Law (*Prawo budowlane, Ustawa z dnia 7 lipca 1994r, tekst jednolity - Dz. U. z 2020r. poz. 1333, 2127, 2320; z 2021 r. poz. 11, 234, 282*);

Comment: *The primary regulation regarding the construction of building in Poland. It contains only essential information regarding fire prevention, stating only the main requirements in a general way. Detailed regulations and requirements are given in the executive documents presented below.*

2. Ordinance regarding buildings and their localization (Warunki techniczne, jakim powinny odpowiadać budynki i ich usytuowanie (tekst jednolity – obwieszczenie Ministra Inwestycji i Rozwoju z dnia 8 kwietnia 2019 r., Dz. U. 2019, poz. 1065));

Comment: *The main executive document regarding the construction of all buildings in Poland. It states detailed requirements for the location of facilities, fireproof requirements of materials, fire prevention building equipment, and so on. The requirements are given for all types of buildings. Selected properties for industrials type of buildings are presented in a further chapter.*

3. Ordinance regarding locating of trees and bushes, noise prevention measures in vicinity of railway. (Rozporządzenie Ministra Infrastruktury z dnia 7 sierpnia 2008 r. w sprawie wymagań w zakresie odległości i warunków dopuszczających usytuowanie drzew i krzewów, elementów ochrony akustycznej i wykonywania robót ziemnych w sąsiedztwie linii kolejowej, a także sposobu urządzania i utrzymywania zasłon odśnieżnych oraz pasów przeciwpożarowych (Dz. U. z 2014 r., poz. 1227, z późn. zm);

Comment: *The executive act regarding elements located in the vicinity of railways. In the case of fire prevention, it states the requirements regarding fire prevention lanes.*

4. Fire Prevention Law (Ustawa z dnia 24 sierpnia 1991 r. o ochronie przeciwpożarowej (dz. U. z 2017 r., poz. 736, z późn. zm);

Comment: *The act regarding general information regarding fire protection in Poland. It contains essential information regarding the responsibilities of each participant in fire protection, regulations regarding professions involved in fire protection, organization of the fire protection units in Poland, and financing of fire protection in Poland. Detailed information is described in related ordinances.*

5. Ordinance regading OSH in mines (Rozporządzenie Ministra Gospodarki z dnia 28 czerwca 2002 r., w sprawie bezpieczeństwa i higieny pracy, prowadzenia ruchu oraz specjalistycznego zabezpieczenia przeciwpożarowego w zakładach górniczych, wydobywających kopaliny otworami wiertniczymi, Dz.U. z 2002 r., nr 109, poz. 961, z późn. zm);

Comment: *The executive act regarding detailed requirements of fire protection in mines: OHS, organization of works and traffic, and specialized fire protection equipment.*

6. Ordinance regarding fire prevention of buildings and other construction (Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 7 czerwca 2010 r. w sprawie ochrony przeciwpożarowej budynków, innych obiektów i terenów, Dz. U., nr 109, poz. 719);

Comment: *The executive act regarding fire prevention in buildings. It contains information regarding storing dangerous fire materials in buildings and their vicinity, hazardous works from the fire perspective, evacuation, regarding fire protection equipment: waterways, sensors, sprinklers, etc. It also contains information regarding the fire protection of forest and agricultural products.*

7. Ordinance regarding water supply and fire evacuation roads (Rozporządzenie Minstra Spraw Wewnętrznych i Administracji z dnia 24 lipca 2009 r. w sprawie przeciwpożarowego zapotrzebowania w wodę oraz dróg pożarowych – Dz.U., nr 124, poz. 1030);

Comment: *The executive act regarding designing the water supply for fire prevention needs contains information regarding the fireproof design of the waterways amount of water needed in the waterways. It also includes information regarding evacuation roads from the buildings and in the vicinity of the construction.*

8. Ordinance regarding accord of fire safety of construction project (Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 2 grudnia 2015 r. w sprawie uzgadniania projektu budowlanego pod względem ochrony przeciwpożarowej – Dz.U. z 2015 r. poz. 2117);

Comment: *The executive act regarding agreements of the construction project for fire safety. It gives information on what is needed to understand and what documents are provided for construction.*

9. Ordinance regarding information regarding utilites used for public and health safety measures (Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 20 czerwca 2007 r., w sprawie wykazu wyrobów służących zapewnieniu bezpieczeństwa publicznego lub ochronie zdrowia i życia oraz mienia, a także zasad wydawania dopuszczania tych

wyrobów do użytkowania – Dz.U. z 2007 r., nr 143, poz. 1002, z późn. zm);

Comment: *The executive act regarding fire prevention materials and the procedure for obtaining certificates for those materials.*

10. Safety Alert Law (Ustawa z dnia 22 listopada 2013 r. o systemie powiadamiania ratunkowego, Dz. U. z 11 lutego 2021 r., poz. 268);

Comment: *The act regarding alarm systems in Poland: its structure, regulations, requirements, and financing.*

11. Ordinance regarding requirements for places for collecting, storing and reusage of wastes (Rozporządzenie Ministra Spraw Wewnętrznych i Administracji w sprawie wymagań w zakresie ochrony przeciwpożarowej, jakie mają spełniać obiekty budowlane lub ich części oraz inne miejsca przeznaczone do zbierania, magazynowania lub przetwarzania odpadów, Dz. U. z 25 lutego 2020 r., poz. 296);

Comment: *The executive act regarding requirements stated for buildings where all parts or selected parts are designated for storage of wastes. It contains detailed information regarding the design of the buildings and requirements for materials used for that building construction. The act is a response to multiple "spontaneous" fires of waste storage places in previous years.*

12. Ordinance regarding the training of fire safety inspectors (Rozporządzenie Ministra Spraw Wewnętrznych z dnia 13 listopada 2015 r. w sprawie szkoleń inspektorów ochrony przeciwpożarowej, Dz.U. z 2015 r., poz 1964 z późn. zm.);

Comment: *The executive act regarding the training of fire prevention inspectors. It contains essential information regarding requirements for training – but only the formal presentation. The Act does not contain detailed information regarding the program of training.*

13. Ordinance regarding detailed organization of fire safety system (Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 2017 r. w sprawie szczegółowej organizacji krajowego systemu ratowniczo-gaśniczego, Dz.U. z 2017 r., poz. 1319);

Comment: *The executive act regarding the organization of the fire protection system in Poland looks into specific regions: provinces and other administrative units. It contains information regarding all protective systems in Poland: health, chemical, technical, and so on. It contains information regarding sending units and documentation of activities.*

14. Ordinance regarding division of funds for fire prevention (Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 30

czerwca 2017 r. w sprawie rozdziału środków finansowych przeznaczonych wyłącznie na cele ochrony przeznaczonych wyłącznie na cele ochrony przeciwpożarowej, Dz. U. z 2017 r., poz. 1317);

Comment: *The executive act regarding obtaining funds for fire protection.*

15. Ordinance regarding safety report for high risk companies (Rozporządzenie Ministra Rozwoju z dnia 23 lutego 2016 r. w sprawie raportu o bezpieczeństwie zakładu o dużym ryzyku, Dz. U. z 2016 r., poz. 287);

Comment: *The executive act is regarding the preparation of a safety report for a company at high risk of industrial malfunction. It states what information needs to be prepared for the report, also considering fire safety and systems of fire safety.*

16. Ordinance regarding exams for fire safety experts (Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 2 grudnia 2015 r. w sprawie egzaminu dla osób ubiegających się o przyznanie prawa do wykonywania zawodu rzeczoznawcy do spraw zabezpieczeń przeciwpożarowych oraz sprawdzianu dla rzeczoznawców, Dz.U., z 2015 r., poz. 2083);

Comment: *The executive act regarding the organization of exams for people applying for fire safety appraiser.*

17. Access to specific jobs Law (Ustawa z dnia 5 sierpnia 2015 r. o zmianie ustaw regulujących warunki dostępu do wykonywania niektórych zawodów, Dz.U., z 2015 r., poz. 1505);

Comment: *The act regarding requirements for obtaining specific permissions. It also contains information regarding professions related to fire safety. It opens the professions to a broader group of people.*

18. Ordinance regarding regulations for metro and its localization (Rozporządzenie Ministra Infrastruktury z dnia 17 czerwca 2011 r. w sprawie warunków technicznych, jakim powinny odpowiadać obiekty budowlane metra i ich usytuowanie, Dz.U., nr 109, poz. 719);

Comment: *The executive act regarding designing metro stations. Similar to buildings, it also contains information regarding fire safety systems used in the metro or design requirement which need to be considered.*

1.2. National and European Standards Used in Poland Related to Fire Prevention

Following national and European standards are currently used in Poland :

1.2.1. Polish Local Standards About Fire Prevention

- PN-B-02852:2001P – Fire prevention of buildings – calculation of the density of fire load and relative duration of a fire
- PN-B-02855:1988 – Fire prevention of buildings – The method of test of toxic fume from burning of materials
- PN-B-02857:2017-04P – Fire prevention of buildings – Water fire tanks – general requirements
- PN-B-02865:1997/Ap1:199P – Fire prevention of buildings – Fire Water supply – fire safety pipeline installation
- PN-B-02867:2013-06P – Fire prevention of structure – the method for calculating the scope of spreading fire through external walls from the exterior side
- PN-B-02870:1993 – Fire Tests – Small chimneys
- PN-B-02877-4:2001/AZ1:2006P – Fire prevention of buildings – gravitational installations for spreading smoke and head – principles of design

1.2.2. European Standards Used in Poland about Fire Prevention

- PN-EN 81-72:2005 - Safety rules for the construction and installation of lifts. Particular applications for passenger and goods, passenger lifts, firefighter lifts
- PN-EN 1021-1:2007 - Furniture - Assessment of the ignitability of upholstered furniture - Part 1: Ignition source smoldering cigarette
- PN-EN 1021-2:2007 - Furniture. Assessment of the ignitability of upholstered furniture ignition source.
- PN-EN 12101-1 - Smoke and heat control systems - Part 1: Specification for smoke barriers
- PN-EN 12101-2 – Smoke and heat control systems - Part 2: Natural smoke and heat exhaust ventilators
- PN-EN 12101-3 – Smoke and heat control systems - Part 3: Specification for powered smoke and heat control ventilators (Fans)
- PN-EN 12101-6 – Smoke and heat control systems - Part 6: Specification for pressure differential systems, Kits
- PN-EN 12101-7 – Smoke and heat control systems - Part 7: Smoke duct sections

- PN-EN 12101-8 – Smoke and heat control systems - Part 8: Smoke control dampers
- PN-EN 12101-10 – Smoke and heat control systems - Part 10: Power supplies
- PN-EN 13238 - Reaction to fire tests for building products - Conditioning procedures and general rules for selection of substrates
- PN-EN 13381-1 - Test methods for determining the contribution to the fire resistance of structural members - Part 1: Horizontal protective membranes
- PN-EN 13381-2 - Test methods for determining the contribution to the fire resistance of structural members - Part 2: Vertical protective membranes
- PN-EN 13381-3 - Test methods for determining the contribution to the fire resistance of structural members - Part 3: Applied protection to concrete members
- PN-EN 13381-4 - Test methods for determining the contribution to the fire resistance of structural members - Part 4: Applied passive protection to steel members
- PN-EN 13381-5 - Test methods for determining the contribution to the fire resistance of structural members - Part 5: Applied protection to concrete/profiled sheet steel composite member
- PN-EN 13381-6 - Test methods for determining the contribution to the fire resistance of structural members - Part 6: Applied protection to concrete-filled hollow steel columns
- PN-EN 13381-8 - Test methods for determining the contribution to the fire resistance of structural members - Part 8: Applied reactive protection to steel members
- PN-EN 13381-9 - Test methods for determining the contribution to the fire resistance of structural members - Part 9: Applied fire protection systems to steel beams with web openings
- PN-EN 13501-1 – Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests
- PN-EN 13501-2 – Fire classification of construction products and building elements - Part 2: Classification using data from fire resistance tests, excluding ventilation services

- PN-EN 13501-3 – Fire classification of construction products and building elements - Part 3: Classification using data from fire resistance tests on products and components used in building service installations: fire-resisting ducts and fire dampers
- PN-EN 13501-4 – Fire classification of construction products and building elements - Part 4: Classification using data from fire resistance tests on components of smoke control systems
- PN-EN 13501-5 – Fire classification of construction products and building elements - Part 5: Classification using data from external fire exposure to roofs tests
- PN-EN 13501-6 – Fire classification of construction products and building elements - Part 6: Classification using data from reaction to fire tests on power, control, and communication cables
- PN-EN 1363-1 – Fire resistance tests - Part 1: General requirements
- PN-EN 1363-2 – Fire resistance tests - Part 2: Alternative and additional procedures
- PN-EN 1364-1 – Fire resistance tests for non-loadbearing elements - Part 1: Walls
- PN-EN 1364-2 – Fire resistance tests for non-loadbearing components - Part 2: Ceilings
- PN-EN 1364-3 – Fire resistance tests for non-loadbearing elements - Part 3: Curtain walling - Full configuration (complete assembly)
- PN-EN 1364-4 – Fire resistance tests for non-loadbearing elements - Part 4: Curtain walling - Part configuration
- PN-EN 1364-5 – Fire resistance tests for non-loadbearing elements - Part 5: Air transfer grilles
- PN-EN 1365-1 – Fire resistance tests for loadbearing elements - Part 1: Walls
- PN-EN 1365-2 – Fire resistance tests for loadbearing elements - Part 2: Floors and roofs
- PN-EN 1365-3 – Fire resistance tests for loadbearing elements - Part 3: Beams
- PN-EN 1365-4 – Fire resistance tests for loadbearing elements - Part 4: Columns

- PN-EN 1365-5 – Fire resistance tests for loadbearing elements - Part 5: Balconies and walkways
- PN-EN 1365-6 – Fire resistance tests for loadbearing elements - Part 6: Stairs
- PN-EN 1366-1 – Fire resistance tests for service installations - Part 1: Ventilation ducts
- PN-EN 1366-10 – Fire resistance tests for service installations - Part 10: Smoke control dampers
- PN-EN 1366-12 – Fire resistance tests for service installations - Part 12: Non-mechanical fire barrier for ventilation ductwork
- PN-EN 1366-3 – Fire resistance tests for service installations - Part 3: Penetration seals
- PN-EN 1366-4 – Fire resistance tests for service installations - Part 4: Linear joint seals
- PN-EN 1366-5 – Fire resistance tests for service installations - Part 5: Service ducts and shafts
- PN-EN 1366-6 – Fire resistance tests for service installations - Part 6: Raised access and hollow core floors
- PN-EN 1366-7 – Fire resistance tests for service installations - Part 7: Conveyor systems and their closures
- PN-EN 1366-8 – Fire resistance tests for service installations - Part 8: Smoke extraction ducts
- PN-EN 1366-9 – Fire resistance tests for service installations - Part 9: Single compartment smoke extraction ducts
- PN-EN 13823 – Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item
- PN-EN 14135 – Coverings - Determination of fire protection ability
- PN-EN 14390 - Fire test - Large-scale room reference test for surface products
- PN-EN 15080-12 - Extended application of results from fire resistance tests - Part 12: Loadbearing masonry walls
- PN-EN 15080-8 - Extended application of results from fire resistance tests - Part 8: Beams

- PN-EN 15254-2 - Extended application of results from fire resistance tests - Non-loadbearing walls - Part 2: Masonry and gypsum blocks
- PN-EN 15254-4 - Extended application of results from fire resistance tests - Non-loadbearing walls - Part 4: Glazed constructions
- PN-EN 15254-5 - Extended application of results from fire resistance tests - Non-loadbearing walls - Part 5: Metal sandwich panel construction
- PN-EN 15254-6 - Extended application of results from fire resistance tests - Non-loadbearing walls - Part 6: Curtain walling
- PN-EN 15254-7 - Extended application of results from fire resistance tests - Non-loadbearing ceilings - Part 7: Metal sandwich panel construction
- PN-EN 15269-1 - Extended application of test results for fire resistance and smoke control for door, shutter, and openable window assemblies, including their elements of building hardware - Part 1: General requirements
- PN-EN 15269-10 - Extended application of test results for fire resistance and/or smoke control for door, shutter, and openable window assemblies, including their elements of building hardware - Part 10: Fire resistance of steel rolling shutter assemblies
- PN-EN 15269-2 - Extended application of test results for fire resistance and/or smoke control for door, shutter, and openable window assemblies, including their elements of building hardware - Part 2: Fire resistance of hinged and pivoted steel door sets
- PN-EN 15269-20 - Extended application of test results for fire resistance and/or smoke control for door, shutter, and openable window assemblies, including their elements of building hardware - Part 20: Smoke control for doors, shutters, operable fabric curtains, and openable windows
- PN-EN 15269-3 - Extended application of test results for fire resistance and/or smoke control for door, shutter, and openable window assemblies, including their elements of building hardware - Part 3: Fire resistance of hinged and pivoted timber door sets and openable timber framed windows
- PN-EN 15269-5 - Extended application of test results for fire resistance and/or smoke control for door, shutter, and openable window assemblies, including their elements of building hardware - Part 5: Fire resistance of hinged and pivoted metal framed glazed door sets and openable windows

- PN-EN 15269-7 - Extended application of test results for fire resistance and/or smoke control for door, shutter, and openable window assemblies, including their elements of building hardware - Part 7: Fire resistance for steel sliding door sets

- PN-EN 15725 - Extended application reports on the fire performance of construction products and building elements

- PN-EN 15882-1 - Extended application of results from fire resistance tests for service installations - Part 1: Ducts

- PN-EN 15882-2 - Extended application of results from fire resistance tests for service installations - Part 2: Fire dampers

- PN-EN 15882-3 - Extended applications of results from fire resistance tests for service installations - Part 3: Penetration seals

- PN-EN 15882-4 - Extended application of results from fire resistance tests for service installations - Part 4: Linear joint seals

- PN-EN 1634-1 - Fire resistance and smoke control tests for door and shutter assemblies, openable windows, and elements of building hardware - Part 1: Fire resistance test for door and shutter assemblies and openable windows

- PN-EN 1634-2 - Fire resistance and smoke control tests for door, shutter, and openable window assemblies and elements of building hardware - Part 2: Fire resistance characterization test for elements of building hardware

- PN-EN 1634-3 - Fire resistance tests for door and shutter assemblies - Part 3: Smoke control doors and shutters

- PN-EN 16733 - Reaction to fire tests for building products - Determination of a building product's propensity to undergo continuous smoldering

- PN-EN 1991-1-2 - Eurocode 1: Actions on structures - Part 1-2: General actions - Actions on structures exposed to fire

- PN-EN 81-58 - Safety rules for the construction and installation of lifts - Examination and tests - Part 58: Landing doors fire resistance test

- PN-EN ISO 1182 - Reaction to fire tests for products - Non-combustibility test

- PN-EN ISO 11925-2 - Reaction to fire tests - Ignitability of products subjected to direct impingement of flame - Part 2: Single-flame source test

- PN-EN ISO 13943 - Fire safety - Vocabulary

- PN-EN ISO 1716 - Reaction to fire tests for products - Determination of the gross heat of combustion (calorific value)
- PN-EN ISO 6940 - Textile fabrics - Burning behavior - Determination of ease of ignition of vertically oriented specimens
- PN-EN ISO 6941 - Textile fabrics - Burning behavior - Measurement of flame spread properties of vertically oriented specimens
- PN-EN ISO 9239-1 - Reaction to fire tests for floorings - Part 1: Determination of the burning behavior using a radiant heat source
- PN-EN ISO 13381-7 -Test methods for determining the contribution to the fire resistance of structural members - Part 7: Applied protection to timber members
- PN-ISO 11925-3 - Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 3: Multi-source test
- PN-ISO 7010 - Graphical symbols - Safety colors and safety signs - Registered safety signs
- PN-ISO 8421-2 - Fire protection — Vocabulary — Part 2: Structural fire protection
- PN-ISO 8421-6 - Fire protection — Vocabulary — Part 6: Evacuation and means of escape
- PN-ISO 9705 -Reaction to fire tests — Room corner test for wall and ceiling lining products
- PN-N 01256-02 – Fire safety signs - evacuation
- PN-N 01256-5 – Fire safety signs – The rules for placing fire safety signs on evacuation and fire-safety roads
- PKN-CEN/TS 1187 - Test methods for external fire exposure to roofs
- PKN-CEN/TS 15117 - Guidance on a direct and extended application
- PKN-CEN/TS 15447 - Mounting and fixing in reaction to fire tests under the construction products directive
- PKN-CEN/TS 16459 - External fire exposure of roofs and roof coverings - extended application of test results from CEN/TS 1187

1.3. Requirements Regarding Industrial Buildings in Poland

Poland does not have specific regulations regarding the construction of industrial buildings considering fire prevention. Storage and production buildings are one of many building types. It does not take into consideration specific characteristics of different industrial sectors. Some specific construction types have additional regulations, but it is only for specific industries, such as mining, oil storage and transportation, and waste management. Most of the buildings are treated the same under regulation of Construction Law (Prawo budowlane (Ustawa z dnia 7 lipca 1994r, tekst jednolity - Dz. U. z 2020r. poz. 1333, 2127, 2320; z 2021 r. poz. 11, 234, 282) [X1] and ordinance for buildings and their location (Warunki techniczne, jakim powinny odpowiadać budynki i ich usytuowanie - obwieszczenie Ministra Inwestycji i Rozwoju z dnia 8 kwi-etnia 2019 r., Dz. U. 2019, poz. 1065). All the regulations are available for download from the government site: https://isap.sejm.gov.pl/. All of the regulations and ordinances are available in Polish.

1.3.1.General information regarding building design

The most critical Polish document for the design of buildings and construction in which fire prevention measures included is Construction Law (Ustawa z dnia 7 lipca 1994r, tekst jednolity - Dz. U. z 2020r. poz. 1333, 2127, 2320; z 2021 r. poz. 11, 234, 282). Chapter 5.1 states that every construction and all its elements should, apart from bearing capacity, durability, and functionality should, provide appropriate fire safety – both from proper construction materials and appropriate measures (equipment, and design of buildings, such as evacuation roads). More detailed information is presented in executive documents of the ordinance level, such as ordinances regarding buildings and their localization, metros and their localization, or bases and station for liquid fuel and their localization. It should be stated that each law document is constantly updated for new means and requirements. The last additions were added in the year 2021. Therefore it should be noted that the presented information was valid for the end of May 2021.

The basic document for design of industrial buildings in Poland is Ordinance regarding technical regulation regarding buildings and their localization (Warunki techniczne, jakim powinny odpowiadać budynki i ich usytuowanie (tekst jednolity – obwieszczenie Ministra Inwestycji i Rozwoju z dnia 8 kwietnia 2019 r., Dz. U. 2019, poz. 1065). Information regarding measures for fire prevention are presented in chapter 6 (titled - Fire safety) of the mentioned ordinance.

In Polish law and regulations, buildings are divided into three classes: buildings for collective housing and public utility – class ZL, buildings for production and storage – class PM (industrial buildings), and buildings for animal breeding – class IN. Further, class ZL is divided into five classes: ZL I – buildings that contain rooms for the simultaneous presence of at least 50 people (temporary users) but not designed for the usage of people with moving inabilities; ZL II – buildings for people with moving inabilities, such as hospitals, nurseries, kindergartens or nursing houses; ZL III – the buildings of public utility not classified as ZL I or ZL II; ZL IV – building for housing; ZL V – buildings for collective housing not classified as ZL I or ZL II. In the case of PM and IN class buildings, they are not divided into more specific subclasses. In the case of PM buildings, specific requirements are stated depending on the fire density loads.

In the case of materials used for construction, fire resistance classes are classified according to PN-EN 13501-1 standard into one of the following classes:

- Non-flammable: A1, A2-s1,d0; A2-s2,d0; A2-s3,d0;
- Flammable:

(non-flammable: A2-s1,d1; A2-s2,d1; A2-s3,d1; A2-s1,d2; A2-s2,d2; A2-s3,d2; B-s1,d0; B-s2,d0; B-s3,d0; B-s1,d1; B-s2,d1; B-s3,d1; B-s1,d2; B-s2,d2; B-s3,d2);

(hard-to-fire: C-s1,d0; C-s2,d0; C-s3,d0; C-s1,d1; C-s2,d1; C-s3,d1; C-s1,d2; C-s2,d2; C-s3,d2; D-s1,d0; D-s1,d1; D-s1,d2);

(easy-to-fire: D-s2,d0; D-s3,d0; D-s2,d1; D-s3,d1; D-s2,d2; D-s3,d2; E-d2; E; F);

- Non-dripping: A1; A2-s1,d0; A2-s2,d0; A2-s3,d0; B-s1,d0; B-s2,d0; B-s3,d0; C-s1,d0; C-s2,d0; C-s3,d0; D-s1,d0; D-s2,d0; D-s3,d0);
- Self-extinguishing: at least E;
- Intensely fuming: A2-s3,d0; A2-s3,d1; A2-s3,d2; B-s3,d0; B-s3,d1; B-s3,d2; C-s3,d0; C-s3,d1; C-s3,d2; D-s3,d0; D-s3,d1; D-s3,d2; E-d2, E, F.

1.3.2. Requirements for Production and Storing in Industrial buildings

Fire resistance of buildings and their parts are divided into five classes (from the highest resistance to the lowest): “A,” “B,” “C,” “D,” and “E.” The required resistance classes for industrial buildings are given in Table 11.

Table 11. *Required fire resistance classes for industrial buildings and their parts.*

Maximum fire load density of fire zone of building Q [MJ/m2]	Building with 1 tier above ground (without height limit)	Multitier building			
		Low	Medium	High	Very high
		(N)	(SW)	(W)	(WW)
1	2	3	4	5	6
Q ≤ 500	E	D	C	B	B
500 < Q ≤ 1000	D	D	C	B	B
1000 < Q ≤ 2000	C	C	C	B	B
2000 < Q ≤ 4000	B	B	B	Not allowed	Not allowed
Q > 4000	A	A	A	Not allowed	Not allowed

Fire resistance classes are determined separately for multi-tier buildings, which are included in different PM or ZL categories. The fire resistance class of the part of the building should not be lower than the fire resistance class of the part of the building located above it. The minimum fire resistance class for underground building parts should be "C." Suppose in the building of the ZL category, and there are parts for production, storage, or technical means (PM category). In that case, these parts should be designed as separate fire zones with particular fire resistance classes. The rooms in which water tanks or other water supply equipment should be designed as distinct fire zones.

If the building is equipped with automatic fire extinguishing equipment, it can be designed as a lower fire resistance class. It is possible to design the industrial building as the fire resistance class "E" (lowest) for one tier building if fire density load Q is lower than 500 MJ/m^2 and all elements of the building are made from non-flammable materials and are equipped with automatic anti-fume equipment for each fire zone bigger than 1000 m^2.

Elements of the building for specific fire resistance classes should be designed as stated in table 12.

Table 12. *Fire resistance classes of building elements for specific fire resistance class*

Building fire resistance class	The class of fire resistance of elements of buildings					
	The main structure	The roof structure	Ceiling	External wall	Internal wall	The roof cover
1	2	3	4	5	6	7
A	R 240	R 30	R E I 120	E I 120 (o↔i)	E I 60	R E 30
B	R 120	R 30	R E I 60	E I 60 (o↔i)	E I 30	R E 30
C	R 60	R 15	R E I 60	E I 30 (o↔i)	E I 15	R E 15

D	R 30	-	R E I 30	E I 30 (o↔i)	-	-
E	-	-	-	-	-	-

R- Fire bearing capacity (in minutes); E – Fire robustness (in minutes); I – Fire isolation (in minutes); "-" – requirements not stated

The elements of the building should be made from non-flammable materials. It is possible to use hard-to-fire materials of elements of a building with one tier if the fire density load of the fire zone is lower than 500 MJ/m^2; external and internal walls and roof structure and cover for "N" category industrial buildings with maximum fire density load of 1000 MJ/m^2. It is possible to design the external walls as a "D" class with a core of an "E" class if the internal cover is made from non-flammable material and the wall is not spreading fire if fire works from the outer side. It is possible to use the "D" class material for internal walls.

The roof cover of roofs larger than 1000 m^2 should be made from non-spreading materials. Flammable isolation should be separated from the building interior by the barrier of fire resistance class not lower than R E 15.

The internal walls and ceilings separating the boiler rooms, the magazines for solid fuel, slag houses, the storages of liquid fuel, and covers of holes in this building parts should have fire resistance classes not lower than stated in Table 13.

Table 13. *Fire resistance classes of selected building elements*

Type of room	The class of fire resistance of elements of buildings		
	Internal walls	Ceilings	Doors and other hole covers
1	2	3	4
Boiler room with boilers for solid fuel, the heat power over 25 kW	E I 60	R E I 60	E I 30
Boiler room with boilers for liquid fuel, the heat power over 30 kW	E I 60	R E I 60	E I 30
Boiler room with boilers for gas fuel, the heat power over 30 kW: - N and SW buildings - W and WW buildings	E I 60 E I 120	R E I 60 R E I 120	E I 30 E I 60
Solid fuel storage and slag house	E I 120	R E I 120	E I 60
Liquid fuel storage	E I 120	R E I 120	E I 60

A light roof made of hard-to-fire materials should be used in rooms with a risk of explosion. The room with a risk of explosion should be located on the highest tier of the building (not applicable for facilities located in closed areas). It is possible to identify these rooms in other locations if appropriate explosion-proof equipment is used and the design is agreed upon with the regional Fire Department.

1.3.3. Fire Zones and Fireproof Barriers

The fire zone is a building, or its part separated from other buildings, with appropriate fireproof elements or appropriate non-build-up area. The part of the building could be a separate tier if stairways and elevator shafts are appropriately designed. The area of the fire zone is calculated as the internal of the building or its part. The permissible area of fire zones is stated in Table 14.

Table 14. *Permissible Areas of the Fire Zones*

Type of fire zone	Fire density load Q [MJ/m2]	The permissible area of the fire zone in m2		
		In on-tier building	In multi-tier building	
			N and SW	W and WW
1	2	3	4	5
Fire zones with risk of explosion	Q > 4000	1000	Not allowed	Not allowed
	2000 < Q ≤ 4000	2000	Not allowed	Not allowed
	1000 < Q ≤ 2000	4000	1000	Not allowed
	500 < Q ≤ 1000	6000	2000	500
	Q ≤ 500	8000	3000	1000
Other fire zones	Q > 4000	2000	1000	Not allowed
	2000 < Q ≤ 4000	4000	2000	Not allowed
	1000 < Q ≤ 2000	8000	4000	1000
	500 < Q ≤ 1000	15000	8000	2500
	Q ≤ 500	20000	10000	5000

The fire zones in the underground part of the building should not exceed 50% of the area stated in table 14. It is possible to expand the fire zone if: permanent automatic water extinguishing equipment is installed (by 100%) and permanent automated anti-smog equipment is used (by 50%). If both types of equipment are used, the fire zone can be expanded by 150%. In one-tier buildings or on the last tier of multi-tier buildings, the fire zone area can be expanded by 100% if there is no room with the risk of an explosion and non-flammable materials are used, and automatic anti-smog equipment is used. In industrial one-tier buildings, the fire zone area is not restricted if automatic water extinguishing and anti-smog equipment are used.

The walls and ceilings used as antifire barriers that separate fire zones should be made from non-flammable materials, and all doors and other hole covers should be fireproof. The required fire resistance class of elements separating fire zones is stated in Table 15.

Table 15 *Required Fire Resistance Class of Elements Separating Fire Zones*

Building fire resistance class	The class of fire resistance			
	Fire zones separation elements	Fireproof doors and other covers	Doors for fireproof entryway	
	Walls and ceilings		For corridor and room	For stairway
1	2	3	4	5
A	R E I 240	E I 120	E I 60	E 60
B and C	R E I 120	E I 60	E I 30	E 30
D and E	R E I 60	E I 30	E I 15	E 15

It is possible to design holes in fire separation walls in industrial buildings if used for technical installations. Still, the fire resistance class of the filling must correspond to the fire resistance class of the appropriate fireproof door.

The wall used to separate fire zones should be constructed on its foundation or element/ceiling of fire resistance class not lower than required for the wall.

1.3.4. Evacuation roads

From each room in which people stay is allowed evacuation roads should be designed. It should lead to a safe place outside the building or another safe fire zone. The road should be direct evacuation roads or public communication roads. The exits from rooms to the evacuation roads should be closed by appropriate doors. Evacuation doors for building for more than 50 people should open outside. The number of evacuation roads or exits should be designed for the proper area of the building/room. From the furthest place in which the people can stay to the evacuation exit, the evacuation road should not have more than 75 m (if the fire density load is higher than 500 MJ/m2 in the multitier building), 100 m (if the fire density load is lower than 500 MJ/m2 of multitier buildings or for one tier buildings). From rooms with a risk of an explosion, the evacuation road should not be longer than 40 m. In rooms with a height higher by 5 m, the evacuation road can be extended by 25%. The length of evacuation roads can be extended by 50% (if permanent automatic water extinguishing equipment is used) and by 50% (if automatic anti-smog equipment is used). The extension of fire road lengths can be summarized. The width of evacuation doors should be designed to amount permissible people in the building, but not smaller than 0,9m. The room should have at least two separate evacuation doors located further than 5 meters from each other if: fire density load is higher than 500 MJ/m2 and its area is higher than 300 m2; fire density load is lower than 500 MJ/m2, and its size is larger than 1000m2; there is a risk of explosion, and its area is higher than 100 m2. The covers of the walls of the evacuation roads should be made from materials of fire resistance class of walls designated for building but not lower than E I 15.

The width of evacuation roads should be designed for an acceptable amount of people in the building, but no lower than 1,4 m. The height of the evacuation road should not be lower than 2,2 m. It is not possible to design evacuation roads stairs with a landing. Using stairs or ramps on evacuation roads is possible, but they should be appropriately marked. Evacuation stairways should be covered with smog-proof doors and automatic antismog equipment. In industrial buildings, if an evacuation road is required from higher tiers, it is possible to use evacuation ladders, which lead to the roof of a lower level or on the ground if the amount of people on higher tiers is not higher than 50 (or 15 if there is a risk of explosion). The ladders should be located in easily accessible places. Placing ladders in windows or other holes is not allowed.

1.3.5. The Fire Prevention Requirements for Permanent Equipment or Cover of Walls.

In rooms designed for people to stay for the covers of walls and interior, it is not permissible to use easy-to-fire materials, which are highly smoky or toxic. On public communication roads also used for evacuation, it is not permitted to use easy-to-fire materials.

Floors higher than 0,2 m above the ceiling or ground level should have: non-flammable construction with the fire resistance class not lower than R E I 30 or R E I 60 if the fire density load is higher than 4000 MJ/m2. The space under the floor should be divided into sectors of an area no larger than 1000 m2 with barriers of fire class not lower than E I 30 and E I 60 for areas with a fire density load of at least 4000 MJ/m2. Wires and electrical cables, and other installations made of flammable materials located in the area under the elevated floor or the suspended ceiling used for ventilation of the room should have the cover of fire class at least E I 30, or at least E I 60 for buildings with fire density load of at least 4000 MJ/m2. Holes in the elevated floor for ventilation or heating are not allowed on the evacuation road. Using easy-to-fire materials for barriers, permanent equipment, or floor carpets is forbidden in rooms dedicated to simultaneous usage of at least 50 people or production rooms. In storage areas or rooms with elevated floors, using easy-to-fire floor car-pets is forbidden. Covers of ceilings or suspended ceilings should be made from non-flammable or non-ignited materials which do not drip or fall under fire load. The area between the suspended ceiling and ceiling should be divided into sectors of an area not larger than 1000 m2 and in corridors with barriers every 50 meters.

1.3.6. Requirements for Fire Prevention Methods for Furnance and Installations

Furnaces should be located on the non-flammable ground with a thickness of at least 0,15 m, and for metal ovens without feet – at least 0,3 m. The easy-to-fire floor in front of the furnace door should be protected by a 0,3m strip made of non-flammable material. Furnaces can be located only in rooms without risk of explosion, at least 0,6m from easy-to-fire parts of the building. Metal ovens and all pipes and installations should be distanced from easy-to-fire, not covered construction elements of buildings at least 0,6 m. If the cover is made from 25 mm plaster, the distance is at least 0,3m. The oven, made from brick or similar non-flammable materials, should be distanced from easy-to-fire, not covered constructions elements of buildings at least 0,3 m. If the cover is made from 25 mm plaster, the distance is at least 0,15.

The fume pipes should be made of non-flammable materials. The ventilation ducts should be made from non-flammable materials, and all flammable isolations and covers can only be used on external sites. In industrial buildings, it is possible to use non-spreading materials for ventilation ducts if they are not located on evacuation roads and the air inside is of temperature lower than 85°C. The distance of non-isolated ventilation ducts from covers and flammable areas should be at least 0,5m.

The mechanical ventilation and air conditioning installations should comply with the following requirements: The ventilation ducts should not affect the construction of a building; the fastening of the installation should be made from non-flammable material; In ventilation ducts, other installations are forbidden; the ma-chine-rooms for ventilation and air conditioning for buildings of at least two tiers should be separated by walls of fire class at least E I 60 with doors of fire class of at least E I 30. It is allowed to install the fans of equipment in ventilation ducts for improvement of air under the condition of the cover of fire class of at least E I 60. Ventilation and air conditioning ducts in the place crossing the fireproof separation should be equipped with a trapdoor of appropriate fire class (E I S). The ventilation and air conditioning ducts in the other fire zone should have fire class E I S similar to the fire zone. In fire zones where the alarm-signal installation is required, trapdoors should be automatically run by this installation. The equipment automatically stopping the work of fans should be used in a room with a risk of explosion. In rooms with a risk of explosion, separate extractor ducts should be used for each fire zone. Extractor ducts should be designed for materials used in the room. In rooms in which flammable dust can explode, the ventilation ducts should be designed in a way that will not hover the dust. The filters, dust chambers, and cyclones for flammable dust should be located in rooms isolated by fire-resistant barriers or outside the building in a safe place. The ventilation ducts in front of dust chambers should be equipped with fire transfer preventive measures.

The smoke-away ventilation duct should: remove the smoke with an intensity that will allow the evacuation; have constant access to external air. The smoke-away ducts should have a smokeproof class of at least E600 S. The fireproof class should be at least the same level as the ceiling. The trapdoors for smoke-away ventilation ducts should be run automatically and have a fire and smoke isolation class of at least E600S AA and a fireproof class of at least the same level as the ceiling. The smoke-away ventilators should have a type of at least F600 60 if the smoke temperature is over 400°C and at least F400 120 in other cases. The trapdoors should have classes of at least B300 30 if opened automatically and at least 600 30 if opened by hand.

1.3.7. Requirements for Location of Buildings

The distance between external walls, which are not part of fire separation, should not be smaller than stated in Table 16.

Table 16 *Required Distance Between External Walls Which are not Part of Fire Separation*

Type of building	Type of building				
	ZL	IN	PM		
			Q ≤ 1000	1000 < Q ≤ 4000	Q > 4000
1	2	3	4	5	6
ZL	8	8	8	15	20
IN	8	8	8	15	20
PM Q ≤ 1000	8	8	8	15	20
PM 1000 < Q ≤ 4000	15	15	15	15	20
PM Q > 4000	20	20	20	20	20

If one of the external walls located near the adjacent building or the cover of the room of one of the buildings is made from fire-spreading material, the distance in table 5 should be extended by 50%, and if it is the case for both buildings – by 100%. If in one of the buildings there is a room with a risk of an explosion, the distance between the external walls of both buildings should be at least 20 m. The distance should be extended if only a part of the wall fulfills the appropriate fireproof class. The distance between the external walls of the buildings could be reduced by 50% if there is permanent water extinguishing equipment in all fire zones of the adjected rooms. The distance between external walls from adjacent parcels without buildings should be at least half as described above. If the adjacent parcel industrial building is designed, it should be assumed that the fire density load will range from 1000 to 4000 MJ/m2 if not stated otherwise.

2. Italy

Italian strategy in preventing fire risks: The right building project is the first step in contrasting fire.

Before the building…

In August 2015, the Ministry of the Interior of the Italian Republic (Department of Firefighters, Public Rescue, and Civil Defense; Central Directorate for Prevention and Technical Security) published the Code for Fire Prevention.

This code highlights the importance of prevention and the importance of the project as the first tool to combat fire damage.

In the Code, the monitoring activity during the design phase of the risks and the solutions to avoid them is very articulated and punctual and entrusts the designers with the planning and executive responsibility of the most suitable solutions to prevent fires and to the Fire Brigade the control of the proposed and implemented solutions and the ability to sanction in case of failure to enforce the required solutions and also possibly to suspend the work. Design is, therefore, the main point through which the attempt to minimize the risk of accidents.

In Chapter G.2, Planning for fire safety, of the Fire Prevention Code, the meaning of the project is articulated as an indispensable preventive step.

In the section General Methodology, this passage is well explained. The project addresses several issues: 1. Evaluation of the fire risk for the activity; 2. Assignment of risk profiles; 3. Fire-fighting strategy for risk mitigation; 4. Attribution of performance levels to fire-fighting measures; 5. Identification of design solutions.

In essence, therefore, the building is already born of itself as an organism that contrasts the risk of the production of fires and their spread.

To this is obviously added the provision of direct contrast instruments, systems that, in the event of a fire, counteract its development, specified in two further paragraphs contained in the chapter "General indications for the design of fire safety systems": Common requirements and Systems or plants with higher availability.

Photo 2. *Steel mills like this in Taranto need an evaluation of the fire risk, the assignment of risk profiles, and a firefighting strategy for risk mitigation.*

Obviously, the philosophy of the Code is not to totally eliminate the risk of fire but to make this risk within acceptable limits, it is, in fact, written: *"the fire risk of an activity cannot be reduced to zero. The fire prevention, protection, and management measures provided in this document are therefore selected to minimize the risk of fire, in terms of probability and consequences, within limits considered acceptable".*

The general philosophy of prevention speaks of two fundamental issues, each of which has different articulations: 1. Design the fire safety of an activity. It means identifying the technical and management solutions to achieve the primary objectives of fire prevention: a. safety of human life, b. safety of persons, c. protection of assets and the environment; 2. The primary goals of fire prevention shall be achieved if the activities are designed, carried out, and managed in such a way as to a. minimize the causes of fire or explosion; b. guarantee the stability of the weight-bearing structures for a fixed period of time; c. limit the production and spread of a fire within the business; d. limit the spread of a fire to contiguous activities; e. limiting the effects of an explosion; f. ensuring that occupants can leave the business independently or that they are rescued in another way; g. guarantee the possibility for rescue teams to operate in safe conditions; h. protect buildings valuable for art or history; i. ensuring continuity of operation for strategic works; j. preventing environmental damage and limiting environmental damage in the event of a fire.

The first step that the project must take into account is clearly to define the risk potential of the building both as a type of operation and as a proposed design solution.

The fire risk assessment represents an analysis of the specific activity aimed at identifying the most severe but credible hypotheses of fire and the consequences for occupants, property,, and the environment. This analysis allows the designer to implement and, if necessary, integrate the planned design solutions.

In any case, the fire risk assessment must include the following:

a. Identification of fire hazards (for example ignition sources, combustible or flammable materials, fire load, ignition-fuel interaction, any significant quantities of mixtures or dangerous substances, hazardous processes for fire or explosion, possible formation of explosive atmospheres.)

b. Description of the context and environment in which the hazards are placed (For example accessibility and viability conditions, company layout, distances, separations, insulation, building characteristics, characteristics of buildings, geometric complexity, volume, surfaces, height, underground floors, planar-volumetric articulation, partitioning, aeration, ventilation and surfaces useful for the disposal of fumes and heat).

c. Determination of the quantity and type of occupants exposed to the risk of fire;

d. Identification of assets exposed to fire risk;

e. Qualitative or quantitative assessment of the consequences of the fire on occupants, property, and the environment;

f. identification of preventive measures that can remove or reduce the dangers that determine significant risks.

Furthermore, in the areas of activities in which flammable substances are present in the state of gas, vapors, mists, or combustible dust, the fire risk assessment must also include the risk assessment for explosive atmospheres.

Photo 3. *The risk of fire is divided into three contexts: risk relating to safeguarding human life, risk relating to protecting economic assets, and environmental protection.*

It should be specified that the risk is divided into three different, exact contexts: "*To briefly describe the type of fire risk of the activity, the following types of risk profile are defined: Life risk profile relating to the safeguarding of human life; Assets: Risk profile relating to the safeguarding of economic assets; Environment: risk profile relating to environmental protection.*"

The document prepared by the Ministry of the Interior proposes some standard design solutions in two sections called Fire Strategy and Vertical Technical Rules, solutions to which the designer of a new building may refer. Therefore the designer can approach the fire prevention design through three different attitudes: in the first, he applies the compliant solutions (i.e., those dictated by the Fire Prevention Code); in the second, he studies alternative solutions; in the third, he asks for exceptions.

The second case involves additional problems: The designer who uses alternative solutions is required to demonstrate the achievement of the performance level, using one of the fire safety design methods allowed for each fire prevention measure. To allow the assessment of this demonstration by the National Fire Brigade Corps, alternative solutions are permitted only in the activities in which the project is evaluated in advance by the same Fire Brigade. The third case (that of design in derogation) can be activated if neither the compliant solutions nor the alternative solutions can be effectively applied. However, the designer who chooses the derogated solutions must demonstrate the achievement of the fire prevention objectives using one of the planned fire safety design methods.

As previously mentioned, this preventive planning process has the National Fire Brigade and its qualified technicians as a reference for approval. To obtain this approval, the project must meet three general criteria that cannot be postponed: a. the appropriateness of the fire safety objectives pursued, of the basic assumptions, of the input data, of the methods, of the models, of the regulatory tools selected and used to support the fire prevention design, i.e., the appropriate application of compliant solutions; b. the correspondence of fire prevention measures to the safety objectives pursued according to the indications of the Fire Prevention Code, for example, the provision of an adequate system of escape routes to meet the objective of the safety of human life; c. the correctness in the application of methods, models and regulatory tools, for example absence of gross calculation errors, correspondence between the numerical results of the calculations and the actual fire prevention measures, etc.

The principles for fire prevention In factories in Italy

The first step in this field is the classification of the factories about their potential risk in the building process and the routine activities after the building.

Photo 4. *Plants for the production, processing, and regeneration of rubber are included in the C category and need complex projects about fire protection.*

The activities are divided into three categories depending on the dangerousness, apart from some other "special categories." Each has different rules to save buildings, human life in the surroundings, and the environment.

The main rules for protecting a hangar are related to its design. There are a lot of specific regulations for the construction of a shed, and the firefighters have control of the project and leave a special license for the construction of the buildings.

About the maintenance of the hangars, any change in the life of the hangars, in terms of activity, or in terms of volume and shape of the building must request authorization from the local fire brigade to certify that the modification is compatible with the fire regulations.

For the responsibility for the illegal practice, the factories that don't respect the law can be sequestered or closed by the police or the fire brigades that can oblige them to make all the transformation into the rules again.

To prevent fires, factories must be checked periodically by the fire brigade, the local authorities, and the authorities responsible for protecting the environment and those for the protection of workers.

2.1. The Main Law

To the safety against fire in industrial sites, the primary Italian law is the "Decreto Pres. Repubblica 01/08/2011 n. 151 (Gazzetta Ufficiale 22/09/2011 n. 221) - Regulation governing the procedures relating to fire prevention". Also, this law considers prevention the first important step to contrast accident in factories. The first aid against fire is, for Italian culture, in the project.

Photo 5. *Industrial buildings must be designed with a fire prevention idea independent of their production activity. The different activities constitute a further evaluation of the risk.*

To explain the philosophy of this law, I'll present some significant articles of the law that can tell the main concepts of that.

Art.2 Purpose and scope of application

3. The activities under control are divided into categories A, B, and C, based on the size of the factory, the type of activity, and the safeguarding of public safety.

6 Industrial activities at risk of a significant accident, subject to the presentation of the safety report, are excluded from the scope of this regulation.

Art. 3 Evaluation of projects

1. Responsible entities and private individuals have to request to the Command the examination of projects for new constructions and for modifications to be made to those existing

3. The Command examines the projects and, within thirty days, can request additional documentation. The Command answers about the

compliance of fire prevention within sixty days from the date of presentation of the complete documentation.

Art.4 Fire prevention checks

Art.5 Certificate of periodic renewal of fire compliance

Art. 6 Obligations related to the exercise of the enterprise

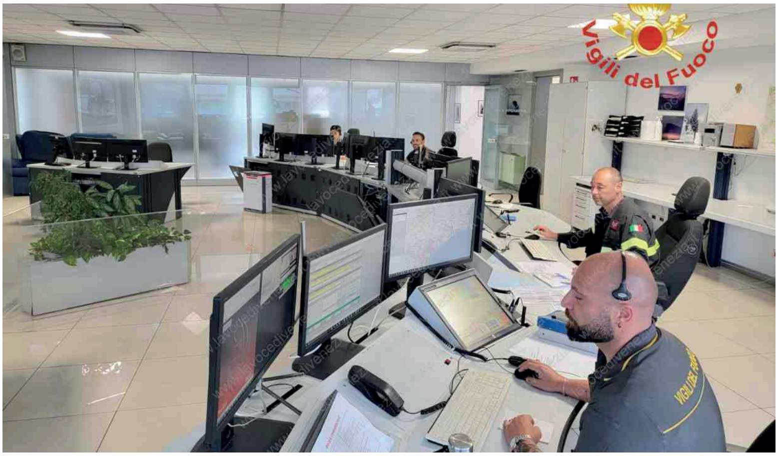

Photo 6. *In the provincial fire brigade headquarter, managers, architects, technicians, and engineers specialized in the evaluation of projects for fire prevention employed*

The institutions and individuals responsible for activities have an obligation to maintain the state of the system's efficiency, devices, equipment, and other fire safety measures taken and to conduct inspection checks. They must ensure adequate information on the fire risks associated with the specific activity, on the prevention and protection measures adopted, on the precautions to be observed to avoid the onset of a fire and on the procedures to be implemented in the event of a fire.

2.2. A Special List

In the "Decreto 3 Agosto 2015," a list of activities has been written about the requirements for a project on fire prevention. This list excludes special activities in which the risk is very high, and the control solution must be specifically studied.

The type of prevention in a project is divided into three categories: A, B, and C.

Category A activities include small hotels with between 25 and 50 beds, companies and offices that have between 300 and 500 people present, garages between 300 m² and 1,000 m², buildings intended for civil use with a fire height between 24 m and 32 m, heat production plants with capacities between 116 kW and 350 kW, health facilities between 25 and 50 beds, theaters and studios for film and television shooting up to 25 people present.

Category B activities include hotels with between 50 and 100 beds, campsites, health facilities with between 50 and 100 beds, premises for the retail or wholesale sale of surfaces between 600 and 1,500 m², companies and offices that have between 500 and 800 people, garages between 1,000 and 3,000 m², buildings intended for civil use with a fire height between 32 and 54 m.

Category C activities include thermoelectric power plants, theaters and television studios with more than 100 people present, health facilities and hotels with over 100 seats, companies and offices with over 800 people, and buildings with fire protection height of over 54 meters, the railway and underground stations.

The requirements in the project for the different categories are as follows.

Category A: 1. The entrepreneur begins to build; 2. When the work is finished, he collects the documentation to certify that the work is in accordance with the requirements of the Fire Brigade; 3. He sends the documentation online to the SUAP (Municipal Office that controls production activities) with the documentation that certifies compliance with the request of the Fire Brigade.

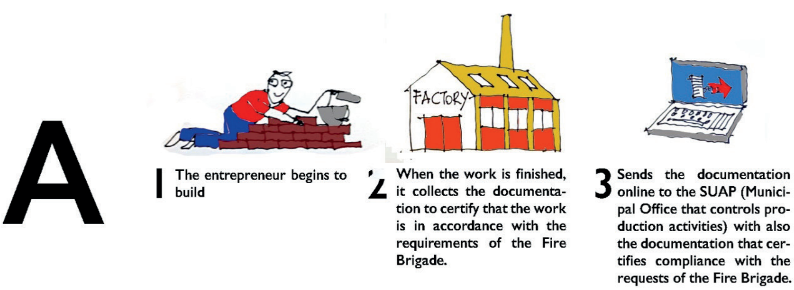

Figure 4. *Category A Requirements*

Category B: 1. Before starting the work, the contractor asks the Fire Brigade for an examination of the project. The Fire Brigade will issue their opinion within 60 days of sending the project. 2. When the work is finished, he collects the documentation to certify that the work is in accordance with the requirements of the Fire Brigade; 3. He sends the documentation online to the SUAP (Municipal Office that controls production activities) with the documentation certifying compliance with the Fire Brigade's request.

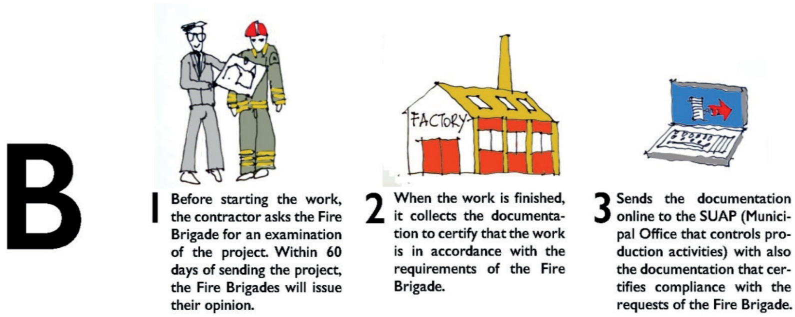

Figure 5. *Category B Requirements*

Category C: 1. Before starting the work, the contractor asks the Fire Brigade for an examination of a more detailed project with a specific solution against fire. The Fire Brigade will issue their opinion within 60 days of sending the project. 2. When the work is finished, he collects the documentation to certify that the work is in accordance with the requirements of the Fire Brigade; 3. He sends the documentation online to the SUAP (Municipal Office that controls production activities) with the documentation that certifies compliance with the request of the Fire Brigade.

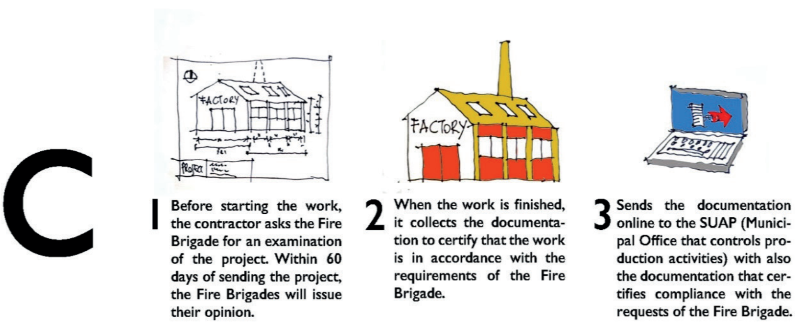

Figure 6. *Category C Requirements*

In the same law, there is a list of activities for what has requested a project with fire prevention, divided into the aforementioned categories:

- Laboratory with metal welding and cutting _C
- Laboratory for painting _B
- Grain mills _B
- Cereal deposits (less than 50 workers) _B

- Factories where coffee substitutes are produced _C
- Sugar factories _C
- Pasta factories _C
- Tobacco factories _C
- Paper production plants _C
- Paper deposits _B
- Wood deposits _B
- Carpenters _B
- Textile factories _C
- Factories for the production of furniture, clothing, leather processing _C
- Plants for the production, processing, and regeneration of rubber _C
- Plants for plastic materials _B
- Deposits of pesticides and/or fertilizers _C
- Factories for the manufacture of cables _C
- Plants for electric lamps _B
- Steel plants (less than 25 workers) _B
- Vehicle repair shops _B
- Plants where bricks are produced (less than 50 workers) _B
- Cement factories (less than 25 workers) _A
- Plants for soap production _B
- IT centers for data processing and/or archiving with over 25 employees (less than 25 workers) _B
- Warehouses with a surface area greater than 600 m2 _B
- Deposits of rolling stock, boats, and aircraft (simple garages are excluded!) (Less than 1000 mq.) _B
- Typographies (less than 50 workers) _A

3. Turkiye

Introduction

Statutory regulations and standards are of great importance regarding industrial fire safety. Not experiencing any fire outbreak is the most critical objective in fire safety. In this part, a summary assessment of the regulation in industrial fire safety in Turkey and European countries will be made. It is essential to be familiar with the regulation, understand its objectives and meet its requirements in providing fire safety. Besides, the failure to fulfill the statutory obligations may result in being held responsible partially or wholly for the life and property losses that may be incurred in the fire outbreaks.

A set of restrictions have been identified and acted on accordingly while preparing this part. The Indfires Project partners have comprised relative authorities, organizations, and sector representatives from Turkey, Denmark, Poland, and Slovenia. For this reason, the participating country's EU framework and fire regulation were taken into account while the industrial fire safety regulation was being searched. Since the dimensions of industrial fire safety are quite a few, there may be provisions related to fire safety at varied levels within the statutory regulations. The basic regulation on industrial fire safety is being discussed in this part in order not to go into more detail.

3.1. Basic Regulation About Industrial Fire Safety

The laws and regulations directly related to industrial fire safety in Turkiye are listed below:

- Law on Occupational Health and Safety numbered 6331
- European Union Harmonization Regulations
- Regulation on Protection of Buildings from Fire
- Regulation on Prevention of Major Industrial Accidents and Minimization of Their Impacts (BEKRA)
- Regulation on Occupational Health and Safety Risk Assessment
- Regulation on Internal Electrical Installations
- Regulation on Protection of Personnel from Hazards of Explosive Atmospheres
- Regulation on Emergencies at Workplaces

The aim, scope, and essential provisions of the regulation have been discussed below.

3.1.1. Occupational Health and Safety Law # 6331

People have caused moral and material losses by working in such a manner that ignores their health to increase their quality of life and cover their needs. An increase has been experienced in the number of workers who underwent occupational accidents and caught occupational illness in conjunction with the deterioration in the working conditions. People had to spend more than the money they earned in their business life to regain their health impaired due to the work they performed since they worked as a result of working for raising their standards of living and the concept "Worker's Health and Workplace's Safety" formed for taking the measures of all these aforesaid adverse events (Akyüz, 1980). The "Occupational Health and Safety" concept, in its traditional sense, is defined as "systematic works performed for keeping the workplaces away from the hazards formed due to the conduct of the work and providing a better working environment by cleaning up from the conditions which can bring damage on the health" (Yağımlı, 2017).

Occupational health and safety (OHS) aim to prevent occupational accidents and diseases and protect the personnel and environment. OHS in businesses seeks to build a healthy and safe environment, to protect the personnel from any hazard and risk, and to remove or minimize these hazards and risks. It is essential to take measures against the occupational accident and occupational diseases that employees will encounter and to maintain the continuance of the work and production without causing harm to the physical and mental health. Once the occupational health and safety studies are evaluated, it is noted that the lifestyle where the occupational safety culture is preferential is the first thing that comes to mind and the most critical factor. The state, employer, and employees are actively involved in creating a healthy and safe working environment with all stakeholders (İşsever, 2015).

The Occupational Health and Safety Law numbered 6331 generated within this scope entered into force after being published in the Official Gazette dated 30 Jun 2012 and numbered 28339. This law was prepared based on the European Union directive dated 12 June 1989 and numbered 89/391/EEC. The primary characteristic of the directive numbered 89/391/EEC is that it has been prepared to follow the improvements in the field of OHS. This directive contains a strategy determining the risk control steps by identifying the hazards in the working environments. In this context, it is based on comprehensive risk management for providing occupational health and safety (Kılıç, 2011).

The OHS Law numbered 6331 consists of five main parts and thirty-nine articles. The main parts of the law are identified as "Aim, Scope and Definitions," "Duty, Power and Obligations of Employer and Employees," "Council, Board and Coordination," "Inspection and Administrative Sanctions," and "Miscellaneous and Temporary Provisions." It is stated in the first article of the law that the law aims to "establish the duty, power, responsibility, right and obligations of the employer and employees to provide the occupational health and safety in workplaces and to improve the existing health and safety conditions" (Bilir and Yıldız, 2014).

The Occupational Health and Safety Law numbered 6331 covers all works and workplaces owned by public and private sectors, employers of these workplaces, agents of the employers, and all employees, including apprentices and interns, regardless of their activity subjects. The law also includes those who work being subjected to the law numbered 4857, those who work being subjected to the Maritime Labor Law numbered 854, Press Labor Law numbered 5953, and Code of Obligations, officials and contracted personnel bearing the statute of a public official (Altınel, 2011).

3.1.2. European Union Harmonization Regulations

European Union is a union to which the most developed states are members and bears political and economic qualifications. The essential object of the said union is to provide the best conditions for the occupational health and safety field in the member states. The Treaty of European Union was signed in Rome on 25 March 1957 to found the union mentioned above. The Treaty described above contains many regulations regarding labor law. Laws, directives, decisions, advices, and opinions generated by the European Union Council and European Union Commission and decisions of the European Court of Justice also bear a binding qualification on the member states (Sümer, 2009).

The regulations related to the field of OHS in the EU were issued in the form of directives the member states are obliged to fulfill, rather than the by-laws which may be directly implemented and have a binding obligation on member states (Nicholson, 2002). "The Council Directive numbered 98/391 on Taking Precautions for the Improvement of Health and Safety Precautions of Employees" is the primary regulatory text in the field of OHS. This directive is supported by 19 different directives issued based on it. For this reason, this directive is recognized as a "Framework Directive." In the framework directive, the employers were deemed as being responsible for employees in any aspect, the responsibility of the employer was kept highly broad. Employers are obliged to appoint employees who will conduct the activities of protection and prevention from occupational hazards and possess adequate knowledge and skills. It paved the way for getting service externally to take the related measures and conduct a study regarding Occupational Health and Safety. The workers were entitled to quit the work in the face of grave danger. It was emphasized to make a risk assessment in all fields.

"A New Occupational Health and Safety Strategy within the Scope of Adaptation to Change in Work and Community" (2002-2006) was published in 2002 to increase work quality across Europe. Additionally, the European Commission published “Improvement of Quality and Productivity in the Work: OHS Strategy of the Community for 2007-2012” (EU Communities, 2007). The legal regulations adopted in European Union regarding occupational health and safety are below. These are;

1. Framework Directive (The Council Directive related to Taking Measures Supporting the Improvement of Safety and Health of Employees)

2. The Council Directive related to Planning Working Hours and Conditions for the Protection of Occupational Health and Safety,

3. The Council Directive related to Social Program 2007-2013 (PROGRESS) for Employment and Solidarity,

4. The Code related to the New Community Strategy on Occupational Health and Safety (2002-2006),

5. The Code related to European Occupational Health and Safety Agency (OSHA),

6. The Code related to the European Foundation for the Improvement of Living and Working Conditions (EUROFOUND),

7. The Code related to the Occupational Health and Safety Advisory Committee,

8. The Code related to the European Occupational Diseases Program.

3.1.3. Regulation on the Protection of Buildings from the Fire

The Regulation on the Protection of the Buildings from Fire issued upon the decision of the Council of Ministers dated 27/11/2007 and numbered 2007/12937 establishes the principles of measures to be taken, organization, training, and inspection related to the fires which may break out in any construction, building, plant and business in our country. The regulation contains detailed technical information and a text prepared on this subject matter. The basic grounds of this regulation are the Law on Organization and Duties of the Ministry of Interior, numbered 3152 and Civil Defense Law 7126, and Presidential Decree dated 10/07/2018 and numbered 1. The regulation is being updated if required.

The fire prevention and extinguishing precautions to be taken in any structure, building, plant, and indoor and outdoor businesses located in the country were explained within the scope of the regulation by associating with the design, construction, usage, maintenance, and operation principles and provisions of the related regulation to minimize the hazards which the fire will lead in terms of the safety of the life and property due to heat, smoke, toxic gas, choking gas and panic (Official Gazette Number 26735:2007)

The objectives of fire protection are to prevent fire generation by taking necessary measures to avoid the fire, to slow down in case of a fire outbreak, to prevent its spreading, and most importantly, to provide human life safety. The design, sizing, and special measures can be considered purposeful structural measures (Table 17).

Table 17. *Structural Measures Intended Objectives*

<table>
<tr><th colspan="3">In terms of design</th><th colspan="3">In terms of sizing</th><th colspan="3">Special measures</th></tr>
<tr><td rowspan="2">Settlement in parcel
Intermediate distance
Transport</td><td rowspan="2">Escape routes

Escape doors</td><td rowspan="2">Flame deflection

Purification from Smoke</td><td rowspan="2">Material fire resistance</td><td rowspan="2">Structural element fire resistance</td><td rowspan="2">Safe sizing to fire</td><td rowspan="2">Special elements and section

Special structure</td><td>Normal installation</td><td>Special installation</td></tr>
<tr><td>Heating
Cooling
Ventilation
Electricity
water</td><td>Fire alarm and extinguishing systems</td></tr>
</table>

Source: (Kayacı, 2014)

While every building designed carries fire risk (Abrahams and Stollard, 2003), the “fire safety” concept containing three main functions of prevention, protection and extinguishing have an important place in the architectural design process. Although the process when the current implementation of fire legislation has become applicable in Turkey goes back to the recent past, the qualification of the legislation to cover not only the design and generation processes but also the operation and maintenance processes is a significant step.

If the development of the fire legislation in our country is considered shortly in this context, the activities intended for the fire-extinguishing included within a military organization in the Ottoman period were turned into a local management service by taking the developments in the world into consideration. With the code of municipalities, the fire protection services were left to the management of municipalities. As urbanization increased, this service became one of the essential local services (Söylemez, 2012).

“The Regulation on the Protection of the Buildings Occupied by State from the Fire” entered into force upon the decree of the Council of Ministers in 1966 is the first legal legislation implemented in Turkey in fire protection. While this regulation did not cover the residential buildings and remained limited with the measures to be taken only in the public buildings, it did not cover the social-purpose, publicly available outdoor structures such as cinemas, theaters, hotels, etc. Since it covered such a limited structure group, this constituted the primary deficiency of the regulation in that period.

Once the status of the fire legislation before 1992 is examined, it is seen that arrangements were made in the by-law and regulations rather than the legal arrangements related to the subject matter. In 1995, "The Regulation on the Protection of the Public Buildings from the Fire" entered into force, and the scope of the regulation remained limited to public structures. The foundation of the Regulation on the Protection of the Buildings from the Fire that is currently in effect and force owes to the "Istanbul Metropolitan Municipality's Regulation on Fire Protection," which entered into force in 1992. The first draft of the Regulation emerged with the Project of "Fire Safety and Fire Protection Research," which Istanbul Metropolitan Municipality had Istanbul Technical University (ITU) conducted. After Istanbul Fire Station Directorate shortened the first draft prepared by ITU academic members, it was issued by taking the opinions of the related professional chambers and administrations. The regulation was put into practice only by Istanbul Metropolitan Municipality and was implemented in other cities soon after. While the attempt of Istanbul Metropolitan Municipality was an important point of origin, the failure to cover the whole country and the implementation only by the voluntary municipalities were restrictive. Once the "Regulation on the Protection of the Buildings from the Fire" entered into force in 2002, the Regulation on the Protection of the Public Buildings from the Fire and all fire protection regulations and instructions issued by municipalities were abolished.

Publication of this regulation covering the fire prevention and extinguishing precautions to be taken in any structure, building, plant, and outdoor and indoor businesses all across Turkey and the principles of design, construction, usage, maintenance, and operation required for the minimization of the hazards of the fire intended the safety of life due to heat, smoke, toxic gas, choking gas and panic, covering all structure groups instead of a limited structure group on the contrary to the previous regulations and containing compulsory provisions were crucial steps in terms of the fire legislation (Erbaş, 2018).

To sum up, the fire sanctions were first implemented with the Regulation on the Protection of the Buildings from Fire in 2002, and some amendments were made to improve the legislation in 2007, 2009, and 2015. The regulation attained its final form, which is currently in effect and force in 2017. The regulation consists of a total of twelve parts. It contains detailed provisions about the fire safety precautions to be complied in any building, including historical buildings (Ulus,2019)

Article 6 of the regulation individually lists the persons responsible and authorized for implementing the regulation provisions in detail. Following this article, owners of industrial businesses, owners of the structures, employees or their representatives, architect, consultant, and advisor who are responsible and authorized in building design and implementation, those who are responsible for the project control, building inspection, and operation are responsible in this regard. The person and authorities listed herein shall be liable by the fault grade due to damages that occurred in case of failure to comply with the provisions of the regulation.

The building's fire detection and extinguishing projects should be prepared apart from the installation projects. The evacuation projects of the floors whose one-floor area is more than 2000 m2 are prepared apart from the architectural projects.

Article 7 of the regulation contains provisions related to the additional fire safety precautions in the industrial plants to be constructed in or adjacent to the forest lands and the evacuation projects required to be made available in the industrial businesses. The points concerning the industrial plants herein may be listed as follows;

"*General responsibilities and prohibitions,*

Article 7-

(4) *(Amendment: Law dated and numbered 10/8/2009-2009/15316) The fire evacuation projects of the building are made available at the entrance of the building and in a place where the fire brigade can easily access during the fire in the* ***factory, workshop, warehouse****..., whose total indoor area of use is larger than 1000m2. In these projects, the location of the building's escape routes, fire escape stairs, firefighter lift, if any, fire cabinets, fire brigade water outlets, fire pumps, and generators are marked.*

(12) *(Additional: Article RG-20/11/2021-31665-CK-4825/3) The* ***additional precautions set out herein*** *are taken in refineries to be constructed within or adjacent to forest lands, ...,..., industrial plants like plants whose total indoor area of use is larger than 2000m2 and storage plants/areas of these.*"

The usage classes of the buildings are shown in article 8 of the regulation as follows;

"*a) Dwellings,*

b) Accommodation-intended buildings,

c) Corporate buildings,

ç) Office buildings,

d) Commercial-intended buildings,

e) Industrial structures,

f) Assembly-intended buildings,

g) Storage intended plants,

ğ) Extra hazard areas,

h) Multiuse intended buildings."

The industrial structures are described in article 14 of the regulation in the following way; ***"Industrial structures*** *are the plants in which any kind of product is produced and buildings and structures about the processes such as processing, assembly, mixing, cleaning, washing, packaging, storage, distribution, and repair. Any plants, sawmills, laundry plants, textile production plants, power plants, food processing plants, filling and discharging facilities, dry cleaning facilities, mine processing plants, refineries, and similar plants are covered by this class."* The storage facilities and plants defined under the high hazard class in this classification may have similar functions as the industrial businesses due to the activity they carry out or the quality of the stored materials.

Article 19 of the regulation shows the hazard classification of the buildings. The hazard classification determined depending on the characteristics of the building, and the quality of the process and activities carried out in the building is as follows;

"Light hazard areas: *These are the areas where materials with low fire load and combustibility are stored, and areas that are fire-resistant for at least 30 minutes and whose single compartment area is greater than 126 m^2'.*

Ordinary hazard areas: *Areas where materials with moderate fire load and combustibility are stored.*

Extra hazard areas: *Areas where materials with high fire load and combustibility and leading to the quick spreading and growth of the fire are stored. "*

If the materials having different hazard classes are made available in various parts of any building, the water and pump quality is determined by the extra hazard classification of the building.

The hazard classification of the buildings is given in tables in the annex of the regulation numbered 1. The ordinary and extra hazard areas of usage are assessed over four different grades and shown in tables. The industrial plants should examine these tables by considering their activities and determining the hazard classification that is convenient for them. Because the obligations established in different aspects of the regulation bear difference by the hazard classifications.

There are provisions related to general fire safety in all buildings in the second part of the regulation. These provisions contain regulatory requirements related to the settlement of buildings, conveyor system durability, fire compartments, walls, furniture, facades, ceiling, and construction materials to be used in the buildings in terms of fire safety. Thus, the existing production or office buildings should have been constructed in the industrial businesses in accordance with these provisions. Different companies may bear more obligations due to their activities and hazard classifications.

It is envisaged in article 21 of the regulation to leave green belts between isolated zones by their functions while even making zoning planning in regard to the settlement of buildings. Accordingly, *"it is compulsory to allocate green belts in such manner which will enable the fire pools and water supply points to be constructed between the functional zones like dwelling, trade, industry and organized industry while preparing zoning plans."* Sub-clause 5 in the same article contains additional fire safety precautions related to the industrial plants that are adjacent or close to forest lands referred to in article 7, sub-clause 12 of the regulation. These precautions vary by nature of the vegetation cover, distance, and land grade.

The third part of the regulation contains arrangements related to the special conditions to be encountered, escape routes and escape stairs in the buildings. The sections of Annex 5/A, Annex 5/B, Annex 3/B, and Annex 3/C should be considered jointly. The "User Load Coefficient Table" given in Annex 5/A is used to calculate the buildings' output capacity and escape distances. "The Longest Escape Distances and Unit Widths Going to Exits" in the buildings are given in Annex-5/B. Industrial businesses must rely on the values shown in the 2nd line of this table.

"Fire Endurance Periods of Building Elements" are given in Annex-3/B in tables, and "Fire Endurance Periods by Building Usage Classes" are shown in Annex-3/C. Industrial businesses should rely on the values given in the related column of Annex 3/C.

The essential provisions related to the emergency exits in the buildings are given below (Article 39);

- Unless otherwise specified, at least two exits should be established, and exits should be protected in all buildings.

- The number of exits may not be less than the number determined based on article 33.

- Unless otherwise specified, it is mandatory to make at least two exits available in extra-hazard areas with more than 25 people and every area with more than 50 people. If the number exceeds 500 people, there must be at least three exits; if it exceeds 1000 people, there must be at least four exits.

Article 52 of the regulation contains a specific arrangement related to escape stairs and exits in industrial plants. Accordingly, making at least two independent escape stairs or other exits in the "factory, workshop, store, warehouse…" is required. However, in case of the existence of the following conditions together, a single escape stair is accepted as adequate;

a. The building height is less than 21.50 m,

b. The number of users on any floor is less than 50 people,

c. The maximum escape distance on all floors complies with the distances set out in Annex-5/B,

d. Non-combustible products are used in the construction,

e. No easily flammable and flammable substance is used in manufacturing and storage.

In the 4th part of the regulation, some arrangements related to the building sections bearing risk regarding fire safety were made. The boiler rooms and fuel tanks are considered by considering the fuels, and the precautions must be explained in detail. Articles 64-66 contain the principles related to installing lightning protection, transformer rooms, and generators in this part. The industrial plants must also implement these provisions completely, like all buildings.

In the 5th part of the regulation, the electrical installation and systems in the buildings are discussed. Within this framework, the regulatory provisions related to the internal installation, emergency lighting and routing, fire detection and alarm systems, and periodical testing, maintenance, and inspection of these systems are regulated under this heading.

It is specified in article 72 of the Regulation what emergency lighting means and in which buildings it is compulsory. Accordingly, *"**Emergency lighting system** is designed in such manner which will be activated automatically and provide adequate illumination in cases where public network or similar external power supply is cut off, the building or structure's electrical power is interrupted for the safety due to reasons such as fire, earthquake and normal illumination is cut off due to opening of any circuit breaker or fuse.*

It is compulsory to make emergency lighting available in all escape routes, areas used for assembly, elevators, and escalators, ***workshops, and laboratories involving chemicals and movable machinery posing a high risk****, electricity distribution and generator rooms, central battery unit rooms, pump stations, indoor parking, areas where first aid and safety equipment are present, divisions where fire alarm buttons and fire cabinets are present and similar divisions and the following buildings:*

a. *Hospitals and senior centers and training-purpose buildings,*

b. ***All buildings whose user load is more than 200,***

c. *Buildings where there are 50 users and above below the ground level,*

d. ***Buildings without windows,***

e. *Hotel, motel, and dormitories,*

f. ***Extra hazard areas,***

g. *High-rise buildings."*

Article 75 of the regulation is about fire detection and alarm system. In accordance with the relative article, 'fire alarm buttons' are mandatory in the below-mentioned buildings:

a. *In all buildings in the range of two-story and four-story* ***whose floor area is larger than 400 m2, excluding dwellings,***

b. ***In all buildings whose floor number is more than four, excluding dwellings,***

c. *In all high-rise buildings, including dwellings.*

If the building height exceeds 21,50 m in buildings used for industrial purposes or the total indoor area is more than 7500 m^2, it is compulsory to install automatic fire detectors in these buildings."

Under article 81, *"Audio and light alarm systems are also obligatory in the buildings where fire alarm button is obligatory. The audio and light alarm devices warn those who live in all used parts of any building from fire or similar emergencies."*

Pre-alarm systems may be prescribed for a period as short as the accuracy of the alarm signal will be examined. Still, the fire intervention will not be delayed between receiving the fire alarm signal and activating evacuation alarm systems in the buildings. However, fire detection has to activate evacuation alarm systems in industrial **and storage-purpose buildings where hazardous substances are kept or processed**. The prealarm system is not permitted in such buildings and structures.

It is obligatory to install automatic audio messages live audio messages and announce systems announced during any fire again **in the buildings bearing some features in terms of use and industrial plants**.

In accordance with article 83, the fire detection and alarm systems and the cables related to emergency communication that are required to be active during any fire must be fire-resistant for a minimum of 60 minutes.

It is compulsory to install a mechanical smoke extraction system in the basement floor warehouses whose total areas exceed 2000 m^2 (Article 88).

If the stairwell height is higher than 30.50 m, it is required to pressurize the escape stairs in all buildings, excluding dwellings, in accordance with the provisions of the regulation. The basement floor's escape stairs are pressurized in the buildings whose basement floor number is more than 4. It is obligatory to pressurize the escape stairs of the dwellings whose structure height is higher than 51.50 m.

It is required to pressurize the emergency lift shafts in order not to leave them under the fire effect in case of fire. Article 89 contains provisions related to the pressurization system in the buildings.

It is compulsory to install an automatic sprinkler system in the following areas in accordance with article 96 of the regulation:

a) *"In all buildings whose height is higher than 30.50 m, excluding dwellings,*

b) *(Amended: Law dated and numbered 10/8/2009-2009/15316) In dwellings whose building height exceeds 51.50 m,*

c) *(Amended: Law dated and numbered 10/8/2009-2009/15316) In indoor parking, whose total area is more than 600 m2, and indoor parking, where more than ten vehicles are received by lift,*

d) *In all hotels, dormitories, pensions, and guest houses in which the room number exceeds 100 or the bed number exceeds 200 in a building with more than one floor and in all facilities with a bed whose building height is higher than 21.50 m,*

e) *(Amended: Law numbered and dated 10/8/2009-2009/15316) in multi-story stores, shopping malls, trade and entertainment centers whose total area is more than 2000 m2,*

f) *In buildings whose total area is more than 1000 m2 and where easy-flammable and flammable substances are produced or kept."*

Part 8 of the regulation contains the arrangements related to the storage, filling, using, producing, and putting the hazardous substances on the market. The general rules required to be obeyed in places where hazardous substances are stored and produced are set out in article 103. The articles addressing the industrial plants in these rules are as follows;

"* *The walls of single-story buildings where flammable and explosive substances are produced, processed, or stored must be fireproof or fire-resistant for 120 minutes. In multi-story buildings, the production, processing, or storing of these substances is permitted to the extent prescribed in the related by-law and regulations, provided that it is performed on the top floor of the buildings. Environmental safety depends on the quantities and hazard class of the hazardous substance in the buildings where a hazardous substance is kept for any purpose.*

* *It is obligatory to construct the bases of the buildings in such a manner which transmits the static electricity and to earth the doors against static electricity by the characteristics of the production and hazardous substance.*

* *It is required to construct the entrance and exit doors, windows, shutters, and ventilation channels to open outwards under pressure so those in the building can easily escape or be evacuated in case of hazard.*

* *No rail or cage will be constructed on the windows of the building. In workplace buildings having multiple divisions, each of the divisions must have at least two doors, one of which will be directly opened outwards, and the other will be opened to a corridor. The internal divisions must have been made of materials resistant to the highest pressure, crack-free flat, non-combustible, painted or whitewashed in light color, and easily washable. The bases constructed with a gentle slope are attached to a warehouse or settling well along with a drainage system. The wastewater treatment plants resistant to hazardous substances may also be used for this purpose.*

* *It is required to construct the ceilings and bases of the buildings of noncombustible, impermeable, non-sparkling with impact and easily-cleaning material in a gentle slope and to construct the windows in large pieces of the wired glass or tempered glass which will not scatter and give damage on the environment."*

Article 105 contains the principles and safety precautions related to "Flammable and Explosive Gases" under the heading of hazardous substances, and articles 106-111 include principles related to bottled and casting storage, stores, usage, and refueling stations of LPG. The safe usage principles of natural gas are given in article 112 in detail.

There are provisions related to the definition of flammable and combustible liquids, restrictions related to storage and limit values, notification and permission obligation if they are stored above specific amounts, forms of storage, description of hazard zones and restrictions, storage in the warehouse building, over outdoor ground storage, storage tanks, and general fire protection procedures as from the article 113 of the regulation. The following table shows the limits related to the storage of combustible and flammable liquids in the factory and workshop buildings and is attached to the annex of the regulation (Annex-12/B).

Table 18. *Storage of combustible and flammable liquids in the processing factory and workshops buildings*

Maximum Storage Area (m2)	Allowable Amount (L/m2)	Fire-resistance (minute)	Fire Protection
15	*70*	*60*	*NO*
15	*175*	*60*	*YES*
50	*140*	*120*	*NO*
50	*350*	*120*	*YES*

Source: (Öner, 2009).

The combustible and flammable liquids should be kept in an area isolated from the processes carried out in the processing factory and workshops. Class IA and Class IB liquid total amounts should not exceed the values set out in the Regulation (Öner, 2009).

A hazard zone is described by taking the sparkling/explosion risk into account in article 116. Accordingly, the hazard zones and limitations in these zones are given below.

“The hazard zones are split into three:

a) Zone 0: Zones like pipes and vessels where the explosive gas-air mixture is available continuously or for a long time.

b) Zone 1: Zones like nearby filling pipes and armatures where the possibility of explosive gas-air mixture formation is available during regular working hours.

c) Zone 2: Zones like the immediate vicinity of tanks where there is no possibility of explosive gas-air mixture formation during regular working hours; however, in case of formation of this mixture, it is available for only a short term.

The limitations in the hazard zones are as follows:

a) “In Zone 0, it is allowed to use only in this zone due to the expected extra operating hazard. It is compulsory to use the devices certified by the Turkish Standards Institute or have a certificate of conformity if any.

b) In Zone 1, only explosive and sparkling-proof devices and systems are used. The entrance of transportation vehicles into this zone is only allowed provided that the measures preventing the formation of explosive mixtures are taken.

c) In Zone 2, the devices and systems which do not form sparkles and do not reach 4/5 temperature of the vapor-air mixture ignition temperature can be used. The compressed, liquefied gas or gasses dissolved under pressure can be stored in enclosed volumes that are fire-resistant for at least 120 minutes, excluding incombustible gases and non-unhealthy gases and extinguishers in this zone.”

The Regulation on Protection of Buildings is a highly detailed and technical regulation prepared in the field of fire safety. The owners of the building are liable to fulfill requirements by taking the factors about fire safety into accounts, such as the use of the building, area of activity, building structure, fire load, number and qualification of human being present in the building, and the existence of the hazardous substances.

3.1.4. Regulation on Prevention of Major Industrial Accidents and Minimization of Their Effects (BEKRA)

The production, storage, usage, and sales of chemicals having an effective function in modern society contain certain risks, like the occurrence of major industrial accidents. Major industrial accidents are incidents causing substantial damage to human life and the natural environment and leading to disorders in economic and social life. Industrial accidents have three important stakeholders; governments, businesses, and communities (Shirivastava, 1987; OECD, 2003). The common feature which brings the three stakeholders together arises from the fact that drawing the lines of the domain of chemical-based accidents precisely is not possible due to the feature of the toxic oscillation, which can spread broadly through the wind. The chemical-based accident in Seveso, Italy, in 1976 demonstrated the obligation of countries to move compulsorily in a synchronous manner. In this regard, preventing chemical accidents played a vital role in establishing the psychological infrastructure in preparation and intervention.

European Union published Seveso Directive with a unique approach to preventing and controlling the major industrial accidents involving hazardous substances following the Seveso accident. This directive is the precursor of the collective movement in terms of the prevention of major industrial accidents. Afterward, the Seveso directive was updated due to the impacts of incidents like Seveso in Bhopal, India, in 1984 and Baia Mare, Romania, in 2000 on a massive scale, Seveso II and Seveso III Directives entered into force through the studies carried out.

The main objective of the Seveso Directive is to prevent chemical accidents or to get through these accidents at minimum damage in terms of society (Seveso Directive, 1996);

a. Prevention of major industrial accidents,

b. Minimization of risks,

c. Limitation of accident impacts.

Seveso Directive imposed some obligations in terms of the prevention of major industrial accidents. States and businesses are the main operators of this approach. The public is responsible for establishing the necessary legal regulations, imposing administrative sanctions and penalties, enabling the required precautions, and controlling and inspecting. It has a primary role in terms of public safety and health. The businesses are responsible for taking necessary precautions, issuing necessary notifications and notifying the resulting changes, making risk analyses, giving training, and preparing reports by implementing the rules imposed by the state.

Under the Directive, the procedures, principles, and methods related to the measures the businesses having hazardous substances have to take to provide high-level, effective, and uninterrupted protection to prevent major industrial accidents and minimize their damages were established (Salvi et al., 2008). The businesses are ranked as out of scope (non-hazardous), low level and high-level businesses within the scope of Seveso. The businesses keeping chemicals at an amount that is equal to the limits previously determined or above these limits have to prepare a “major accident prevention policy,” “safety report,” and “emergency plan,” depending on the grade of the Corporation, to prevent probable major industrial accidents and minimize their impacts and provide long-term protection. Whereas the “low-level businesses” are liable to prepare only “major accident prevention policy” by the limit values. “High-level businesses” are additionally responsible for preparing “safety reports” and “emergency plans” and executing these reports/plans (Quensy University, 2009; Regulation on Prevention of Major Industrial Accidents).

Certificate of Major Accident Prevention Policy (Low and High-Level Businesses): It contains a safety management system, identification, and assessment of major accidents, organization, and personnel, planning for emergencies, operating control, change management, performance monitoring, inspection, and examination.

Preparation of Safety Report (High-Level Businesses): It contains a major accident prevention policy, a general description of the Corporation, a community of the Corporation, the organization, general protective services, an explanation of predictable hazards, and clarification of internal emergency plans.

Internal and External Emergency Plans (High-Level Businesses): These contain the identification and implementation of necessary measures, transmitting the required information to related authorities on time, those who are responsible for providing the restoration and cleaning after an important accident, resources, safety equipment, and duties and cooperation procedures (Seveso Directive, 1996; Regulation on Prevention of Major Industrial Accidents).

Turkey first put Seveso II Directive into practice in compliance with the EU harmonization process by publishing in the Official Gazette dated 30 December 2013 and numbered 2886 with "Regulation on Prevention of Major Industrial Accidents and Minimization of Their Impacts." Later, the same regulation was updated in compliance with the Seveso III directive by publishing in the Official Gazette dated 2 March 2019, numbered 30702. This regulation is still in effect and in force. The regulation mentioned above is known as the Legislation on Minimization of Major Industrial Accident Risks (BEKRA) in Turkey. BEKRA Legislation imposes different responsibilities on business administrators, public authorities, and local administrations. Its objective is to set out the procedure and principles related to the measures to be taken for providing effective and continuous protection at a high level to prevent major industrial accidents in businesses keeping hazardous substances, and minimizing the damages of probable accidents on people and the environment (Article 1). The Competent Authorities responsible for the implementation of BEKRA legislation are given below;

- At the central level: The Ministry of Environment and Urbanization (ÇSB), Ministry of Labor and Social Security (ÇSGB), Disaster and Emergency Management Presidency (AFAD).
- At the local level: Governorates, Municipalities, Provincial Directorates of the Ministry of Environment and Urbanization, and Disaster and Emergency Management Presidency.

The Ministry of Environment and Urbanization set up BEKRA Notification System to fulfill BEKRA legislation's obligations. BEKRA Notification System included in the body of Environmental Information System is a system in which the businesses retaining the hazardous substances listed in the annex of "Regulation on Prevention of Major Industrial Accidents, and Minimization of Their Impacts" notify the Ministry the substances they retain and the maximum substance quantity which it can store. This declaration to be issued by the businesses by the regulation is called as BEKRA Notification.

The Business Administrators are liable to enter the necessary data into the system in the following cases, excluding the exceptions in Article 3 of BEKRA legislation. Only in the following cases the business administrators shall notify the Competent Authorities:

- Existence of the hazardous chemicals set out in Annex 1 of the Regulation in the business (including those which are available as raw material, byproduct, residual and/or intermediate product or those which may be formed during control loss of any industrial chemical process)

- If the quantities of these substances exceed the lower and/or upper threshold values set out in Annex I, Part I, and Part II of the Regulation.

The notification procedure consists of two phases; Businesses sign up in the 'Environmental Information System' and issue a notification to BEKRA Notification System.

The quantities of the hazardous substance determining the scope of the businesses are explicitly given in two lists titled "Named Substances" and "Unnamed (General Substance and Patent Medicine Categories) Substances." These lists identify the lower and upper limit values for hazardous substances. After the business administrators notify the BEKRA Notification System of the dangerous substances, the system automatically determines the scope of the business. The scope and level of the notifying enterprises are classified as follows;

- High-Level Business,
- Low-Level Business,
- Out of Scope.

All business administrators included in the scope of BEKRA are liable to;

- Prevent major accidents and

- Take all necessary measures to limit the impacts in such a manner that will give minimum damage to the environment and people in case of any major accident.

BEKRA Legislation imposed certain obligations for Low and High-Level Businesses to attain this objective. As a result of this notification, the businesses classified as Low Level and High Level should fulfill the below-listed obligations:

The following items are the common obligations for all Low and High-Level Businesses:

- Notification
- Risk Assessment
- Major Accident Prevention Policy
- Domino Effect: Information Exchange
- Responsibilities in case of Major Accident: Action, Communication, and Reporting

The following items are the obligations for High-Level Businesses:

- Safety Report
- Safety Management System
- Internal Emergency Plan: Preparation, Review, and Updating
- Information Exchange for External Emergency Plan
- Public Information

It is controlled in the inspections whether the business is included in the scope of the regulation or not. The inspections of the businesses included in the scope of the regulation are performed by the Ministry of Environment and Urbanization and/or Ministry of Family, Labor, and Social Services as scheduled and nonscheduled inspections (Article 18/1). The inspection plan/program is prepared in such a way it will be performed at least once for high-level businesses within two calendar years and at least once for low-level firms within four calendar years by considering all low and high-level businesses (Article 18/2). Unscheduled inspections are performed in case of a major accident and in cases where an investigation is deemed necessary (Article 18/3);

- It is engaged in investigations aiming to determine the reasons for the accident and precautions to be taken to prevent similar future accidents by analyzing the accident.
- It is asked from the business administrator to take necessary precautions to prevent similar accidents.

3.1.5. Regulation on Occupational Health and Safety Risk Assessment

Under article 4 of the Occupational Health and Safety law numbered 6331, the risk assessment expresses the work required to be performed to identify the existing or external hazards, grading of factors leading to the conversion of these hazards into risks arising from the hazards by analyzing and comparing the control precautions. Also, according to article 10 of the Occupational Health and Safety Law, 6331, employers must make or get risk assessments regarding occupational health and safety. Accordingly, the procedure and principles of the risk assessment to be performed in the workplaces in terms of occupational health and safety are set out in the Regulation on Occupational Health and Safety Risk Assessment which entered into force on 30.12.2012 after being published on Official Gazette dated 29.12.2012 and numbered 28512. The provisions of this regulation are enforced by the Ministry of Labor and Social Security (Regulation on Occupational Health and Safety Risk Assessment, 2012; Sarı, 2020).

It is noted in this regulation that any team created by the employer shall perform the risk assessment. This risk assessment team shall consist of the employer or employer's agent, occupational safety specialists, and workplace physicians providing the health and safety service in the workplace, employee representatives in the workplace, supporting personnel in the workplace, and employees who are selected in such manner which will represent all departments in the workplace and are familiar with the works carried out in the workplace and the existing or probable hazard sources and risks. It is provided to include the employees in the process at any phase needed and to take their opinion while carrying out the risk assessment.

Adopting the Risk Assessment and Risk Management approach is among the employer's duties in developing the occupational safety culture (Pala, 2005). The risk assessment is performed starting from the design or establishment phases for all workplaces by pursuing the following phases; definition of hazards, identification, and analysis of risks, deciding on risk control measures, documentation, updating of works performed, and renewal works if needed.

Table 19: *Phases of Risk Assessment*

Hazard Description	Determination and Analysis of Risks	Risk Control Steps	Documentation

Source: (Pala, 2005).

According to COSO (Committee of Sponsoring Organizations of the Treadway Commission), we can define corporate risk management as a dynamic and disciplined system that enables businesses to recognize the risks preventing them from attaining their objectives and the opportunities which will facilitate achieving the objective in advance and to manage the conditions (COSO, 2004).

Workplace employees, representatives, and employees coming from other workplaces for working and employers of these are informed of the health and safety risks that may be encountered in the workplace and corrective and preventive precautions.

By the hazard class, the risk assessment is renewed every two, four, and six years in extremely dangerous, dangerous, and low dangerous workplaces. The risk assessment is wholly or partially renewed by considering the following conditions; moving of workplace or making changes in buildings, changes in the technology applied, substance and equipment used in the workplace, changes in the production method, the incidence of an occupational accident, occupational disease or near miss incidents, the existence of a legislation amendment pertaining to the limit values of the working environment, being deemed necessary by the working environment measurement and health surveillance results, the emergence of a new hazard arising externally and affecting the workplace and new risks.

3.1.6. Electrical Internal Installation Regulation

Electrical Internal Installation Regulation was first published as 'Electrical Internal Installation Guide and Technical Specification' on December 29, 1954. There was no significant update until 1996. It underwent an administrative change to harmonize the Law on Construction Inspection in 2004.

The regulation also contains technical arrangements along with administrative arrangements. The regulation consists of 9 parts and 72 articles. It was prepared to be compatible with other regulations such as Regulation on Electrical Internal Installation Project Preparation, Regulation on Health and Safety Conditions in the Use of Work Equipment, Regulation on Energy Performance in Buildings, and Regulation on Health and Safety Measures to be Taken in Workplace Building and Annexes.

The regulation covers the provisions about the establishment and operation of internal electrical installations; however, plants related to the generation and distribution of electrical power within the building are not included in the regulation (Article 1). The plants deemed as internal electrical installations are discussed under three headings within the scope of the regulation.

1. **Continuous electrical installations:** All low-voltage installations installed for being used continuously within, adjacent to buildings or clusters, or in addition to these buildings, excluding elevator installations. Buildings' internal illumination, power, low-voltage compensation installations, calling, alarm, seeking, lightning rod, battery, rectifier (redresser), loudspeaker, antenna, phone and television installations, garden illumination installations of these buildings and sections of the installations described above installed outdoor are deemed as continuous installation.

2. **Independent low-voltage electrical installations not containing energy transmission lines confined within the land of the individual who constructed the installation:** (A motor pump installation and similar installations to be allocated for covering only its requirements of any house, vineyard, or garden) are considered within the scope of internal installation.

3. **Temporary electrical installations:** Transient electrical installations are low-voltage installations installed transiently for use until the continuous installation in and out of the structures connected to the plants described in the above clauses (a) and (b) and not used continuously. Facilities like a funfair, fair, and construction sites are transient installations.

The frequently referred to, and outstanding matters within the scope of the regulation may be expressed as the determination of the size and locations of the counter and fuses, protection earth, connectors, insulated conductors and cables, and lying of the conductors and cables.

During the determination of the size and locations of the counter and fuses; molded case circuit breaker or automatic fuse (individually or jointly) should be placed into the building's junction box (main junction box or terminal box) along with fire protection and the counter column circuits along with life protection threshold, excluding very simple agricultural buildings, huts, simple country houses, and selectivity should be provided among all protection assemblies (article 18).

Protection earth aims to prevent the high contact voltage which can occur in the conductive installation sections not being under the voltage from staying live to protect people and animals against dangerous contact and step voltages. It is envisaged that the protection earth will be applied by connecting the installation mentioned above to the earthing rods or earthed sections (Article 35).

The plug and sockets on the connected devices have to conform with Turkish Standards, and there must be a protector contact in the earthing contact of these. At least two sockets must be installed for sitting rooms (with an area larger than 20m2), a kitchen in residences, and at least one socket for the rooms and bathroom. Three different lines must be installed for the washing machine, dishwasher, and self-contained lines, excluding the huts and simple country houses. A minimum of 1.5 mm of sectioned copper conductors must be used for the illumination outlets and a minimum of 2.5 mm of sectioned copper conductors for the illumination lines. A minimum of 2.5 mm of sectioned insulated copper conductors should be used for socket outlets and cords. The number of outlets to be connected to any lighting line is determined depending on the load (power) of the line and voltage drop. The requirement shall determine the number of outlets connected to any socket line; minimum 300W for sockets whose socket power is single-phase (excluding the socket power feed by self-contained line in residences), minimum 600W for sockets whose socket power is three-phase (Article 52).

The following color codes are expected for the conductors to be used in the internal electrical installations (Article 57):

- For the protective conductors: Green- Yellow
- For medium and neutral conductors: Light blue
- For phase conductors: Different colors for each phase in compliance with the current cable standards.
- Once the rule of laying conductors and cables is considered, the conductors shall only be connected with screwed clips, non-screwed clips, soldering, or welding on insulating components or in an insulating case. Reaching the releasing connection points (such as clip connectors) is required. The points connected by casting are regarded within the scope of non-releasing connections. The connection of conductors (Article 58);
- Only within boxed in the pipe installations,
- Only within boxed or extra boxes (flanges) in the installations made of multi-core insulated conductors or cables.

3.1.7. Regulation on Protection of Employees from Hazards of Explosive Atmospheres

The objective of the regulation is to establish the procedure and principles about the measures to be taken for protecting the employees from the hazards of the explosive atmospheres in the workplaces regarding health and safety. The regulation is implemented in the workplaces included in the scope of Occupational Health, and Safety Law numbered 6331 and where it is likely to form an explosive atmosphere (Article 1-2).

However, places allocated for applying medical therapy on patients and application of medical therapy, using of devices included in the scope of Regulation on Gas Burning Devices (2009/142/AT), production, processing, usage, storage, and transportation of explosive substances and substances in a chemically unstable state, mining works by drilling method and underground and overground mining works, use of the highway, airway and seaway vehicles on which the related provisions of the international agreements are applied, excluding all and any vehicle used in locations where it is likely to form an explosive atmosphere, are excluded from the scope of this regulation (Article 2).

Following article 10 of the regulation, the employer must prepare an explosion protection document. It is possible to summarize the responsibilities at this point in the following way:

- Prevention of the formation of explosive atmosphere,
- Prevention of the ignition of explosive atmosphere if it is not possible to prevent the formation of the explosive atmosphere by the nature of the processes,
- The obligation to take measures that will reduce the hazardous impacts of the explosion will provide the health and safety of employees.

The explosion protection document is prepared before starting an activity in the workplace. It is revised by reviewing cases where expansion, repair, or substantial change is made in the work organization or workplace. The explosion protection document is a document prepared to inform about the measures required to be taken for protecting the employees from the hazards of explosive atmosphere to occur in the workplaces in terms of health and safety by detecting the probable explosive atmospheres in the workplaces through certain approaches. While assessing the explosive risks; the possibility of explosive atmosphere formation and permanence of this atmosphere are evaluated as a whole by taking the possibilities of existence and activation of the igniting sources, including static electricity, installation retained, substances used, processes, and probable mutual interactions of these in the workplaces, size of the possible explosion impact and locations that are open to the places where explosive atmospheres may form or locations that can be opened. Mathematical calculations are made while making such assessments, and according to these calculations, the "Zone" identification is made. Emergency exit paths, medicine chests, emergency stop buttons, fire extinguisher tubes and hydrants, emergency assembly centers, work equipment, etc., including the zones identified in the workplace sketch, are shown by creating a sketch (Yavuzlar OSGB, 2021). The explosion protection document should be prepared in workplaces with a full combustion risk in case of contact with any igniting source and circumstances created by gas, vapor, mist, and powders of the combustibles under atmospheric conditions.

Once we examine the classification of the spaces where it is likely to create an explosive atmosphere, the areas where it is expected to create an explosive atmosphere are defined as follows (Regulation, Annex-1):

- Spaces where explosive mixture may be formed at such amounts which will require special measures to be taken to protect the health and safety of employees (areas regarded as hazardous per the regulation),

- Spaces which is not likely to form an explosive mixture at such amounts which will require special measures to be taken to protect the health and safety of employees (areas regarded as non-hazardous per the regulation),

- Unless it is proved by research to be carried out that the mixtures which flammable and/or combustible substances make with the air will not generate an explosion independently, these substances shall be regarded as substances that can create an explosive atmosphere.

The hazardous spaces are classified into zones based on the formation frequency of the explosive atmosphere and the duration of such an atmosphere. This classification identifies the measures to be taken. Accordingly;

- **Zone 0** is defined as areas where an explosive atmosphere consisting of a mixture of inflammable substances in gas, vapor, and fog state with the air, originates continuously or for a long time or frequently.

- **Zone 1** is defined as areas where an explosive atmosphere consists of a mixture of inflammable substances in gas, vapor, and fog, with the air sometimes originating under normal working conditions.

- **Zone 2:** It is defined as areas where the mixture of the inflammable substances in gas, vapor, and fog state with the air is not likely to form an explosive atmosphere under normal working conditions or if it is expected to develop such an atmosphere, the explosive atmosphere is permanent for a short period.

- **Zone 20** is defined as areas where the combustible powders in the form of clouds in the air can form an explosive atmosphere continuously, for a long time, or frequently.

- **Zone 21** is defined as areas where the combustible powders in the form of clouds in the air can sometimes form an explosive atmosphere under normal working conditions.

- **Zone 22** is defined as areas where the combustible powders in the form of clouds in the air are not likely to form an explosive atmosphere under normal working conditions; however, even if such an opportunity exists, this is effective for only a short time.

The requirements of this regulation regarding the fulfillment of the minimum requirements for protecting the employees from the risks of the explosive atmosphere (Regulation, Annex-2) are applied on;

- Areas where there is a risk of explosive atmosphere arising from the nature of workplaces, work equipment, materials used or activity, carried out, and included into hazardous class,

- Equipment that is required for the safe operation of the equipment placed in hazardous areas or that assists the safe operation of this equipment but not available in the hazardous area.

Workplaces in which it is likely to develop an explosive atmosphere have to meet the above-mentioned "minimum requirements" in terms of the work equipment that is made available for use or that is already being used in the areas where it is likely to form an explosive atmosphere. The workplaces with sections expected to form an explosive atmosphere and open before 26.12.2006 have to make their conditions fully compatible with the provisions of this regulation within the last three years from the publication date of this regulation.

3.1.8. Regulation on Emergencies in Workplaces

The Regulation on Emergencies in Workplaces, numbered 28631, covers the workplaces included in the Occupational Health and Safety Law, 6331. The object of the regulation is to regulate the procedures and principles related to the studies required to be carried out in preparation of emergency plans, prevention, protection, evacuation, fire-fighting, first aid, and similar matters in workplaces and safe management of these studies and selection of employees to be assigned in these matters. The obligations of employers and employees in emergencies are set out in this regulation. The responsibilities of the employers and employees in this context are given below:

Obligations of the Employer:

1. To identify the potential emergencies by assessing the emergencies that can affect the employee and working environment in advance by considering the working environment, materials used, work equipment, and environmental conditions.

2. To take preventive and restrictive precautions for the adverse effects of the emergencies.

3. To make necessary measurements and assessments for being protected from the impacts of emergencies.

4. To prepare emergency plans and to enable the drills conducted.

5. To assign an employee who is knowledgeable and trained regarding the prevention, protection, evacuation, fire-fighting, first aid, and similar aspects at the adequate number and to make them available at all times by taking the size and special characteristics of the workplace, nature of the work performed, the number of employees and other people being present at the workplace into account for the intervention into emergencies.

6. To make necessary arrangements to provide contacts with external organizations, particularly in first aid, emergency medical intervention, rescue, and firefighting.

7. To make necessary arrangements related to the deactivation of the power sources and systems which can pose a hazard in emergencies that will not cause unfavorable conditions or affect the protective systems.

8. To provide the sub-employers, if any, temporary business partners and their employees, customers, visitors, and participants at public activities such as meetings, seminars, conferences, and training and other people in the workplace information about emergencies, evacuation plans, escape paths, assembly points and emergency teams.

9. To provide the personal protective equipment and intervention equipment to be used in emergencies to be suitable for the emergencies identified in the workplace and duties of the emergency teams.

Obligations of Employee:

1. To obey the preventive and restrictive precautions taken within the scope of the issues set out in the emergency plan.

2. To inform the closest supervisor, the person who is in charge of the emergency, or the employee's representative immediately once they encounter any emergency which will endanger their health and safety and the health and safety of other people in machinery, device, tool, installation and buildings at the workplace.

3. To follow the instructions of the employer and teams who arrived at the scene from external related organizations to eliminate the emergency.

4. To act in such a manner that does not endanger the life of him/her and colleagues during emergencies.

The regulation also contains provisions related to the preparation of emergency plans, identification of emergencies, preventive and restrictive precautions, emergency intervention and evacuation methods, emergency teams and their duties, renewal of emergency plans, information and training of employees, and emergency plan in major industrial plants.

3.1.9. Regulation on Equipment and Protective Systems Used in Probable Explosive Environments

In accordance with the article Annex 2 of the Regulation, *"all equipment and protective systems should be marked in such way which will include the following minimum details, legibly and will not be deleted"* in the hazardous environment.

In industrial businesses, the equipment and protective systems are marked on plates. The plates should be placed onto the equipment. However, once the site and production conditions are taken into account, it is observed that there are deformations on the labels on the product, and important information cannot be reached. For this reason, it is recommended to prefer writing the marking on a plate using embossing or metal removal techniques.

3.1.10. Regulation on Health and Safety Measures in Working with Chemicals

The risk assessment is defined as a function ranked among the employer's obligations in the Second Part of the Regulation. Following article 6 of this part, *"It is specified that the following points should be considered in the risk assessment to be conducted in working with chemicals:*

…

b) Turkish material safety data sheet to be provided from manufacturer, importer, or sellers."

Problems are experienced with "Safety Data Sheets" as a basis in risk assessment and specified as an obligation in the preceding clause. That is, the safety data sheets that the manufacturers get prepared by receiving consultancy or by their own authorized employees could not meet the conditions set out within the scope of the "Regulation on Safety Data Sheets about Hazardous Substances and Mixtures." There is no mechanism supervising conformity with these conditions. Each manufacturer publishes sheets with different standards and delivers them to the users.

The users cannot satisfactorily use the sheets prepared to various criteria. Publication of the safety data sheets prepared by competent persons after being approved by the Ministry of Environment and Urbanization will make the sheets standard in terms of content.

Per clause 3, article 6 of the same regulation, it has a provision *"Employer gets the additional information required for the risk assessment from a supplier or other sources. This information also contains special risk assessments of the chemicals given in the current legislation for the users."* Manufacturers are required to prepare the risk assessment document setting out the necessary safety measures to be taken in order not to turn the hazards that users related to the chemicals will encounter into threats, deliver these documents to users or provide the users access by publishing this document in the internet page of the company. In case these applications are performed effectively, it will be possible for the users to perform the works to be carried out with chemicals more consciously.

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CHAPTER 3.

COMMON FIRE CAUSES IN INDUSTRIAL SITES

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COMMON FIRE CAUSES IN INDUSTRIAL SITES

Introduction

Many components can cause a fire in the workplace or business. Fire hazards can cause rapid and significant damage to property and cause injury to workers or worse. The most important part of developing a fire safety management system is recognizing and eliminating hazards in the workplace. First of all, to clarify the conceptual framework of our department, it is thought that the concept of combustion and fire hazard should be briefly examined.

Combustion is a chemical process in which energy stored in the combustible material is released as heat energy due to the rapid reaction of flammable materials by being fed with oxygen after being ignited by fire. Although the energy released during this process is usually in the form of hot gases, it also appears in very small amounts in the form of electromagnetic (light), electrical (free ions and electrons), and mechanical (sound) energies. The fire that causes high temperature is the uncontrolled burning of solid, liquid, and/or gaseous substances. "Combustion is a chemical oxidation reaction. "For this reaction to occur, flammable material and air or oxygen are needed. This mixture usually initiates combustion with initial energy. However, due to the characteristics of some combustible materials, initial energy may not be required. The mixing ratio between the combustible material and the air is also the main factor in the formation of combustion. The beginning of combustion is ignition. For ignition to occur, heat, oxygen, and fuel must be present, and the reaction will cease when one of these three is removed. For a fire to occur, these three conditions must be met together simultaneously, called the Fire Triangle (Genç and Pekey, 2014, p. 56).

Both firefighters and the public use the term fire hazard. So what does fire hazard mean? Conditions that cause a fire or are likely to increase the extent or severity of the fire are defined as fire hazards. The terms hazard or dangerous are also used to indicate the type of material or its burning rate (Davletshina, 1998, p. 13). The hazard may be a heat source, such as an easily ignited fuel or a malfunctioning appliance. Danger can also be an action, such as melting a pipe with a torch, or negligence, such as not having a wood stove chimney cleaned. Common fire hazards are found in most buildings and are not associated with any particular use.

1. Data/Statistics on Fire Hazards

Although great developments in fire extinguishing techniques have been achieved and fire losses have been greatly reduced due to developed technologies in construction, fires continue to create risks in many countries.

In particular, fires threaten people, nature, other living things, buildings, and much larger elements. For example, local fire departments responded to an estimated 1.35 million fires in the United States in 2021, according to the US National Fire Protection Association (NFPA). These fires caused 3,800 deaths and 14,700 injuries. Property damage caused by these fires is estimated at $15.9 billion. On average, a fire department responds to a fire every 23 seconds. A fire was reported every 93 seconds, a fire-related death occurred every three hours and eight minutes, and a fire-related injury occurred every 47 minutes. More than a third (486,500 or 36 percent) of fires occurred inside or on structures. Massive fires at the Colorado wilderness/urban interface (WUI) caused $648 billion in direct property damage. Only a quarter (25 percent) of fires occurred in household properties, including one- or two-family homes, apartments, or other multi-family residences. However, these fires caused three-quarters of civilian fire deaths (75 percent) and injuries (76 percent). One in every five fires (20 percent) occurred in homes with one or two families. In half (49 percent) of the fires reported in 2021, neither buildings nor vehicles were involved. It is possible to give bush, grass, or forest fires as examples of these fires that do not include buildings and vehicles (Hall and Evarts, 2022, p. 1).

If we were to make an Istanbul-based inference for Turkey in general, according to the Istanbul Fire Department 2020 Fire Statistics Report; as of the end of March 2020, in Istanbul; 1,331 houses, 39 factories, 2,139 other buildings, 436 vehicles, 150 grass, 1,172 garbage, and 12 forest heath fires were responded. There was an 11% increase in all fires compared to the same period of the previous year. There was a 16% decrease as of 2019 compared to 2015. In general, structural fires increased by 6% compared to the same period of the previous year, and non-structural fires increased by 29% compared to the same period of the last year (Istanbul Metropolitan Municipality Fire Brigade Department, 2020, p. 9).

2. Fire Hazards and Causes

The transport, storage, and use or misuse of ignition sources create various hazardous conditions. This section covers some common fire hazards that can occur in a workplace, depending on the nature of the work and industry considerations.

2.1. Electrical Equipment

Electrical problems are a major cause of fires. Electricity service is available in almost all buildings. By observing an ordinary toaster, you can easily see that there is plenty of energy to start a fire. However, if properly designed, installed, and maintained, electrical systems are useful and safe;

otherwise, they may be liable for fire and injury. Arcing or heating occurs when a current-carrying electrical circuit is interrupted intentionally or unintentionally.

Electrical fires can be divided into three categories. The first category consists of fires started by worn or "tired" electrical equipment. These cause the largest percentage of electrical fires. Examples include worn or dirty electric motors and deteriorated insulation. The second category of electrical fires is caused by improper use of approved equipment. The most commonly misused electrical equipment includes electric motors, overloaded wiring, and improper use of heating appliances. The third cause of electrical fires is accidental or operator error, such as clothing remaining in contact with lamps, parts falling into electrical equipment, heating equipment left on, or faulty installations (Nevada State Police State Fire Marshal, 2022, p. 4).

Fire hazards from electrical equipment are common in manufacturing or industrial facilities. Exposed wires, overloaded outlets, or static discharge can increase the risk of fire in the workplace. Therefore, employers and workers should be checked with regular inspections to control fire risks and properly maintain the work area. Electrical appliances should always be turned off when not in use, and the work area should be properly maintained and free of flammable materials.

2.2. Combustible or Waste Materials

Today, many businesses contain combustible waste materials such as paper or cardboard. Combustible or waste materials require extra attention regarding the safety or storage of such materials. When thrown incorrectly or ignored, flammable materials can work as fuel and ignite a fire. Moreover, fires involving waste have the potential to cause significant damage (WISH, 2020, p. 7-8):

- Risk of death and/or serious injury and damage to health due to high thermal energy and smoke inhalation.
- Combustion products, even from non-toxic materials, release airborne pollutants that can potentially have short- and long-term effects on human health, including public health.
- Firewater runoff can threaten water resources, public health, and wildlife by contaminating drainage systems, rivers, lakes, groundwater, and soil.
- It can cause significant property damage.

- Explosions, sparks, and bullets have the potential to harm people and can also spread fire to other areas.

Many people are injured and sometimes killed annually during emergency operations at facilities where combustible dust or waste materials are found. Business owners, employees, the environment, and society will suffer less when incidents are handled quickly and safely. In this respect, measures to help reduce risks can be listed as follows (Aviva, 2016):

- Workplace areas require special attention to regularly clean up process waste from engines, exhausts, dust collection bags, machinery, floors, and work benches. Used and soiled papers, clothes, or clothing should be stored in metal-lidded containers for hazardous materials.

- Waste should not be stored in areas where potential ignition sources such as heaters, electrical distribution boards, battery chargers, engines, machinery/plants, or hot surfaces may block hydrants, fire exits, or exit routes.

- Waste should be stored in non-combustible metal containers such as a skip, compactor, or baler with self-closing lockable metal lids. These containers should be inspected and monitored regularly to ensure they do not overflow, the area is kept tidy, and adequate waste collection arrangements. Each waste container should be identified to ensure everyone knows the contents and potential hazards.

- At the end of the shift, all bulks must be moved to the storage area.

- Storage areas reserved only for hazardous waste materials should be kept from other storage areas with proper separation for different types of waste. The area is free from surface water drainage and potential ignition sources (including vehicle engines/exhausts and smoking areas), and trees, vegetation, etc., should be far away.

- Waste incineration should not be done on-site and should be prohibited.

- "No smoking" signs should be positioned where combustible wastes are stored.

- Mobile containers not in a secure fenced and gated compound should be locked to prevent unauthorized movement. Trained personnel should be appointed as the waste manager responsible for the overall control and management of site waste.

- Routine cleaning assessments should include monitoring waste control procedures.

2.3. Hot Work Activities

Hot work involves the use of open fire, the use of flame, and the application of heat utilizing tools or equipment. This process includes the unintentional application of heat, such as using power tools or hot rivets or hot particles from cutting or welding processes, falling on and igniting flammable material or flammable vapors (HSE, p.1). Heat-generating devices and related equipment are also among the common causes of accidental fire. Heat-generating devices normally operate at temperatures above the ignition temperature of many common materials. Therefore, heating system installation, use, and maintenance must be carefully planned. Issues include proper maintenance, flammable materials, fuel storage, fuel controls, proper chimneys or vents, and usable air for combustion. For example, commercial cooking equipment must be properly installed, ventilated, and protected by a suppression system. Wood-burning equipment requires the chimney to be cleaned regularly to prevent the build-up of debris that can ignite a chimney fire. Installation and ventilation of solid fuel heating equipment (wood stoves, fireplaces, attachments) are very important. Installation must meet the requirements of the relevant procedures and the manufacturer's instructions (Nevada State Police State Fire Marshal, 2022, p. 5).

After all, industrial activities such as welding, heating, or soldering can cause high temperatures and generate sparks. Employers and managers must ensure that their employees receive adequate hot work training to carry out work safely, all materials are properly stored and handled, and fire risks can be reduced. As mentioned earlier, employers have a legal duty to ensure that risks in their workplaces are assessed, controlled, and monitored so that their employees are not harmed, including risks from hot work activities. Control methods should be chosen according to the control hierarchy outlined below (Martinelli, 2022):

Elimination – Elimination means avoiding hot work activities. This measure can be applied in several ways. For example, if a tank requires hot work to repair, it may be appropriate to replace it completely rather than repair it.

Substitution – The second step in the hierarchy involves replacing hot work with a safer or less dangerous alternative, such as using cold cutting or repair methods.

Engineering controls – This activity includes using physical solutions to reduce risks, such as general mechanical ventilation (ducted air with fans) or local exhaust ventilation (to remove fumes from exit points).

Administrative controls – This approach involves changing how the activity is carried out to make it safer.

Personal Protective Equipment (PPE) – The final stage of the control hierarchy is using PPE to reduce residual risks. PPE includes respiratory protective equipment, hearing protection, eye protection, and antistatic clothing and boots. PPE should only be used as a last resort when all other stages in the control hierarchy are considered.

2.4. Dust and Debris

A dust explosion is the rapid combustion of a dust cloud. In a closed or semi-enclosed space, the explosion is characterized by the relatively rapid development of pressure by flame propagation and the evolution of large amounts of heat and reaction products. The combustion air mostly supplies the oxygen required for this combustion. The necessary condition for a dust explosion is the presence of a suitable concentration of dust clouds to support combustion in the air and an appropriate ignition source simultaneously. There is a danger of explosion when the dust is produced, stored, or processed in a facility and mixed with air. An explosive mixture is present when combustible dust is present in the air in quantities that will explode after ignition. Industries where the danger of flammable and explosive dust can be commonly found, are (Vijayaraghavan, 2011, 84):

- Wood processing and storage facilities,
- Grain elevators and silos,
- Flour and feed factories,
- Manufacturing and storage of metals such as aluminum/magnesium (Al / Mg),
- Chemical production,
- Plastic production,
- Starch or Sugar producers,
- Production and storage of spice sugar and cocoa,
- Coal processing or processing area Pharmaceutical facilities,
- Dust collection boxes or bags,
- Shelves, corners, cranes, equipment interiors, and suspended ceilings in facilities.

NFPA's standard 654 provides comprehensive guidance on the control of dust to prevent explosions. Some of the recommendations presented within the framework of the said standard are as follows (OSHA, 2015, p. 5):

• Minimizing dust escape from process equipment or ventilation systems,

• Use of dust collection systems and filters,

• Preferring surfaces that minimize dust accumulation and facilitate cleaning,

• Providing access to all hidden areas to allow auditing,

• Checking for dust residues in open and hidden areas at regular intervals,

• Cleaning dust residues at regular intervals,

• If ignition sources are available, use cleaning methods that do not create dust clouds,

• Using only vacuum cleaners approved for dust collection,

• Placing relief valves away from dust-hazardous areas,

• Development and implementation of a hazardous dust inspection, testing, cleaning, and control program (preferably in writing with specified frequency and methods).

When it comes to fire safety in the workplace, dust or debris build-up can be a great problem. Dust from wood, plastic, or metals can cause explosions in closed work areas with improper ventilation. For this reason, it is recommended that employers and employees keep their office environments clean. To protect themselves from potential hazards, they must regularly check their work tools and equipment and, if necessary, carry out appropriate cleaning.

2.5. Human Error or Negligence

Negligence and human error are huge factors that cause workplace fires. Fire hazards from human error can occur in various ways, including misuse of work equipment, spills of liquids on electrical appliances or equipment, leaving cooking unattended, or other accidents. Or smoking in the office or work environment can also cause a fire hazard. A misplaced cigarette butt can cause a fire.

The human factor is the most unpredictable element in any security system. It is broadly defined as "the factor caused by certain individuals and groups of people who fill organizational structures and implement their own specific goals and aspirations alongside the duties and tasks arising from their role in their organization." In special situations, such as evacuation in the event of an immediate threat to life and health, the "special goals" understood as instinctive behavior outweigh the duties and tasks arising from the functions performed in the organization. The only way to overcome instinctive reflexes in reducing the unpredictability of the human factor is to learn the right responses almost automatically. Humans are the dominant element in the duty cycle for fire protection and evacuation of buildings. Therefore, the human factor is essential for correctly and effectively implementing preventive and emergency hazard tasks.

Consequently, it seems logical to separate groups of human factors and those that affect fire protection and evacuation of objects. The separation will allow greater control and management of the human element and, consequently, increase the safety of the occupants. Considering that the role of the human factor is dominant in occupational health and safety management systems, people who will assume managerial functions in the future, and these people are students of management departments, should be adequately trained. Only learned and applied procedures and codes of conduct can reduce the unpredictability and possible irrationality of the human factor. Such actions require appropriate management and control in the context of their implementation. This establishes the commitment of all persons responsible for the tasks entrusted to him and all persons remaining on the site. It can be realized that the dominant element in this duty cycle is humans. Therefore, the human factor is crucial in correctly and effectively implementing preventive and emergency hazard missions. Consequently, it seems logical to separate groups of human factors and those that affect fire protection and evacuation of objects. The separation will ensure the control and management of the human element and consequently increase the safety of the people staying inside (Sroka, 2019, p. 96-97).

3. Electricity as a Fire Cause in Industrial Facilities

Electricity is one of the aspects that need to be considered as a potential fire source in industrial buildings and constructions. Properly constructed electrical circuits are rarely a source of ignition. Nevertheless, all elements are subjected to usage and damage during the use of the building. When the electrical circuits are expanded and reconstructed, and new features are added to the construction, original installations may change. Therefore even properly constructed electrical circuits can be a source of the fire.

Electrical ignition is a wide area of fire sources and can be caused by many different issues. Among the most common electrical sources of ignition, one can mention:

- **Incorrect fitting/designing of the electrical equipment** – for example, the equipment is located in the vicinity of the combustible products or not correctly fitted without appropriate security measures. The source of the fire can also be damage to the device connector.

- **Electrical malfunction** – electrical components or connections can malfunction, due to which extensive overheating can appear. In consequence, it can be a source of fire ignition. A potential source of the fire can be malfunctions of devices such as laps and light sources, ovens, and heaters, or domestic appliances in the social rooms, such as cooking equipment.

- **Short circuit** – higher electrical circuit/device current can be caused by an external source, such as water, or malfunction.

- **Incorrect use/operation** – the used electrical circuit can sometimes be incorrectly used – for example, the devices can have to much load for the circuit, and too many devices are connected, which can lead to overloading. Also, it can be caused by the fault of the extension cords.

- **Design faults** – the circuit can be wrongly designed and does not foresee the prolonged usage of connected devices. Also, the cause can be the fault of the device due to the wrong design of the cooling devices.

- **Arcs (for example, high voltage or parting)** – arcs are high-temperature luminous electric discharges across the gaps, with temperatures ranging from several thousand degrees. They can be of different origins and severity (for example, caused by device malfunction, parting of the connector, or fault of grounding). Usually, they are short-term and need unfavorable factors to ignite a fire. Sometimes arcs can lead to the appearance of sparks.

- **Static electricity** –static electricity is a static charge that builds up on some objects. It is built on the surface between two different materials. The build-up of static electricity is usually caused by the flow of steam/air/gas through the pipe or hose (motion of the surfaces of two different materials, such as liquid and solids) or moving vehicles. For the appearance of the ignition, very unfavorable factors are needed, such as the discharge or arc formation in the ignitable atmosphere.

- **Wear and tear** – properly designed, and new devices should be produced to mitigate the temperature caused by the flow of the electricity. But all materials are subjected to damage, either by external factors (such as climatic factors) or by in-building works. Electrical circuit damage can break or damage the device isolation, leading to fire ignition due to overheating or other factors. From the construction industry perspective, this kind of failure is one of the most common sources of fire from electricity.

- **Dangerous self-repairs or improvements** – circuits in the older building were usually designed for lower usage, which in the present-day can lead to wear of the fuses. In many facilities, the typical practice was to repair it with wire or nails, due to which the fuse was not properly working and could lead to overheating or overloading the whole circuit.

- **Lack of proper conservation of the electric devices** – overheating can also be caused by a lack of appropriate preservation of the used appliance, for example, clogging of the device's ventilation or accumulation of dust or waste on the device.

It should be noted that to the appearance of fire originating from electricity, very unfavorable factors must appear: the formation of temperature/heat for a long enough period, the vicinity of flammable material, or an ignitable atmosphere. Properly maintained and audited devices and circuits can minimize the risk of ignition of fire originating from electric sources.

Conclusion and Evaluation

Fire hazards are common in almost any work environment and can occur without prior warning. Those at the management level must take appropriate workplace fire protection measures to protect themselves and their staff from fire hazards.

There are some common fire risks in almost every workplace. Depending on the job's nature and the company's size, employers and senior management should have adequate fire protection measures to mitigate risk.

There should be appropriate training sessions for staff and responsible persons, including in-office fire safety training, industry fire safety training, fire door inspection course, fire risk assessment training, and more.

Employers should also have a good workplace risk assessment process to assess fire risks. They must also provide their employees with adequate tools and equipment to safely undertake the job, along with proper planning and communication to prevent workplaces.

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CHAPTER 4.

HAZARDOUS MATERIALS IN INDUSTRIAL SITES

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HAZARDOUS MATERIALS IN INDUSTRIAL SITES

1. Flammable And Explosive Gases

What is an Explosion?

An act of releasing explosive substances in a solid, liquid, or gas state suddenly and violently within the air, creating heat, light, gas, sound, and pressure extremely as a result of a sparkle, reaction, or shock effect is called an explosion.

Types of Explosion

a) Mechanical Explosion

We can give explosions caused as a result of the increase in the internal pressure of the closed vessels, boilers, and pipelines due to various physical effects as a mechanical explosion. Suppose closed vessels, boilers, and pipelines are not equipped with pressure relief valves. In that case, the increasing vapor pressure exceeds the material's mechanical strength from which the container is made, and it blows up. A high amount of heat is generally released in such types of explosions. Gases or vapor release rapidly, and a noise arises.

b) Chemical Explosion

Chemical explosions occur with the conversion of the explosive substance in liquid or solid state into gases whose volume is far greater than the volume of the substance at a great pace. The conversion period happens within time frames, which can be measured in split seconds, and creates an extremely high heat (thousands of degrees).

What is the Explosive Atmosphere?

Space, where gas, powder, or vapor featuring explosive, flammable, and combustible quality comes to an explosive consistency by combining with air is called an explosive atmosphere. This environment is called an explosive atmosphere. Three elements must combine to create an explosive atmosphere and pose a danger.

a. **Explosive substance;** Explosive, flammable, and combustible gas, vapor, or powder

b. **Air (Oxygen),**

c. **Energy;** a sparkle or power supply which will ignite the explosion. The danger of explosion is eliminated if one of these three elements is excluded. This incident, known as the explosion triangle, is symbolized in the following figure.

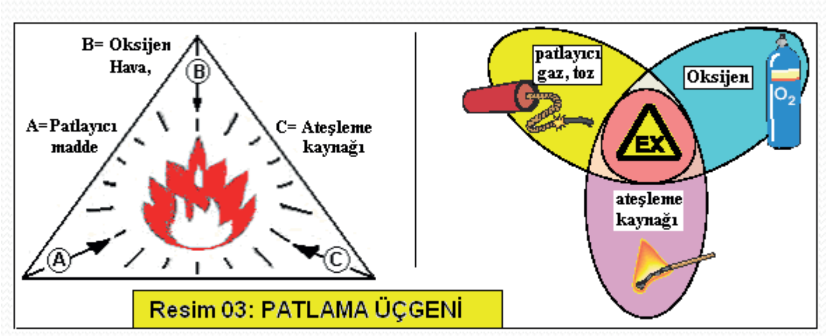

Figure 7. *Explosion Triangle*

1.1. Explosive, Flammable, and Combustible Gases and Their Vapours

Natural gas, bottled gas (LPG) domestically used, and hydrogen and acetylene gases used in welding are the leading ones of widely-known explosive gases. Once these and similar gases get mixed with the air, they become volatile, and they can explode with any triggering (sparkle). The explosion depends on the rate of mixing with the air. The mixture has a lower and upper explosive limit. Those interested in gases refer to LEL measurement (LEL= lower explosive limit), the English abbreviation of the lower explosive limit. LEL value is very important data for the measures to be taken and determines the degree of hazard of the gases (explosive ability).

In the same way, the upper explosive limit of the gases is called UEL (UEL= upper explosive limit). Carbon hydrates constitute an important part of volatile substances. The physical characteristic of the carbon-hydrates varies by the number of carbon and hydrogen. The first 4-carbon element of this group, called alkane, constitutes gas, those with 11-18 carbons constitute fuel oil (liquid), those with 19-40 carbons constitute machine oil/grease, and those with longer carbons constitute pitch and wax.

1.2. Ignition Sources

"Explosive, flammable and combustible gas, vapors" need an energy source to explode once mixed with the air's oxygen. While this energy source is generally arc-making contacts and heating surfaces of the electrical devices, all sources leading the accumulative energy to be discharged can explode any hazardous atmosphere. For example, static electricity from friction and metal components sparkling by friction may easily be a source of hazard. The primary incident and energy sources igniting the hazardous atmosphere are as follows:

- Electric arc and spark
- Once power switches are turned on and off
- Once the electrostatically loaded elements are discharged
- Once the cables are crushed and broken or in case of a short circuit
- Any arc and spark released in such incidents as equalizing current occurring in case of any short circuit may endanger the atmosphere.

Electrical appliances may always endanger the explosive atmosphere as they release arc or generate heat. For this reason, great care should be shown, and necessary measures should be taken for the electrical appliances used in explosive atmospheres.

2. Gases Frequently Used in Industry and Their Properties

LPG (Liquified Petroleum Gas):

- Features flammable, combustible, and explosive characteristic
- Produced as a mixture of 30% propane and 70% butane by the conditions of Turkey
- Ignition temperature 530 °C
- Lower Explosive Limit (LEL): 2,1% Upper Explosive Limit (UEL): 9,6%.
- Colorless and odorless. It ignites and burns easily.
- LPG is about two times lighter than water in a liquid state. It is two times heavier than air in a gas state.
- It subsides in case of gas leakage.
- It should be kept away from all ignition sources.
- In case of leakage, mercaptan-releasing malodor is mixed so that 1% of concentration can be noticed.

Acetylene Gas

- Features combustible and inflammable characteristics.

- It smells like garlic.
- Its fire and explosion hazard is a bit more than LPG.
- It needs too little energy for inflaming in the air or with oxygen.
- Since copper constitutes explosive compounds with acetylene, it is not used with high copper and brass alloys.
- Lower Explosive Limit (LEL): 2,5% Upper Explosive Limit (UEL): 81%.

Hydrogen Gas

- Features combustible and inflammable characteristics.
- Odorless.
- It is lighter than air.
- It accumulates at the top of the confined space where there is no ventilation in places close to the ceiling.
- It has an invisible fume.
- It has fire and explosion hazards.
- Its ignition energy is too low.
- It burns with invisible fume.
- Lower Explosive Limit (LEL): 4%, Upper Explosive Limit (UEL): 75%.

Oxygen Gas

- It features an oxidizing, blasting characteristic.
- It is odorless.
- It is accepted that it is not toxic under atmospheric pressure.
- It does not burn, but it assists and facilitates combustion.
- It leads to an explosion by interacting with oil, grease, or lubricant.

Carbon monoxide Gas

- It is flammable, explosive, and extremely toxic.
- It is colorless.
- It is odorless.
- It is a gas that is slightly lighter than air.

➢ Lower Explosive Limit (LEL): 12%, Upper Explosive Limit (LEL): 75%.

Hydrogen Sulfide Gas

➢ It is flammable, explosive, and toxic.

➢ It is colorless.

➢ It is heavier than air.

➢ It smells like a bad, rotten egg.

➢ Lower Explosive Limit (LEL): 4,3%, Upper Explosive Limit (UEL): 72%.

Ammonia

➢ It is flammable, explosive, and toxic.

➢ Irritant

➢ Colorless

➢ It is a keen and ripe-scented gas

➢ Lower Explosive Limit (LEL): 15%, Upper Explosive Limit (UEL): 28%.

Dye Solvents Vapours

➢ The primary dye solvents of volatile liquids are butanone, xylene, ethyl benzene, and similar organic compounds.

➢ Dye solvents and even vapors of all other dye constituents are combustible and toxic

➢ Lower Explosive Limit (LEL): About 1% concentration leads to sparkling and explosion in case of any spark.

Natural Gas (Compressed natural gas)

➢ It is a combustible gas mixture consisting of notably methane, ethane (C2H6), and hydrocarbons formed due to bacterial growth, chrogenization, and photodecomposition of organic substances in the substratum of the earth in a similar way to the formation of petroleum.

➢ Since it largely consists of methane gas, it completely acts as methane.

➢ It is colorless and odorless. In case of any leakage, the malodorous Tetra Hydro Thiophene is added into it so that only a concentration of 1% could be noticed.

➢ It is about two times lighter than air. In case of gas leakage, it rises upward. It should be discharged by sweeping away.

➢ Lower Explosive Limit (LEL): 5%, Upper Explosive Limit (UEL): 15%.

3. Gases Produced and Used In the Iron and Steel Industry

During the production of iron and steel, the following gases are also produced by production;

1. Coke Gas
2. High Furnace Gas
3. Converter Gas

3.1. Coke Gas

The coke gas is evaluated as a byproduct by decomposing into its constituents such as naphthalene, crude tar, road tar, ammonium sulfate, and benzol.

Photo 7. *Coke Gas*

Properties of Coke Gas:

- Colorless, odorous (*distinctive keen smell of Naphthalene*)
- Lighter than air (0.44 Kg/Nm^3)
- Explosion range (4.3 – 32%)
- Combustion temperature: $640\,^0C$
- Calorific value: 4500 $Kcal/Nm^3$

Constituents of Coke Gas:

- Hydrogen (H2) 56-60%
- Methane (CH4) 20-25% Methane (CH4)
- Carbon monoxide (CO) 5-10%
- Nitrogen (N2) 5-10%
- Carbon dioxide (CO2) 2-3%
- Other 2-8%

The coke gas released from the production of metallurgical coke from the hard coal is converted into byproducts. Since the remaining coke gas's calorific value is high, it is used as fuel in operating units and energy generation.

3.2. High Furnace Gas

Raw liquid iron is generated from the raw iron ore and sintered ores in high furnaces using metallurgical coke as energy. High furnace gas is released during the generation of the liquid raw iron. The high furnace gas is used as fuel in operating units and energy generation.

Properties:

- Colorless, Odorless, Tasteless
- Heavier than air
- Sneak and toxic (It is not easily noticed).
- Combustion temperature: 6800C
- It explodes in case of gets mixed with air at certain rates.
- Explosion range: 30 – 70%
- Calorific value: 800 - 1000 kcal/m3

Photo 8. *High Furnace Gas*

Constituents:

- Nitrogen (N_2) 50-60%
- Carbon monoxide (CO) 20-30%
- Carbon dioxide (CO_2) 10-15%
- Hydrogen (H_2) 2-4%
- Methane (CH_4) 0.1%

3.3. Converter Gas

The liquid raw iron produced in high furnaces is subjected to the acierage process. During the acierage process, oxygen is blown to the converter. The gas is released in the converter, the first phase of steel production. The released converter gas is used to generate vapor by combusting in boilers.

Photo 9. *Converter Gas*

Properties:

- Colorless, odorless, tasteless
- Calorific value: 1850 kcal/nm^3
- Heavier than air (1.03)
- Flame temperature:650 °C
- Extremely toxic
- Explosion range: 12-72%

Constituents:

- Carbon dioxide (CO2) 10-15%
- Carbon monoxide (CO) 50-60%
- Nitrogen (N2) 20-25%
- Others, Oxygen, Hydrogen, and Methane in small quantities

CHAPTER 5.

INDUSTRIAL FIRE SAFETY MANAGEMENT

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INDUSTRIAL FIRE SAFETY MANAGEMENT

1. Management Commitment

The attitude toward the company's fire safety starts with the management's commitment to providing a **safe working environment**. Appropriate management approaches can prevent business disruption due to possible fire incidents.

When fire safety is a part of the **holistic safety approach** and is recognized as a benefit and notas an unnecessary cost, the doors are opened to a working environment of continuous improvement driven by direct participation, i.e., the commitment of top management.

The commitment of top management should include the following:

- Demonstrating organizational concern for employee safety and commitment to the protectionof the environment;

- Assigning responsibility for the various aspects of the workplace fire prevention measures to ensure that all managers, supervisors, and employees understand theirobligations;

- Allocating appropriate authority and resources to all responsible parties;

- Maintaining a system of accountability for involved managers, supervisors, andemployees;

- Establishing a comprehensive program of education and training on fire prevention andprocedures when a fire occurs;

- Supporting and implementing appropriate fire safety novelties whenever changes in the working process, premises, environment, etc.

The level of fire safety in the company depends on attitude towards it and the input that management is willing to invest into prevention measures on common terms. The results of the firesafety management policy will be better when **incorporated into the overall management policy**of the premises, written in a fire safety management manual or similar document, which presents the basis for a fire safety management plan.

To implement the commitment, i. e. the fire protection policy of the company, the owner/manager/employer has to **provide resources**: appoint the employees with defined roles and fire safety responsibilities, which carry out the procedures described in the Fire safety management plan.

2. Fire Safety Management Plan

Fire safety actions described in the fire safety management plan should be based on the **risk assessment**. Information that influences the desired level of fire safety should be kept upto date, especially because change is the only constant in modern industry. The Project Cycle Management (PCM) method can effectively manage the fire safety of the premises (see Fig. 8).

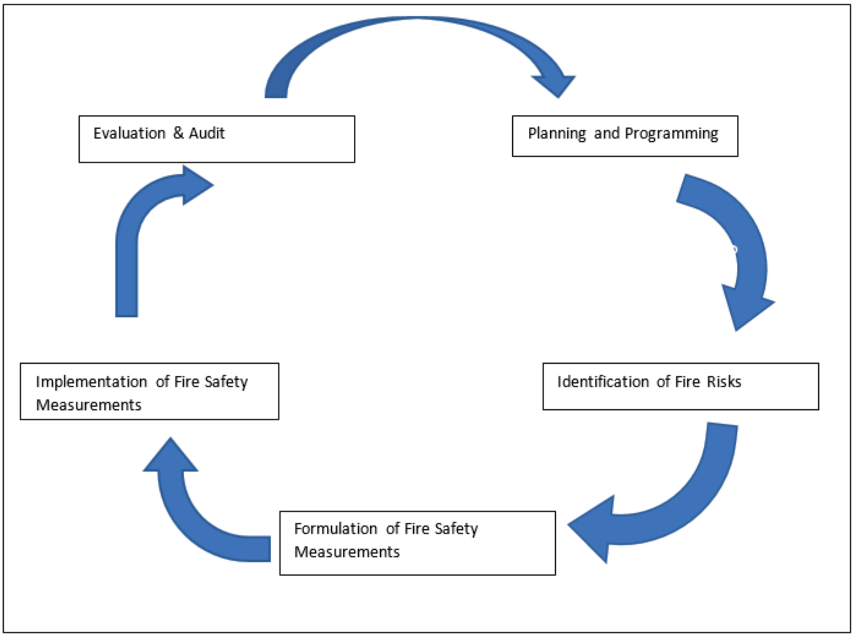


Figure 8. *Project Cycle Management*

The financial aspect should not prevail over the requirements based on risk assessment,legislation, and/or conditions of insurance companies.

Fire prevention actions should be defined, like the ones listed in Guidance of UKGovernment for Responsible Persons and Duty Holder (RP & DH, 2021), but not limited to:

- Minimize the risk of a fire occurring, and ensure that it cannot easily spread through the building if a fire starts.
- Make sure escape routes are available, emergency exit doors are not locked,and can be quickly and easily opened without needing a key.

- Where a door on the escape route is shut for security purposes, ensure this can be easilyopened from the inside by installing push bar devices - these should not be blocked or obstructed.

- Make sure there is a way to detect fires and that this raises the alarm to alert everyone toevacuate.

- In a workplace, train staff on what to do if a fire happens.

- Cooperate and coordinate with other owners where there is more than one company onthe premises (such as in an office building with more than one owner).

- Check that shared escape routes are always clear, for example, by making certain stored goods do not block the escape routes from an office when there is a stock delivery.

Actions must be written in the Fire Safety Manual or similar document, in which the company's management defines responsibilities for maintaining adequate fire safety in all premises. The Manual sets general procedures and precautions to be followed and outline the use and care of firefighting equipment. Examples of the Fire Safety Manual or similar documents with the same aim can be found on Internet; see examples of the University of South Florida Fire Safety Manual (USF, 2022) and Outcomes First Group Fire Safety Policy (The Shires, 2020). The document, called Manual or different, must reflect the actual situation and be adapted to each case.

3. Responsibilities to Maintain and Improve Fire Safety

The employer or owner of the industrial premises shall set up a fire safety system and define the responsibilities of employees. With the cooperation of other employees, appointed competent persons can maintain and enhance fire safety if basic conditions are provided, and people are adequately stimulated.

Tasks of providing fire safety can be various in larger companies distributed over different levels of management. The number of trained in-house personnel for fire safety planning and implementing fire safety measures at the premises depends on many factors. Insmaller companies with low fire risk, the outsourced fire protection consultant – a fire risk assessor or other fire safety professional - may provide the appropriate services if the connection with the management of a small business is very tight.

Especially in large industrial companies, and those with higher fire hazards, in-house personnel is needed to manage the work that must be done to provide the appropriate level of fire safety. For example, fire safety standards are higher in the chemical industry than in other industrial branches. Another example is industrial companies, where technological changes are happening daily, which is quite common nowadays. In such cases, thefire safety professionals who are employed in the company usually play an important role inthe management system. They are indispensable in planning and implementing fire safety measures. If needed, fire protection consultants can be outsourced as well.

Competent persons for fire safety employed at the factory are best acquainted with fire hazards shown through a fire risk assessment and can identify the proper fire protection measures. If necessary, technicians and engineers should be appointed to maintainand repair key components of the fire safety measures for the premises: installed fire protection systems like fire detection systems and automatic extinguishing systems.

Furthermore, having an industrial fire brigade in companies with high fire hazards, explosion risk, and/or other special hazards is reasonable. In some countries, e.g., Slovenia,the type and scope of the fire brigade are determined by the criteria for organizing and equipping fire brigades prescribed by the competent authority (Uredba Organizinanju, 2022).

The need for an industrial fire brigade depends on several circumstances:

- level of fire hazard,
- type of activities (production of combustible, flammable, or explosive materials andsubstances),
- number of employees,
- area of the premises,
- distance to the nearest fire brigade, which provides public fire service,
- built-in active fire protection systems,
- connection of the installed detection system to the nearest public fire brigade,
- requirements or recommendations of insurance companies etc.

The presence of firefighters can also be obligatory outside working hours (Saturdays,Sundays, and holidays) if needed.

The industrial fire brigade can play an important role in providing the desired fire safety on-premises. In addition to being constantly prepared to intervene in fires or accidents and prevent the fire from spreading and growing to the point of flashover (Figure 9), the fire brigade should be invited to cooperate in planning, auditing, and performing drills, according to Fire Safety Manual. Because they are well acquainted withfire hazards, buildings, equipment, employees, etc.

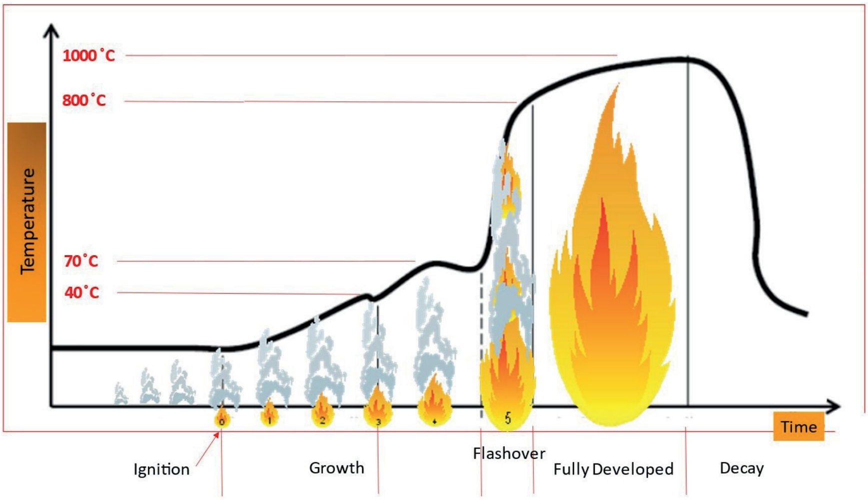


Figure 9. *The industrial fire brigade should be constantly prepared to intervene in fire or other accidents and prevent the fire from spreading and growing in its early stages – at least to the point of flashover (stage 5 on the timeline).*

The tasks of industrial fire brigades are as follows (Lozic, 2006):

- permanent control over the implementation and improvement of fire safety measures;
- organization and implementation of systematic training of workers on regular and specificfire safety measures;
- familiarization of workers with procedures in case of fire, other accident, or catastrophe, including acquaintance with methods of evacuation and the use of fire extinguishers andother firefighting equipment;
- carrying out fire watch during hot work and other fire-hazardous tasks on temporary constructions sites and other areas, and during events where many people are present;
- immediate action and management and implementation of all activities in case of fire;
- keeping records of fires, studying and analyzing the causes of fires, and proposing measuresto prevent fires;
- periodic reporting to management on situation analysis;

- proposing measures to improve fire safety, cooperating with expert advice onreconstructions, construction, and design of elements of the working environment;

- maintenance, inspection, and servicing of fire extinguishers, fire hydrants, and otherinstalled fire safety equipment and devices;

- preparation and updating of a fire plan.

An example of good practice where firefighters of industrial fire brigade have helped toimprove actions for prevention of damage through innovative approaches:

In the storm, some of the roof domes of the warehouse were blown away. Rapid action was needed to prevent further damage. Coordination occurred between firefighters from the industrial fire brigade, the construction company, and the company's employees. The temporary remediation was carried out within a few hours, thus preventing major damage that the water could cause in the warehouse.

Photo 10. *Immediate repair of roof domes after the storm. Photo: Intersocks d.o.o.*

There are other possibilities to improve fire safety in industrial companies with the support offirefighters. When the fire risk is increased only occasionally, companies may have a contractwith a local fire brigade that provides a public fire service.

Photo 11. *Under the contract between the industrial company and the municipality, the public fire brigade provides fire service for the company. Photo: Domzalec.si*

In Slovenia and other countries with a high percentage of voluntary firefighters, there is atradition that companies financially support local volunteer fire departments with members employed in the company. In some cases, the industrial fire brigade contracts with a municipal government and intervenes outside the company premises as a public fire service.

4. Management of the Company in case of a Fire or Other Accident

An action plan must be prepared for possible scenarios and immediate consequences of a fire or other accident (see examples in Table 20) to preventunnecessary damage and panic and enable operation in crises (Loncarevic, 2022).

Table 20. *Examples of different possible scenarios and immediate consequences of a fire or other accidents*

Scenarios	Immediate consequences
Fire in one sector of a warehouse, limited by firewalls	A part of the warehouse is damaged. Stored goods aredamaged by fire and firewater. Load-bearing construction of the warehouse buildingis not affected seriously.
Fire in the entire warehouse	The whole warehouse is damaged. All stored goodsare damaged by fire and firewater. Load-bearing construction of the warehouse buildingis seriously affected.
Fire in the warehouse. The fire spread to the nearby production premises.	The whole warehouse and part of the production premises are damaged, bringing production to a standstill. All stored goods are damaged by fire and firewater. Load-bearing construction of the warehouse buildingis seriously affected. Electrical installations in production premises aredamaged, but the load-bearing construction is notaffected seriously.

The warehouse and the production premises are floodedduring the storm	There is up to 0.2 m of mud and dirty water on thefloor. The roof covering is damaged in one part of thewarehouse. The ventilation system is partly damaged. Load-bearing construction of buildings and electricalinstallations are not affected seriously. Some machines and products are damaged.
A minor earthquake	Load-bearing construction of all buildings is notaffected seriously. The ventilation system is partly damaged. Some goods are damaged in the high-rack storage.
A devastating earthquake	Load-bearing construction of all buildings is seriously affected. Most goods are damaged in the high-rack storage.Some machines and products are damaged.

Various possible scenarios dictate crisis management actions that can reduce damages during and immediately after a fire, flood, storm, etc., such as determining temporary storagelocations, relocating some or all production lines to neighboring facilities, and establishing a contractual relationship with cleaning and other services. The crisis management actions should also be included as measures to enable a stable business or at least enable the company's minimum scope of work (Table 21) (Loncarevic, 2022).

Table 21. *Examples of crisis management actions and purposes of these actions*

Crisis management actions	Purpose
Check the availability of resources (people, supplies) at different locations and with diverse suppliers in various scenarios	The state and timing of the continuation of the business are assessed
Check the possibilities of reservingresources for each scenario	Chances of transferring part of production and services to other locations, availability of additionalpeople (working force)
Check the possibilities of continuation of business with alimited number of people, raw materials, locations	Determination of key people, method, and scope ofwork
Check the possibilities of continuation of business in caseof a major decline in orders	Determination of operating with reduced capacities
Assessment of energy supply problems (gas, oil, coal, water,electricity)	Determination of the effect of the energy supply delays to the production process and finding additionaland backup resources
Check the servicing of equipment, machines, and facilities: electrical installations,HVAC, water and sewerage network, and other vital systems in buildings, appliances, and equipment	Stocks and service possibilities in the event of a fire or other incidents are checked with available service andparts suppliers, finding additional and backup resources

An example of the crisis management process is shown in Figure 10 [6].

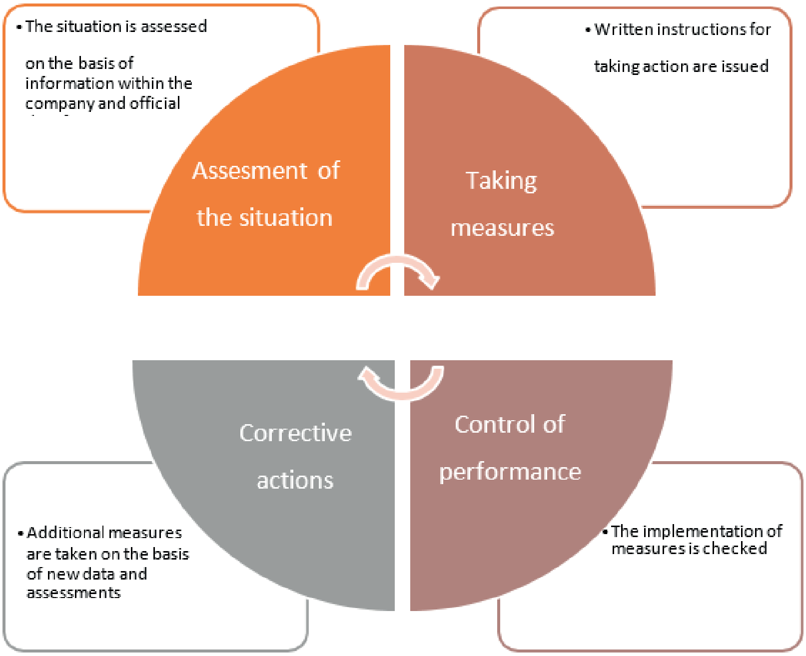
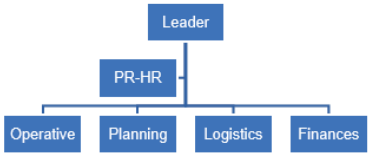
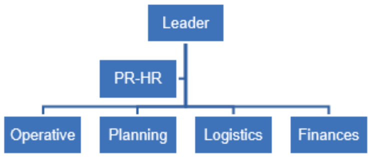
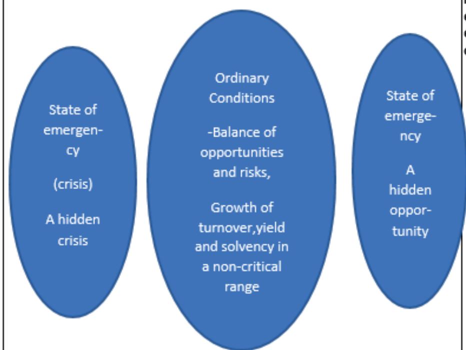


Figure 10. *Crisis management process*

Procedures of the crisis management process are described in more detail in Table 22 (Loncarevic, 2022).

Table 22. *A detailed description of each procedure of the crisis management process*

No.	Procedure	Figure	Short description of theprocedure
1.	Management plan		A leadership and authority scheme is prepared. Duplication of management functions has to be provided.
2.	Communication plan		A communication plan isprepared with contact data of all persons and services: telephone numbers, e-mail addresses, and internet communication links. The document should be accessible indifferent ways (printed,on a server, etc.).
3.	Issuing measures		Measures are issued in writing through established communication channels: e-mail, bulletin board, personaldelivery of a printed document
4.	Anticipated measures		a. Review of the situation after the accident b. Creation of a business crisis plan c. Redistribution ofwork and locations d. Reducing the scopeof work e. Temporary suspension of business f. Prolonged suspension of business

If appropriate, further, more detailed instructions should be prepared for each procedure of each scenario. See an example of detailed instructions in case of a major fire in table 23 (Loncarevic, 2022).

Table 23. *An example of detailed instructions in case of a major fire in a company*

No.	Action	Description	Yes/No ✓
0	**Establishment of a crisis Managetaent**	A crisis management team is formed based on the management's decision	
	Communication with the rescue services and the police	After the accident, the person responsible for ctwith the rescue services and the police is determined	

1	**First condition check and evaluation**	The extent of the fire and the damage are being examined • of raw materials • of products • of machinery • on the infrastructure and facility	
2	**A second status check**	• The inspection is carried out with thedesigners and contractors of the rehabilitation • Rough plan of rehabilitation (prices,delivery dates, • Inspection visit by the insurance company	
3	**Instructions for the employees**	• Instructions are given to employees for further work, specific for each department	
4	**Unit shutdown**	• Depending on the situation, individualunits are closed partially or completely • Work is carried out from home as much as possible • Working with small groups in departmentsthat can work independently • Production at other company locations	
5	**Temporary closure of the business**		
	INFORMATION and COMMUNICATION		
a)	**Notification toemployees**	• The employees are informed in writing andorally through the managers of when the company will be closed • The tasks of individual employees	
	Public notice	• The director or a person authorized by him prepares a media release	
	Notice to customers	• The sales manager/deputy, after consulting with the management, informs the customers about the situation (a letter mustbe prepared in advance)	
	Notification to suppliers	• The purchasing manager/deputy informs the suppliers about the situation after consultation with the management (a lettermust be prepared in advance) • Procurement/Distribution: check the raw materials in transit and the arrival date. The possibility of the collection is checked, otherwise notice of non-collection of theraw material • Notify the post office of non-receipt ofgoods and non-delivery	
	Notification to transporters/ logistics partners	• Logistics/distribution/samples: inform thecarrier about the stop of collection and release of goods	
b)	**SECURITY, FIRE SAFETY, AND SYSTEM OPERATION**		
	Security of thecompany	• All available alarms are turned on. ATTENTION: Check the automatic activation and deactivation of warnings at thefacilities • The security company is notified about the additional security of the company and theclosing of the company • Additional fences and security systems, if necessary	

	Fire safety	• Before closing, check all devices under voltage or with higher temperatures. Turnoff all unnecessary devices • The operation of the systems that are not damaged is checked	
	Functioning of systems and installations (heating, ventilation,cooling, etc.)	• Maintenance personnel perform daily preventive inspections of equipment • In the event of defects, they contact the management, which gives further instructions • In the event of suspicion of damage,immediate action is taken	
c)	**PERSONAL INCOME PROVIDING AN EXISTENCE**		
	Payroll accounting	• Employees receive instructions on activities, possible help with remediationor special leave • If there is no data on the activity of the employees, the basic or minimum personal income is calculated,athe rest is paid with the next salary	
	Reduced range ofoperation	• Absence from work/ compensation ofhours • Leave/sick leave • Waiting to work • Termination of employment due to areduction in the scope of work	
d)	**OTHER ACTIVITY**		
I.	**Restarting the business**	• Summons of heads of sectors • Preparation and verification of chain production • The gradual return of departments • Starting one shift after another	

Business restarts will not be universal. The restart of the business will take different forms, with varying business sectors opening up in different ways and at different speeds.Actions should ensure a safe relaunch of activity in steps (Hatami & Mieszala, 2022), such as:

- Creating a detailed relaunch map
- Providing customers with safety guarantees that restore trust
- Safeguarding the health of employees
- Reviving demand
- Rebooting operations and supply chain
- Shifting IT and technology to restart mode
- Steering the restart with care
- Sustaining value creation born from crisis and reinvesting in recovery

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CHAPTER 6.

FIRE RISK ASSESSMENT IN INDUSTRIAL PREMISES

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FIRE RISK ASSESSMENT IN INDUSTRIAL PREMISES

1. General Information on Fire Risk Assessment

Preparation of the fire prevention strategy should be a common activity during the design of the new construction or verification of the old structure. One must first require the general risk assessment plan to properly design the fire prevention strategy. In all construction, one needs first to assess the potential sources of fires, assess their probability (which is the Risk Analysis part), and then prepare and monitor and verify the fire prevention strategy (which is the Risk Evaluation or Risk Control part). It is of essential issue that all Risk Assessments are consulted with people working inside an analyzed building or who have high knowledge of specific buildings. Hence, the prepared plan based on risk assessment can be implemented and used in normal work conditions.

The risk of fire is defined as the multiplication of the probability of a fire's appearance by the fire's severity. The fire risk assessment and the fire prevention strategies depend on fire protection. It can be either people or property. But in specific situations, especially in industrial buildings subject to fire assessment, the production and environmental protection can also be continuity. Fire risk assessment should present structured information regarding the current level of the fire risk and the adequality of the existing building fire prevention systems and measures.

On the most basic level, the subject of the fire assessment can be a separate analysis of each potential fire incident (both the probability and the severity). Next, the combination of the incidents should be considered as to how they can change the analyzed fire risk as the probability, severity, location, continuity of the production, and the aspects of environmental protection.

The risk analysis can give different results depending on the need of its carrying out. In many cases, it is mostly done to comply with a specific country's law. Other effects can be obtained when the fire risk analysis is conducted to prepare the fire prevention strategy, and more complicated combinations of factors are considered.

The analysis can be prepared in either a probabilistic or deterministic manner. In the first one, the engineer analyzes the designed construction with the requirements of the law or specific construction standards. Each factor is determined quantitatively (probability and severity), and later their combination is analyzed by either direct multiplication or utilization of the statistical tools. In the second analysis type, the engineer prepares different fire development scenarios and analyses the results. The scenarios taken into consideration should be the most unfavorable ones. Current computational analytical technics allow to design of multiple and random scenarios and assess the comprehensive fire risk analysis. But such detailed analysis is still not required by the law. The visualization of different risk assessment elements and techniques is presented in Figure 11 (Sowa, 2009).

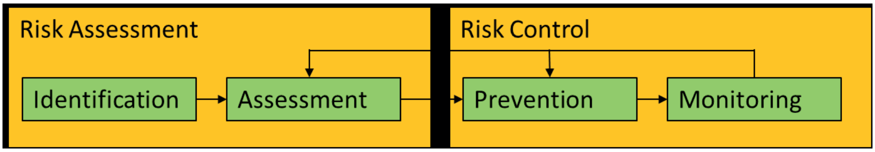

Figure 11. *Elements of risk assessment, after (Sowa, 2009).*

It should also be checked during the fire risk assessment if the information given in the project is correct and correspond to the existing state and if the building is used exactly as it was designed.

Generally, the fire risk assessment end when the risk of fire is at an acceptable level, no further precautions are required, or the cost of the used precautions methods exceeds the value of the protected goods (Sowa, 2009). Various technics can be incorporated to determine the risk of fire, such as a bow-tie method, risk matrix, profile of the risk method, strategic fire plan, and so on (Condor et al., 2011). Selected methods will be presented below

1.1. Identification

In the beginning, one should first identify all potential sources of fire, such as the use of open flame, the used machines, and utilities (also for social usage), technological processes which are conducted inside the building (both processes which are done on the daily matter such as welding, cutting, heating, etc., and processes which can be done during a renovation of the building.

Another part that should be considered is the existing state of all installations inside the building (especially for electricity, gas, and heating systems), whether their state is controlled and in good condition, or if their state can potentially become the source of the fire.

Also, goods and liquids used or stored in the building should be identified and analyzed to determine whether they are the potential risk of fire initiation. It is essential when highly flammable materials are stored in the building or used in the processes performed in the analyzed building.

The other part is the analysis of the personnel working typically or temporarily inside the analyzed building. One should examine the pattern of work (stationary or in different parts of the building), psychophysical condition, the age of people, and their potential behavior, such as smoking in restricted ways, obedience to OHP rules, knowledge of evacuation measures, plans, and so on.

1.2. The Assessment Of The Risk

The next part analyzes the elements presented in the last part with one of the existing methods. Methods can assess the general level of risk and help to choose sufficiently one.

1.2.1. Risk Matrix

The risk matrix is one of the assessing the risk of fire and the level of acceptance. On one of the axes (horizontal), we give points to each aspect that increases the fire risk appearance, and we decrease for prevention measures. On the other axis, we put the severity of a fire, for example, the number of losses or other actions. And on the intersections, we can set the level of risk, which depends on the value of measures, the risk of fire, and the potential losses. An exemplary risk matrix is presented below.

Table 24. *Exemplary risk matrix based on (Sowa, 2009).*

Sum of risk/Loses	**0 < x < 10**	**10 < x < 40**	**40 < x < 80**	**80 < x < 100**
Small	Low	Low	Medium	Acceptable
Medium	Low	Medium	Acceptable	High
Big	Medium	Acceptable	High	Non-acceptable
Catastrophic	Acceptable	High	Non-acceptable	Non-acceptable

Based on the measures/risks/losses, we evaluate the level of fire risk and take appropriate measures. If it is too high, we can: a) reduce the potential sources of fire – reduce the sources of heat, check and upgrade the installations inside the building, change the used materials (like unnecessary gases or liquids) or change the way they are stored, b) use another technical solution in the building, such as fire alert systems, fire suppression systems, passive systems, materials used in the building or c) make additional education for people which work or stay inside the building how to behave in case of fire and how to prevent the appearance of fire.

1.2.2. Bow-tie method

It is a method that is made based on an event tree or failure tree. It is the method that builds the potential scenarios of fire based on the partial events. For example, "did the sprinklers work" can end in two possible answers – yes or no. So for more complicated scenarios, the multiple branches of scenario are developed. During the evaluation, we assess the possibility and severity of such scenarios and their potential. The failure tree is made the other way. We start from the unfortunate event and make the tree based on unfavorable and favorable states. The result is the initial event that started the fire. Each event in the tree can have a form of 0 or 1. Each event is connected with the logical gate OR or END, and we analyze it based on states and rational calculations to assess their probability. The exemplary bow tie method illustration is given in the figure below.

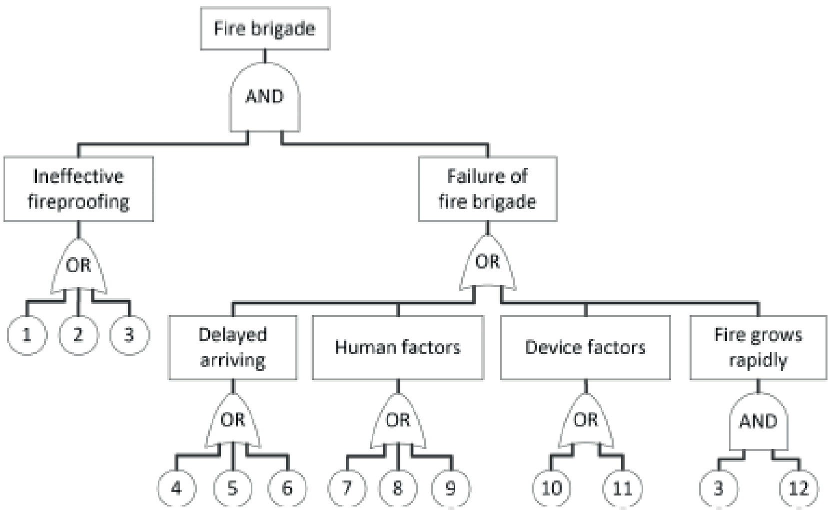

Figure 12 *Exemplary fault tree, after (Ding et al., 2020).*

1.3. Risk Assessment According to the BS 9999

One way of assessing the risk of fire safety is by making the profile of the risk of fire. It can be made based on different conditions, such as type or size of the building, utilization of the building, people who work in the building, the probability of the fire, density of the fire load, the importance of the building for the industry, the costs of the discontinuity of the work, the environmental costs and risks, the probability of the development of the fire and so on. In most cases, similar industrial buildings can have a similar risk profile. Still, it can change depending on the type of industry, the building profile, the presence of easy-to-fire materials, the type of used machines, and so on. Figure 13 presents the graphic interpretation of the BS 9999 Standard profile of the risk (Brzezińska & Bryant, 2018a).

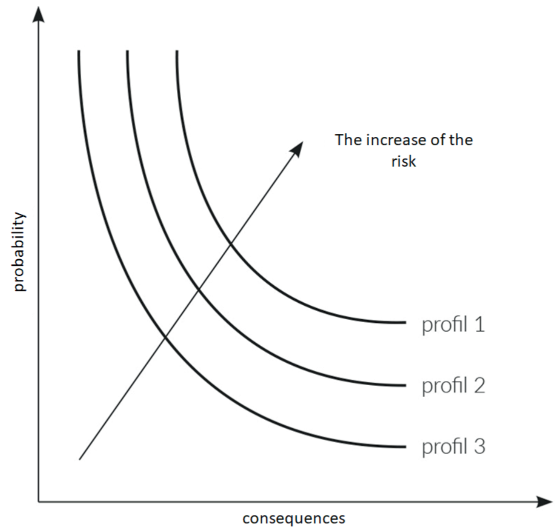

Figure 13. *Elements of risk assessment after BS9999 (Brzezińska & Bryant, 2018a).*

According to the BS9999, the risk profile is divided into Occupancy characteristics and fire growth rate. From the point of view of industrial buildings, the classes which can be considered for industrial buildings are:

- **Occupancy characteristics – A** (Occupants who are awake and familiar with the building, for example, Office and <u>industrial</u>) **and B** (Occupants who are awake and unfamiliar with the building, for example, Shops and <u>assembly</u>)

- **Fire growth rate: 2** (Medium, Wooden pallets, stacked cardboard boxes), **3** (Fast, Stacked plastic products, baled clothing), and **4** (Ultra Fast, Flammable liquids, expanded cellular plastics).

BS 9999 does not allow to design of a building with the four fire growth rates, but it is possible to decrease the category by using additional fire protection measures. Depending on the initial profile of the risk, specific elements of fire protection can be determined (dimensions of the components or dedicated equipment)

1.4. Conditions

Fire risk assessment is part of preparing the strategic plan for fire protection (Brzezińska and Bryant, 2018b). Brzezińska and Bryant (2018b) state that two conditions must be considered: terrain, construction, and human issues. The human issue should take into consideration four main rules: a) all people in the building should have enough time to leave the building safely, b) all evacuation routes should provide appropriate fire characteristics so that all people can evacuate, c) the construction have enough fire resistance to allow people to evacuate and appropriate safety services can work safely, d) if the evacuation is not possible, people should have a possibility to move to the shelters.

As for terrain, localization, and construction issues, for proper evaluation of the risk and preparation of the strategy, not only the properties of the building should be evaluated, but also the vicinity of the building. From the construction point of view, the following aspects are important:

- The fire resistance of the construction – in each country, as presented in chapter 2, there is specific regulation on what materials can be used for particular building parts. For example, there are requirements for the main construction parts, usually the harshest ones (so the building can sustain fire load for long enough time to allow the evacuation of the people and safe work to the fire brigades) and requirements for the facings of the building: both for ceilings, walls, and floors (depending on the used materials, for example for decorative issues, one can contribute to the fire loading of the building). Usually, each element's fire resistance requirements are given in local design ordinances or specifications, with the minimum fire resistance class of each component. During fire risk assessment, one can compare the designed elements with the requirements or prepare the simulation model to evaluate the designed parts.

- The type of production or stored products – the issue is very important in the case of industrial buildings. Many industries provide processes with a very high fire risk (like processes that work on an open fire) or store highly flammable liquids, gasses, or products. Depending on the country, each industry type can have its requirements from the fire risk point of view or only additional requirements for localizing specific functions in the industrial buildings. On the other hand, in the second approach, particular industries, such as gas transit and the petrochemical industry, due to their strategic importance and high cost of potential fire (both for economic and environmental aspects), can have specific additional law regulations.

- Additional impact on the fire risk assessment in the building have installed equipment and design of specific elements (like sprinklers or/and smoke exhaust devices), like evacuation routes. Each of the components should be taken into consideration depending on the function of the building and the possibility of working with each other. Some of the elements can change the risk category of the building.

But in the case of making a risk assessment and during the preparation of the risk strategy, terrain consideration should be included. Localization of the building and its vicinity are very important factors. Elements that should be taken into consideration are, for example:

- **The localization of the nearest fire department services and its equipment.** For each industry type, fire experts should assess how long it will take to provide the service of the fire department and if the department would be enough to provide the appropriate safety and rescue services

- **The roads lead from the fire department to the analyzed building.** Fire experts should take into consideration the possibility of arriving at the facility at different times of the day (for example, during rush hours, if the building is located in the vicinity of work/school / shop places) and the possibility of arriving at the fire source (lack of terrain barriers, or artificial barriers on the building locations – such as parking vehicles or storage of goods on the fire roads)

- **The neighboring buildings and other land usages:** Fire experts should analyze what impact the studied building or industry plant can have on the adjacent buildings and their fire strategies if known. A fire that can appear near the analyzed building can spread to the analyzed location. Usually, there are specific regulations (ordinances, standards) regarding the building spacing from neighboring sites.

- **Additional considerations.** While regulations do not require it, additional aspects can be included in the fire risk assessment and protection strategies. Some industries can be located near natural water storage like lakes or on the seaside, which also can be included as a fire protection measure.

As stated before, different analysis methods can be used during risk assessment. It can be either a direct comparison of the values of the designed building with specific requirements, or more complicated computational simulations can be prepared. Nevertheless, each method should assess the fire risk and provide enough information for its prevention or preparation of the appropriate fire prevention strategy.

2. Strategic Plan of Fire Prevention

A strategic fire prevention plan is made based on one or more of the methods presented above of risk assessment. It combines each aspect (materials/building/ fire prevention appliances/people) to determine the general risk of fire. One can prepare different strategic fire prevention plans depending on the most important aspect: people, products, processes, or environment. And for each aspect, one can analyze additional measures with different scores. Based on such analysis, one can choose the best combination for each building and process.

Brzezińska and Bryant (2018b) presented one such strategic plan. They explained the evaluation of the fire strategy based on the PAS 911 standard. It combines Polish-specific design parameters (Ordinance, 2019) into the assessment. The fire strategy value grid and the properties are considered and reported after (Brzezińska et al., 2019).

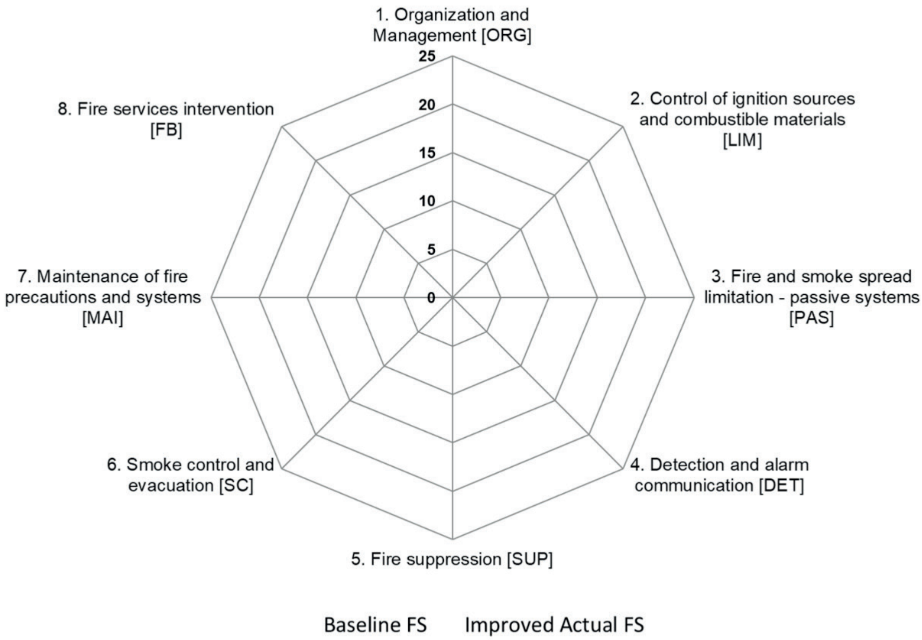

Figure 14. *Fire strategy value grid, after (Brzezińska et al., 2019).*

Table 25. *Detailed questions for the fire strategy safety factors scoring method (Brzezińska et al., 2019).*

1. Organization and Management	Score Scale
1. Have internal procedures/instructions been implemented, which take into account the specific requirements for power plant facilities? For example: general instructions regarding the scope of fire safety management organization, procedures for hazardous work, fire safety instructions, explosion protection documentation, the rules concerning the operation of equipment and installations in case of fire,	0 ÷ 5
2. Are emergency and evacuation drills regularly conducted in line with emergency plans? Do fire and rescue service operatives participate in the exercises? How often are fire scenario drills conducted?	0 ÷ 4
3. Are systematic periodic and documented fire safety inspections carried out on facilities/grounds/areas as well as equipment, installations and fire safety and protection infrastructure and safeguards against disasters?	0 ÷ 4
4. Is round the clock protection of the power plant facilities operations ensured by its own or stationed on-site FRS (fire and rescue service)?	0 ÷ 6
5. Has an integrated system of coordination of all fire and explosion protection activities been implemented as well as for the scope of protection against disasters and local unspecified hazards?	0 ÷ 4
6. Is a fire fighting training program systematically conducted for company's staff? Have work conditions been established for external contractors with respect to fire and explosion protection?	0 ÷ 2
2. Control of Ignition Sources and Combustible Materials	**Score Scale**
1. Have procedures of flammable materials and industrial gases storage management been implemented?	0 ÷ 4
2. Have proper conditions been ensured for the storage and processing of fire-hazardous materials? For example: location, arrangement, fire load of a building/ground, access etc.	0 ÷ 4
3. Have organizational and technical measures been applied to reduce explosion hazards? For example: removal of accumulated dust, reduce emission of explosive agents, etc.	0 ÷ 4
4. Have possible ignition sources and other fire hazards been identified?	0 ÷ 3
5. Have proper detection systems been selected for the identified sources of ignition?	0 ÷ 5
6. Have appropriate ignition/explosion reduction systems been identified for the identified ignition sources?	0 ÷ 5

7. Maintenance of Fire Precautions and Systems	Score Scale
1. Has an inventory been taken, and criticality established, of fire protection and firefighting systems? This should also consider "EX"-rated devices, protection systems, and facilities to protect against environmental disasters and other local hazards, etc.	0 ÷ 4
2. Have the rules/procedures for regular maintenance and inspection of such systems been established?	0 ÷ 4
3. Are inspections, maintenance, repairs, and overhauls of fire protection equipment undertaken against the rules/procedures?	0 ÷ 4
4. Are there adequate documents and records confirming the maintenance regime is being properly attended to?	0 ÷ 3
5. Are support systems or methods to allow proper operation of these systems also regularly checked (e.g., room integrity testing for gaseous extinguishing systems)?	0 ÷ 6
6. Are changes in fire protection system design and arrangement recorded and monitored?	0 ÷ 4
8. Fire Services Intervention	**Score Scale**
1. Are awareness and skills of operational employees/staff sufficient to undertake or support firefighting and rescue operations?	0 ÷ 4
2. Is the arrangement and layout of facilities/installations conducive to fire-fighting and rescue operations? Considerations should include complexity of building layout, high-rise structures, availability of internal passageways, etc..	0 ÷ 4
3. What is the expected attendance time of the fire and rescue service: [s] (>900)/(>600, ≤900)/(>300, ≤600)/(≤300)?	0 ÷ 4
4. Is there a good internal fire-road network on any part of the site?	0 ÷ 3
5. Do facilities/installations have equipment to facilitate rescue operations: "dry risers", ladders, staircases to be used by firefighters, fire-proof staircase vestibules, cranes for rescue operations and other?	0 ÷ 4
6. Are there fire-fighting and rescue operations based on-site? Are they equipped with specialized equipment such as vehicles, special firefighting systems, etc.?	0 ÷ 6

5. Fire Suppression	Score Scale
1. Are there fire water mains in place ensuring a sufficient and reliable supply of water (including reserve sources/intakes)? Have all requirements for the fire-water pump housings been met?	0 ÷ 5
2. Are all high risk facilities/process systems properly fitted with dedicated hydrant network? Is the hydrant network properly maintained?	0 ÷ 4
3. Are portable extinguishers properly arranged and labelled? Are extinguishers periodically inspected?	0 ÷ 2
4. Have localized fixed fire extinguishing devices and explosion protection systems been installed to protect specific risk areas? Are they designed and installed in accordance with established standards?	0 ÷ 4
5. Have systems been chosen to minimize delay in fire suppression and control?	0 ÷ 4
6. Will the choice and design of fire suppression systems ensure containment of a fire (and smoke) within a specific fire zone?	0 ÷ 6
6. Protection of Evacuation Routes (Smoke Control and Evacuation)	**Score Scale**
1. Have the required characteristics of escape routes and exits been implemented?	0 ÷ 6
2. Has it been ensured that staircases and lobbies are sufficiently fire separated from risk areas by walls of, say, at least 60 fire resistance?	0 ÷ 6
3. Are escape passages and exits labelled with safety signage complying with local standards? Have escape passages and exits been fitted with appropriate emergency escape lighting?	0 ÷ 4
4. Has the building been equipped with smoke and heat exhaust ventilation systems for horizontal escape routes to provide proper conditions for evacuation and for firefighting?	0 ÷ 3
5. Has the building been equipped with smoke and heat exhaust ventilation of staircases to provide proper conditions for evacuation and for firefighting?	0 ÷ 4
6. Are main spaces within the building covered by smoke and heat exhaust ventilation to provide proper conditions for evacuation and for firefighting together with structural protection?	0 ÷ 2

3. Fire and Smoke Spread Limitation—Passive Systems	Score Scale
1. Have the industrial buildings been properly divided into fire zones while observing their permissible size, which depends on: fire load, existence of explosive zones, status of automatic extinguishing and smoke ventilation systems?	0 ÷ 6
2. Has a strategy of fire compartmentation been used in the facility, adopting appropriate levels of fire resistance?	0 ÷ 5
3. Is the systematic monitoring of the condition of fire compartmentation carried out, for example, after repairs or alterations?	0 ÷ 4
4. Are periodic inspections of the condition of supporting passive fire protection installation carried out? For example: lightning connectors, vertical flues (e.g., chimneys), ventilation ductworks, etc.	0 ÷ 4
5. Is the process equipment fitted with devices ensuring limitation of fire/explosion spread?	0 ÷ 5
6. Are fire detection systems integrated with process system protection, especially taking into account domino effect possibilities?	0 ÷ 3
4. Detection and Alarm Communication	**Score Scale**
1. Have buildings/process systems been fitted with fully functioning fire detection and alarm system signaling to a central fire panel?	0 ÷ 6
2. Have the fire sensors been chosen to ensure optimum fire detection within the areas they are used?	0 ÷ 4
3. Does the arrangement of sensors comply with their specifications with regard to siting and spacing?	0 ÷ 4
4. Do detection circuit and communication cables have sufficient resilience against a fire and mechanical damage?	0 ÷ 3
5. Is the functionality of the fire detection and alarm system periodically checked against approved check-lists? Are records kept of this?	0 ÷ 5
6. Is the system and use of that system configured to minimize the impact of false alarms, equipment service point properly organized and equipped? Does the system require confirmation by local staff before contacting the fire brigade or is automatic coincidence-based fire detection used to communicate a fire without manual intervention?	0 ÷ 3

Using such detailed analysis can allow us to determine the numerical assessment of the provided strategy using, for example, the fire risk index. First, one should assess the points for each factor, and the assumed or recommended weight ratios determine the fire protective measures. Next, one should evaluate the fire risk based on the assumed fire risk class. The last element is the assessment of the fire risk frequency, considering the statistical information regarding the fires in specific types of industries to the total number of particular kinds of industries. It should be noted that different strategies can be provided for the same type of building, depending on the most important aspect taken into consideration during the preparation of the fire strategy: people safety, goods safety, production continuity, and environmental protection.

Conclusions

The chapter presented only the most basic fire risk analysis methods. Still, they are sufficient to evaluate the specific industry building for identifying sources of fires, determining the required prevention methods, analyzing their rationality based on costs, and selecting the most optimum strategic plan for fire prevention. As presented, many basic and sophisticated ways are available, but in most cases, they evaluate the probability of events that lead to the ignition. But one should also consider that a valid database of previous fire events is essential for correctly assessing risk. It is an element that could be lacking in many countries. But at the end of the day, it is always the role of the investor which accepts the appropriate level of risk based on regulations, possible losses, and potential costs of fire prevention methods installed in the building. And the more important/strategic building, the potential fire risk should be as low as possible.

Fire risk analysis is not a single event. One should monitor its validity of it regularly. All aspects of the basic strategy should be verified in such an event. Each aspect should be controlled regularly, and the report should be done from each control. One should check the state of the building, the state of internal installations, the state of fire prevention methods, the state of general appliances, and so on. Each element wears with time and should be monitored and replaced if needed. Also, the routine during work and storing products on evacuation doors/ways could negatively affect fire risk.

Other important aspects are regular drills and education courses for the employees to know the fire prevention methods, the evacuation plans, what the evacuation roads are, and where the safe places or evacuation points are. Also, one should monitor if the employees or temporary visitors obey the OHS plans. And general practice shows that in many cases, not enough attention is given to this matter.

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CHAPTER 7.

FIRE DETECTION, WARNING, AND EXTINGUISHING SYSTEMS

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FIRE DETECTION, WARNING, AND EXTINGUISHING SYSTEMS IN INDUSTRIAL PREMISES

Fire detection and warning systems, one of the most important mechanisms of fire extinguishing systems, consist of devices detecting the fire starting behind the scenes in the early phase. These systems assist in the prevention of both life and property loss. The thing that starts the fire extinguishing process is these systems. The fire extinguishing systems are functioning in the extinguishing of the fires in the early phase. In this chapter, the extinguishing systems and their characteristics will be discussed after the fire detection, and alarm systems are introduced.

1. Fire Detection and Alarm Systems

Fire detection and alarm systems have different headpieces or sensors to detect fire types. It is possible to identify the fire detection systems over two headings as those displaying sensitivity against smoke and heat. Optical (ionized), photoelectric, and ionized/photoelectric types are sensitive to smoke. The heat-type detector is heat-sensitive (Fire Risk Consultancy Services, 2022).

1.1. Smoke Detectors

The most common three smoke detectors are a combination of ionization, photoelectric, and ionization/photoelectric. All smoke detectors sound alarms to inform the residents of the building once they detect smoke. What differentiates these detectors is the mode of detecting the smoke.

1.1.1. Ionized Smoke Alarms

These detectors are perfect for the detection of fires flaming quickly. They are relatively cheap systems, and they are cost-efficient. They are too sensitive to the small smoke particles that flame rapidly, like paper and wood, and they detect such fires before the smoke becomes thick.

Photo 12. *Smoke Detector*

1.1.2. Photoelectric (Optical) Alarms

These detectors are effective in the detection of smoke particles arising from the fires burning slowly and internally. They are slightly expensive; however, they are more effective than ionized smoke detectors in detecting bigger smoke particles from slowly burning fires.

Photo 13. *Optical Alarm*

1.1.3. Ionized/Photoelectric (Multiple Sensor) Alarms

They are designed to be sensitive to a wide range of fires and quickly react to both fast and slow-burning fires. Since this system monitors two different byproducts of the fire (smoke and temperature), their reaction to any fire has significantly developed further compared with the conventional single-sensor alarms.

Photo 14. *Ionized Alarm*

1.2. Heat Detectors

Although they can detect any increase in temperature, they are insensitive to the smoke. The heat detectors detect heat and any increase in air temperature. Detection of any fire lasts longer than detection by smoke detectors. Once it is considered that the smoke detectors may lead to wrong alarms in vaporous, humid, or dusty atmospheres, the heat detectors are ideal sensors. For this reason, they are suitable for places such as kitchens, garages, and attics. The heat-sensitive detectors may be divided into two types. The first type runs once exposed to a pre-designated temperature (constant temperature). The second type runs by the rate of temperature increase.

Photo 15. *Heat Detector*

1.3. Fire Alarm (Warning) Systems

Fire alarm systems are designed to enable any fire to be detected at an early phase. These systems help the people at risk escape and move away from the fire zone, intervene and extinguish the fire early, and prevent probable material damages. These systems, which can be applied in almost any part of life, play an active and effective role in building a more reliable environment. The fire alarm systems generally have the following components (State Fire Marshal, 2022, pg. 3-4):

1. Alarm Starting Circuits: These are the circuits connecting starting devices such as smoke detectors, heat detectors, manual alarm stations, and water flow alarms. Additionally, many system monitoring devices, important in terms of the total fire safety of the building, are connected to starting circuits. These devices display an "abnormal" circumstance, not a fire or "alarm" circumstance.

2. Alarm Indication Circuits: Devices giving audible and visual alarms to warn the building residents are connected to these circuits. Devices sending a signal out of the plant may also be connected to these circuits.

3. Fire Alarm Control Panel: The fire alarm control panel contains electronic accessories that supervise and monitor the fire alarm system. The starting and indication circuits are directly connected to this panel.

4. Primary Power Supply: Primary power supply provides power to the fire alarm system. The primary power is typically supplied by connecting to the infrastructure of the building, providing energy for the fire alarm systems.

5. Backup Power Supply: If primary power is turned off, a separate power supply that will operate automatically and activate the whole system is regarded as a secondary power supply.

The audible types are largely and commonly used in alarm systems. Besides there are also electronic sirens that contain verbal announcements previously recorded of different types. Many alarm siren types that are different from each other are available. The selection of these devices depends on whether they have distinctive tones, determined by the application zone, legal requirements, and need (Bhatia, 2022).

1. Alarm bells are the most common and familiar alarm-sounding device, enabling the application in many buildings.

2. Horn is another option and is particularly suitable for areas where a loud signal is required, particularly libraries and buildings that are architecturally sensitive and where devices are parts needed to be hidden.

3. Gongs like healthcare facilities and theatres may be used where a soft alarm sound is preferred.

4. A loudspeaker is the fourth alarm sound option sounding repeatable signals like a recorded audible message.

5. Audible communications devices can be integrated into loudspeakers installed in a building or into a fire alarm system connecting the general speaker systems to central control. In such cases, the audible alarm signal runs for a pre-designated period and can be muzzled while the loudspeakers are active. These systems enable the fire department personnel to instruct the building residents about the procedures to be pursued during any fire. They are generally ideal for other similar large, multistory buildings where gradual evacuation is preferred.

The sound levels should generally be 65 dBA or five dBA above the constant background noise level. The sound level can be reduced to 60 dBA in rooms smaller than 600 m^2, well holes, or at certain limited points of the building. Most sirens have an adjustable output level providing a balance between covering the requirements of the intended standards and providing an audible sound at a reasonable level. The sirens generally with lower outputs are better than the sirens with several high outcomes in this respect.

2. Fire Extinguishing Systems

Fire protection systems are designed to detect, control, and extinguish fires. It is possible to discuss passive and active systems under two main groups. Passive systems are the devices installed as a process or any part of the structure designed to prevent the fire's ignition, constrain the fire's development and growth, prevent the fire from spreading, and contribute to lose prevention and control attempts without any active intervention. We can give the firewall as an example of a passive system. The firewall fulfills its task by its internal design without changing its character or function in case of emergency. The active systems are the components that are protected from an installed fire and participate in the fire extinguishing process by operating mechanically in case of emergency. For example, a sprinkler system works to discharge water to control and extinguish the fire at the moment when the fire breaks out (Craig, 2002).

2.1. Passive Fire Protection Systems

Passive Fire Protection is a group of systems that separates the structure with high fire-resistant wall and fixtures and prevents the quick spreading of fire, save time for the escape of the users at the building, and creates fire-resistant structures. Passive fire protection does not require any external power. There are three types of passive fire protection measures (Janssens, 2003, pg. 2-103):

1. Fire Growth Rate: Any fire in a room can be controlled to such an extent by using internal coatings having certain ignition, flame spread, and heat spread characteristics. A slow fire gives more time for a safe exit of the building residents and minimizes material damage generally during manual or automatic extinguishing.

2. Separation/Dividing: If the fire is big enough to cover the exit room, the next step is to keep the fire within a limited area, at least for a while. Thus, the fire spread to the other divisions of the building or adjacent building is delayed or prevented. This process is called separation. The separation is performed by rendering the mechanisms on the ground, wall, and ceiling fire-resistant and protecting the gaps and leakages throughout the room borders. Hence, it also includes the protection of structural elements and mechanisms for preventing or delaying the collapse partially or wholly in case of fire.

3. Emergency Exit: The third type of passive fire protection measure relates to the emergency exit. The escape corridors, doors, and stairs should be broad enough to enable the flow of people in case of an emergency evacuation. The building residents should have access to emergency exits at adequate numbers for the maximum distance to reach a safe area before the conditions become intolerable.

The following may be shown as examples of the Passive Fire Protection Systems commonly used (DEF Fire, 2022):

- Passive Fire Suppressor Foam: These are solid and rapidly cured materials with a high level of water resistance to create fire, smoke, and moisture barriers around the cable conduits and mixed passages.

- Passive Fire Suppressor Panel Systems: These are the systems covered by one or two-sided fire retardant paint depending on where fire isolation will be performed and equipped with a material serving to minimize the high-intensity temperature increase. Two types of structural fire suppressor material are generally used; metal and rock wool.

- Passive Fire Suppressor Brick: These bricks create a barrier for temporal and permanent isolation of cables in the wall and fixture cavities, cable trays, and pipes. These bricks are made of heat-resistant sensitive special materials.

- Passive Fire Suppressor Clamp, Winding, and Bandages: Fire suppressor pipe windings are designed to protect the fire-resistance integrity of the penetrations through which the various plastic pipes pass.

- Passive Fire Suppressor Paint: These are acrylic-based mineral additive materials. These materials are intumescent (increasing volume at high temperature) and ablative (protecting the material beneath itself without burning by absorbing the heat and charring at high temperature).

- Passive Fire Suppressor Mortar: A plaster or cemented powder generally reinforced by inorganic light filling, composite, and blended with chemical regulators. The composites are designed to be mixed with water creating a rigid seal around and among the penetrating services.

- Passive Fire Suppressor Mastic Sealant: These are the fire suppressor mastic sealants consisting of different main materials to offer solutions to various details, such as acrylic, silicone, and graphite. The fire suppressor mastic sealants provide fire insulation for up to 4 hours in the joints with low, medium, and high motion capacity and various electric and mechanical penetrations.

2.2. Active Fire Protection Systems

Active Fire Protection systems are a system group requiring intervention to operate efficiently in case of probable fire. These system groups may be applied as Manual Intervention Systems (Portable Fire Extinguisher, Indoor Hose Cabinet, etc.) or Automatic Intervention Systems (Automatic Sprinkler System, Automatic Gaseous Fire-Extinguishing System, etc.). For this reason, a fire alarm will warn those in the building and operate to actively extinguish or control the fire once any heat and smoke are detected in a plant. The commonly used Active Fire Protection Systems are given below (DEF Yangın, 2022):

- Sprinkler Systems: In the wet pipe extinguishing systems, the automatic sprinkler is connected to a particular water supply and mounted to the pipe systems containing water. The sprinkler is opened upon the impact of the heat arising from the fire, and the water intensively flows onto the burning material. The fire's heat activates the system automatically; the water can be discharged onto the flammable material through a sprinkler.

- Foam Extinguishing Systems: Foam fire-extinguishing systems are generally used to extinguish flammable and liquid chemicals or fuels. Protein-based, synthetic-based, alcohol-resistant, and film-former foam types may vary depending on the chemical characteristics. While they are automatically designed, the foam fire-extinguishing systems are produced manually to prevent the fire's growth by immediately intervening in the fire zone.

- Gaseous Fire-Extinguishing Systems: Gaseous Fire-Extinguishing Systems are preferred in cases where the material in the environment to be protected is valuable, it will be damaged by water, or there are risks of fire which cannot be extinguished and can spread through water.

- Kitchen Hood Extinguishing Systems: They help extinguish the fires breaking out in the areas where hoods are used. Such fires are frequently encountered in kitchens where particularly hoods are mostly preferred. The hoods serving to clean the ambient air take the internal air out of the space. For this reason, it accumulates flammable materials like oil in itself. If the Hood Extinguishing System is not regularly cleaned, the intensity of the volatile material like oil increases daily; in such case, a fire is likely to break out. Therefore, cleaning the hoods regularly and removing the waste accumulating in them is required. Otherwise, the accumulating flammable materials and wastes may lead to a big fire.

- Water Mist Extinguishing Systems: Water being kept in a mist cloud in small particles is called a water mist fire-extinguishing system. Water mist extinguishing systems increase the absorption area of the ambient heat energy; thus, they are called water mist extinguishing systems within the fire-extinguishing systems. Being divided into two groups, this system may be discussed individually as single-agent and double-agent systems. The most common one between these two systems is the double-agent system. Cylinders kept in an unpressurized mode are activated upon the explosion of nozzles utilizing Nitrogen cylinders stored at a pressure of 200 bars. A homogenous water mist occurs at the intended level and volume thanks to a special piping system.

- Indoor Fire Hose Cabinet Systems: The fire cabinet system is where the pressurized water from the fire cabinet system, pump station, or free pipeline reaches the nozzle at the tip of the hose being kept within the cabinet. The purpose of the installation is to provide reliable and adequate water in the fire intervention within the building. For this purpose, the fire brigade's water inlet line and fire cabinets are positioned within the building.

- Hydrant Systems: Fire hydrants supply the water required for the trained firefighters to intervene in the fire. The hydrant connects the main fire supply line to take water from the main fire supply line to the hose and other fire protection devices. Fire hydrants are the nozzles left for the fire brigade to connect during the fire intervention. The brigade trucks are supplied water by the hydrants positioned out of the building at certain intervals during the fire, or the fire can be intervened by connecting to the hose directly. The connections of the hose lines are fed by the municipal water system or the fire pump in large-sized enterprises.

- Foam/Water Monitor Systems: Water and foam monitors are ranked among the fire equipment used for supplying the risky or affected zone the water or foam at required and correct amounts as soon as possible from a reliable distance in the high-risk fires which could not be closely intervened and typically spread on wide areas. They provide high performance in phases of extinguishing and suppression of the fire. While they can be used by fixing several areas in the fires that required to be intervened for a long time or environments spreading onto wide spaces, they can be easily used by mounting from the intended angle through the portable monitors.

- Foam Spray Systems: These are the fixed systems operating by mixing the foam concentrate at a certain amount with the pressurized water and spraying this mixture through a sprinkler or nozzle. Once the system is activated, a particular amount of the foam concentrate in a tank mixes in water. With this method, a highly effective extinguisher, low or high-expansion foam, is formed. This foam mixture hits the sprinkler's deflector or nozzle under a particular pressure or flow rate and is sprayed onto the area where the extinguishing process will be applied. At the same time, the water flow in the pipes activates the local alarm system; thus, the fire brigade is informed. As in the sprinkler extinguishing systems, the foam extinguishing systems may also be reusable after the fire is controlled. However, a new foam concentrate must be added to the tank. It is a complicated, reliable, and very effective system providing fast extinguishing. It is ideal for use in regions where flammable liquids are stored.

2.3. Portable Fire Extinguishers

There are many fire extinguisher types and each of which has certain advantages and disadvantages. For this reason, it is essential to understand each fire extinguisher's abilities while selecting one to protect a particular hazard or area.

2.3.1. General Principles

The type and number of portable extinguishing tubes are determined by the existing conditions and risks in the spaces (Regulation on Protection of Building from Fire, Article 99). Accordingly;

- Multi-purpose extinguishing tubes containing dry chemical powder or water are kept in the places where Class A fire is likely to break out,
- Extinguishing tubes containing dry chemical powder, carbon dioxide, or foam in the areas where Class B fire is expected to break out,
- Extinguishing tubes containing dry chemical powder or carbon dioxide in the places where Class C fire is likely to break out,
- Extinguishing tubes containing dry metal powder in the areas where Class D fire is expected to break out.

It is required to make 1 () proper type fire extinguishing tube of 6 kg available for every 500 m^2 of a construction site in the light hazard class and every 250 m^2 of a construction site in the ordinary hazard and extra hazard class. Also, making wheeled-type extinguishing tubes in parking lots, warehouses, plumbing rooms, and similar areas is compulsory. The extinguishing tubes are distributed outwards in a balanced manner and near passage spaces, marked visibly, and placed in easily accessible places under any circumstances and into and near the fire cabinets. The access distance of the extinguishing tubes is a maximum of 25 meters. For portable extinguishing tubes, the wall-mounting hanging ring of the extinguisher could be easily removed from the wall. An international quality certificate must accompany the wheeled fire extinguishers and other portable fire extinguishing tubes. The national and international standards perform the periodical control and maintenance of the fire extinguishers. The manufacturers or services engaging in the care of the extinguishers must have a filling and service competence certificate certified by the Ministry. The corporations providing service must show their certifications to their customers upon request. It is an obligation to check the extinguishing tubes every six months, to perform their annual general maintenance, to use a powder that complies with the standards, and to replace the powder at the end of four years. The local fire brigade may be consulted regarding establishing the type, quantity, and places of the fire extinguishing tubes to be positioned in buildings if required.

2.3.2. Types of the Portable Fire Extinguisher

A portable fire extinguisher is a pressurized device serving to cut the connection between heat and oxygen thanks to the materials in its content. These devices, which can be produced in many different sizes and characteristics, are of great importance, particularly in extinguishing fires that are in an early phase. The fire tubes are made in different types on the features of the fires in which they are used. The most popular and commonly used portable fire extinguisher types are given below.

2.3.2.1. Water-based Fire Extinguishers

Photo 16. *Water-Based Fire Extinguisher.*

Water extinguishers are available in two types: pump-type fire extinguisher, which discharges the water utilizing a pump operated by the user, and pressurized extinguisher, which employs air pressure to release the water. The pressurized water extinguishers are suitable only for Class A fires. Once it is first discharged, it has a range of about 30 ft. (9,2 meters) and a discharge period of about one minute. They are pressurized with a pressurized air of 100 psi (690 kilopascals). Water extinguishers have many advantages. Cleaning water is usually easy and does not lead to too little or too much extra damage. Charging the extinguisher is cheap, and they are easily returned to the service by in-house personnel with limited training. The water's wetting capability is a significant advantage in fighting Class A fires. The water extinguishers also have some disadvantages. For example, these units are only effective in Class A fires and can be dangerous once used in another fire class. The extinguishers are relatively heavy. The team can be exposed to freezing in any area not being heated continuously. An anti-freeze may be added to prevent freezing; however, this further complicates maintenance (Craig, 2002).

2.3.2.2. Foam-Based Fire Extinguishers Foam spray extinguishers (AFFF-Aqueous Film Forming Foam) are ideal for too-risky situations in which both Class A combustible materials and Class B flammable liquid risks directly represent a hazard. The foam spray extinguishers are suitable for Class B fires containing flammable liquids such as oils, alcoholic beverages, greases, and certain plastics. The covering impact of the foam spray provides a fast demolition choking the flame and preventing the flammable vapors' re-flaring by covering the solution's surface (Tyco, 2012).

Photo 17. *Foam-based Fire Extinguisher.*

2.3.2.3. Dry Chemical Extinguishers

Dry Chemical Extinguishers are available in different types. You can see them in the labeled form:

- "DC" is an abbreviation of "dry chemistry."
- "ABC" specifies that they are designed for extinguishing Class A, B, and C fires or
- "BC" specifies that they are designed to extinguish Class B and C fires.

"ABC" fire extinguishers are filled with a thin yellow powder. A large part of this powder consists of mono-ammonium phosphate. Nitrogen is used for pressurizing the extinguishers. "ABC" extinguisher has a label showing that it can be used in Class A, B, and C fires. Dry chemical extinguishers extinguish the fire by separating the fuel from the ambient oxygen and covering the fuel with a thin powder layer. Since the powder also operates to interrupt the fire's chemical reaction, these extinguishers are highly effective in extinguishing the fire. These extinguishers may be kept in laboratories, mechanical rooms, resting rooms, chemical storage areas, offices, etc. (Capital Fire Protection, pg. 6).

Photo 18. *Dry Chemical Extinguishers.*

2.3.2.4. Carbon-dioxide Fire Extinguishers

Carbon dioxide extinguishers are filled with non-flammable carbon-dioxide gas under overpressure. You can distinguish any Co^2 extinguisher from its firm horn and the lack of its pressure gauge. The pressure in the cylinder is so big that once you use one of these extinguishers, dry ice particles can fly from the horn. Co^2 cylinders are red, and their sizes vary between 5 pounds-100 pounds and above. The carbon-dioxide extinguishers are designed only for Class B and C (flammable liquid and electricity) fires. Carbon dioxide is a non-flammable gas that extinguishes the fire by substituting oxygen and taking the oxygen element of the fire triangle. Since it comes from the fire extinguisher, carbon dioxide is too cold at first. Thus, it also cools the fuel. The carbon-dioxide extinguishers may be ineffective in extinguishing the Class A fires because they could not satisfy the oxygen satisfactorily to extinguish the fire successfully. Class A materials can also burn internally and reignite. The carbon-dioxide fire extinguishers are frequently kept in laboratories, mechanical rooms, kitchens, and inflammable liquid storage areas (Capital Fire Protection, pg. 5).

Photo 19. *Carbon-dioxide Fire Extinguisher.*

2.3.2.5. Halon Extinguishers

Halon extinguishers contain a halogenous hydrocarbon agent forced into the liquid state under pressure. The most common halons for portable extinguishers are Halon 1211 (bromochlorodifluoromethane) and Halon 1301 (bromotrifluoromethane). Such type of fire extinguisher has various sizes in a range of 1,5 and 22 pounds (0,68 and 9,9 kilograms). The discharge time varies between 8 and 30 seconds. The discharge range is between 9 and 15 ft. (2,7 and 4,6 meters). These extinguishers also have a discharge time of 30-35 seconds and a range of 10 and 18 ft. (3-5,5 meters). There are also wheeled units weighing 150 pounds (68 kilograms) (Craig, 2002).

Photo 20. *Halon Extinguisher*

Photo 21. *Halon Extinguisher (Wheeled Unit).*

Halon extinguishers have many advantages. They can be used in Class B or C fires, and it has also been approved that bigger units can be used in Class A fires. Halon does not leave any residual. For this reason, the cleaning is not a trouble. The units are not exposed to freezing. Thus, they can be placed out of the building. They generally provide more effective fire control than the carbon-dioxide extinguishers. Halon extinguishers also have some disadvantages. For example, smaller units are not suitable for Class A fires. Also, halon is expensive. The refilling costs may come close to the first purchasing price or exceed it. It was found that the halons contribute to ozone layer depletion in the atmosphere. It is likely to make the regulations regulating the use of halon more restrictive.

2.3.2.6. Halotron

Halotron I does not leave any residual. It quickly evaporates and discharges in the form of liquid. It effectively extinguishes the Class A and B fires by cooling and choking and does not conduct the electricity to the user. Halotron is pressurized with Argon gas and is an EPA and FAA-certified agent suitable for being used in Class A, B, and C fires. It has a low Global Warming Potential (GWP) like 0,04-0,24 and 0,014 (permissible maximum ODP of EPA is twelve times lower than 0,20) and a low Atmospheric Life ($3^{-1/2}$ – 11 years). Halotron I is an environmentally-acceptable chemical mixture based on HCFC-123 raw material, reliable and effective. It was primarily used in place of Halon 1211, depleting the ozone layer or bromchlorodifluoromethane (BCF) in 1992. Halotron I is discharged as a rapid evaporative liquid in a shooting length of 6 ad 45 ft (1,8 and 13,7 meters). A relatively high boiling point at 80.6°F (27°C) provides an advantage compared with other clean fire extinguishing substances tending to have a lower boiling point and evaporate more quickly; this restricts the shooting length and general effectiveness for non-expert fire-fighters. Also, in contrary to conventional dry chemical substances like mono-ammonium phosphate (ABC Dry Chemical) or potassium bicarbonate (Purple K), which can be abrasive, Halotron I is a clean material that does not leave residue after application and consequently gives less damage or no secondary damage (American Pacific).

Photo 22. *Halotron.*

2.3.2.7. FE-36

Photo 23. *FE-36.*

FE-36 is a safe, clean, and electrically non-conductive substance. Since it has a similar boiling point (–1.4 °C [29.4 °F]) to Halon 1211(–3.4 °C [26 °F]), it is ideal for being used in all flow applications. FE-36™ is also useful as a full flood and explosion suppression substance. FE-36™ is a perfect alternative for Halon 1211 in portable fire extinguishers. FE-36 is not abrasive, is not electrically conductive, does not contain residual, is low toxicity, has a zero ozone depletion potential (ODP), and is highly effective. FE-36 discharges liquid and has an effective discharge range of up to 16 ft (4,9 meters). It is an agent preferred to protect valuable equipment or irreplaceable assets that may be damaged or destroyed by water, foam, carbon dioxide, or dry chemicals. The application areas are typically communication facilities, computer rooms, control rooms, data/document storage areas, electronic production, museums, art galleries, laboratories, and planes. The low acute inhalation toxicity of FE-36 is suitable for fire extinguishers that may be carried by aircraft. Planes are confined spaces. For this reason, it is important to consider the acute inhalation toxicity of the agent used in clean agent availability. FE-36™ has ideal characteristics for this application (Chemours, 2017, pg. 3).

2.3.2.8. Dry Powder Extinguishers

A dry powder (ABC) fire extinguisher is a multi-purpose fire extinguisher generally recommended for use in vehicles and homes. It should be noted that dry powder fire extinguishers may not be used in confined spaces. For example, once such fire extinguishers are used in closed areas such as offices, schools, and hotels, it creates a dust cloud, and this dust may lead to respiratory problems. An important point to consider is that Ammonium phosphate used in dry powder may react with water and can create a highly abrasive phosphoric acid infiltrating into the smallest cavities in electrical equipment. For this reason, dry chemical ABC grade fire extinguishers should never be used in precision electrical equipment unless there is another fire extinguishing equipment.

Photo 24. *Dry Powder Extinguisher.*

2.3.2.9. Wet Chemical Extinguishers

Wet chemical extinguishers are suitable for Class F fires containing cooking liquid and solid oils like olive oil, sunflower seed oil, corn oil, and butter. They are highly effective once they are used properly. Wet chemical extinguishes the flames quickly, cools the burning oil, creates a soap-like solution by reacting chemically, covers the surface, and prevents re-ignition. Although they are essentially designed for being used in Class F fires, cooking oils, and deep fryers, they can also be used in Class A fires (wooden, paper, and fabrics) and Class B fires (flammable liquids). The wet chemical extinguishers have a yellow label (Marsden Fire Safety).

Photo 25. *Wet Chemical Extinguisher.*

2.3.3. Placement of Portable Extinguishers

Portable fire extinguishers constitute the first defense line for the fires recently breaking out; however, these extinguishers must be accessible to be useful. The first step of this approach is selecting the correct extinguisher suitable for the type of fire. It is thought that the National Fire Protection Association (NFPA) standards may be guiding standards in this regard. NFPA-10 standard has been developed for portable fire extinguishers. NFPA-10 uses the term “maximum travel distance to the extinguisher” at the point where the fire extinguisher should be placed. This approach expresses the maximum distance to reach a fire extinguisher from any point within the building. The distance measured here is expected to comply with the distance rule of NFPA-10. Any person is required to walk to reach the fire extinguisher. The following table helps determine the necessary travel distance and maximum ground area (NFPA, 2021).

Table 26. *Maximum Travel Distance*

Extinguisher Class	Max Travel Distance	NFPA 10 Section (2018 ed.)	Notes
Ordinary A Combustibles	75 ft	Table 6.2.1.1	Travel distance can be altered by the type of hazard anticipated and the numerical A rating of the extinguisher.
Flammable B Liquids	30 ft or 50 ft	Table 6.3.1.1	Travel distance is based on the type of hazard anticipated and the numerical B rating of the extinguisher. See table 6.3.1.1 below.
Electrical C Equipment	N/A	6.4.3	Since extinguishers are never only Class C rated you need to follow the Class A or Class B rating requirements.
Combustible D Metals	75 ft	6.5.2	
K Cooking Media 	30 ft	6.6.2	Class K: Cooking Media

Since it is required to be open for the use of building residents during the evacuation, the extinguishers should be placed throughout the normal travel routes. That placement is a measure for residents to reach the fire extinguishers on their path to the exit without being stranded. Under normal conditions, the extinguishers are required to be placed at points that everybody can see. However, if a structural obstacle prevents the extinguisher from being placed, a sign showing where the fire extinguisher is placed should be posted.

The ground clearance of the fire extinguishers should be a minimum of 4 inches maximum of 5 ft. However, the weight of the extinguisher may create a special rule. For example, since the fire extinguishers are heavier than 40 Ibs and will be wheeled type, and the wheels will not enable the extinguisher to be mounted on a wall, there is no need for placing them at height.

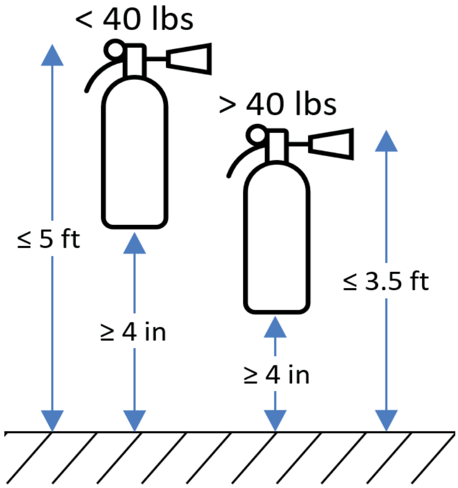

Figure 15. *Wall-Mounting of Fire Extinguishers.*

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CHAPTER 8.

EMERGENCY PLANS IN INDUSTRIAL PREMISES

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EMERGENCY PLANS IN INDUSTRIAL PREMISES

Introduction

Nobody expects an emergency or disaster -- especially one that affects them, their employees, and their business personally. Yet the simple truth is that emergencies and disasters can strike anyone, anytime and anywhere. You and your employees could be forced to evacuate your company when least expect it.

This chapter is designed to help you, the employer, plan for that possibility. The best way to protect yourself, your workers, and your business is to expect the unexpected and develop a well-thought-out emergency action plan to guide you when immediate action is necessary.

What is a workplace emergency?

A workplace emergency is an unforeseen situation that threatens your employees, customers, or the public; disrupts or shuts down your operations; or causes physical or environmental damage. Emergencies may be natural or artificial and include the following:

- Floods,
- Hurricanes,
- Tornadoes,
- Fires,
- Toxic gas releases,
- Chemical spills,
- Radiological accidents,
- Explosions,
- Civil disturbances,
- Workplace violence results in bodily harm and trauma.

How do you protect yourself, your employees, and your business?

The best way is to prepare to respond to an emergency before it happens. Few people can think clearly and logically in a crisis, so it is important to do so in advance when you have time to be thorough.

Brainstorm the worst-case scenarios. Ask yourself what you would do if the worst happened. What if a fire broke out in your boiler room? Or did a hurricane hit your building head-on? Or a train carrying hazardous waste derailed while passing your loading dock? Once you have identified potential emergencies, consider how they would affect you and your workers and how you would respond.

What is an emergency action plan?

An emergency action plan covers designated actions employers and employees must take to ensure employee safety from fire and other emergencies. Not all employers are required to establish an emergency action plan. See the flowchart on page 17 to determine if you are. Even if you are not specifically instructed to do so, compiling an emergency action plan is a good way to protect yourself, your employees, and your business during an emergency.

Putting together a comprehensive emergency action plan that deals with all issues specific to your worksite are not difficult.

Including your management team and employees in the process may be beneficial. Explain your goal of protecting lives and property in an emergency and ask for their help establishing and implementing your emergency action plan. Their commitment and support are critical to the plan's success.

What should your emergency action plan include?

When developing your emergency action plan, it's a good idea to look at various potential emergencies in your workplace. It should be tailored to your worksite and include information about all potential sources of emergencies. Developing an emergency action plan means you should assess what, if any, physical or chemical hazards in your workplace could cause an emergency. If you have more than one worksite, each site should have an emergency action plan.

At a minimum, your emergency action plan must include the following:

- A preferred method for reporting fires and other emergencies;
- An evacuation policy and procedure;
- Emergency escape procedures and route assignments, such as floor plans, workplace maps, and safe or refuge areas;

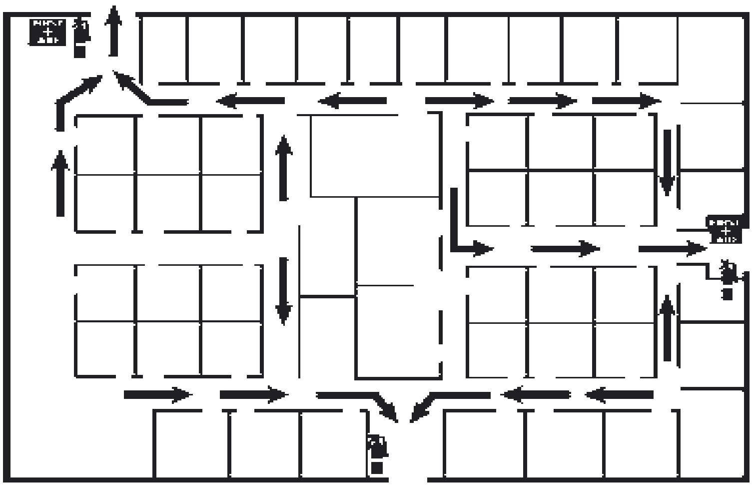

Figure 16. *Floor Escape Routes Plan*

• Names, titles, departments, and telephone numbers of individuals both within and outside your company to contact for additional information or explanation of duties and responsibilities under the emergency plan;

• Procedures for employees who remain to perform or shut down critical plant operations, operate fire extinguishers, or perform other essential services that cannot be shut down for every emergency alarm before evacuating; and

• Rescue and medical duties for any workers designated to perform them.

• You also may want to consider designating an assembly location and procedures to account for all employees after an evacuation.

• **In addition, although they are not specifically required, you may find it helpful to include in your plan the following:**

• The site of an alternative communications center to be used in the event of a fire or explosion; and

• A secure on or offsite location to store originals or duplicate copies of accounting records, legal documents, your employees' emergency contact lists, and other essential records.

How do you alert employees to an emergency?

Your plan must include a way to alert employees, including disabled workers, to evacuate or take other action and how to report emergencies, as required. Among the steps, you must take the following:

- Make sure alarms are distinctive and recognized by all employees as a signal to evacuate the work area or perform actions identified in your plan;

- Make available an emergency communications system such as a public address system, portable radio unit, or other means to notify employees of the emergency and to contact local law enforcement, the fire department, and others; and

- Stipulate that alarms must be able to be heard, seen, or otherwise perceived by everyone in the workplace. You might consider providing an auxiliary power supply if the electricity is shut off. Although it is not specifically required, you also may want to consider the following:

- Using tactile devices to alert employees who would not otherwise be able to recognize an audible or visual alarm; and

- In order of priority, provide an updated list of key personnel, such as the plant manager or physician, to notify in the event of an emergency during off-duty hours.

How do you develop an evacuation policy and procedures?

A disorganized evacuation can result in confusion, injury, and property damage. That is why when developing your emergency action plan, it is important to determine the following:

- Conditions under which an evacuation would be necessary;

- A clear chain of command and designation of the person in your business authorized to order an evacuation or shutdown. You may want to designate an "evacuation warden" to assist others in an evacuation and to account for personnel;

- Specific evacuation procedures, including routes and exits. Post these procedures where they are easily accessible to all employees;

- Procedures for assisting people with disabilities or who do not speak English;

- Designation of what, if any, employees will continue or shut down critical operations during an evacuation. These people must be capable of recognizing when to abandon the operation and evacuate themselves; and

- A system for accounting for personnel following an evacuation. Consider employees' transportation needs for community-wide evacuations.

Under what conditions should you call for an evacuation?

In the event of an emergency, local emergency officials may order you to evacuate your premises. Sometimes, they instruct you to shut off the water, gas, and electricity. If you have access to radio or television, listen to newscasts to keep informed and follow whatever official orders you receive.

In other cases, a designated person within your business should be responsible for deciding to evacuate or shut down operations. Protecting the health and safety of everyone in the facility should be the priority. An immediate evacuation to a predetermined area away from the facility is the best way to protect employees in a fire. On the other hand, evacuating employees may not be the best response to an emergency such as a toxic gas release at a facility across town from your business.

The type of building you work in may be a factor in your decision. Most buildings are vulnerable to the effects of disasters such as tornadoes, earthquakes, floods, or explosions. The extent of the damage depends on the type of emergency and the building's construction. Modern factories and office buildings, for example, are framed in steel and are structurally more sound than neighborhood business premises may be. However, nearly every type of structure will be affected in a disaster, such as a major earthquake or explosion. Some buildings will collapse, and others will be left with weakened floors and walls.

What is the role of coordinators and evacuation wardens during an emergency?

When drafting your emergency action plan, you may wish to select a responsible individual to lead and coordinate your emergency plan and evacuation. Employees must know who the coordinator is and understand that person has the authority to make decisions during emergencies.

The coordinator should be responsible for the following:

- Assessing the situation to determine whether an emergency exists requiring activation of your emergency procedures;
- Supervising all efforts in the area, including evacuating personnel;
- Coordinating outside emergency services, such as medical aid and local fire departments, and ensuring that they are available and notified when necessary; and

- Directing the shutdown of plant operations when required.

You also may find it beneficial to coordinate the action plan with other employers when several employers share the worksite.

In addition to a coordinator, you may want to designate evacuation wardens to help move employees from danger to safe areas during an emergency. Generally, one warden for every 20 employees should be adequate, and the appropriate number of wardens should be available at all times during working hours.

Employees designated to assist in emergency evacuation procedures should be trained in the complete workplace layout and various alternative escape routes. All employees and those assigned to assist in emergencies should be aware of employees with special needs who may require extra assistance, how to use the buddy system, and hazardous areas to avoid during an emergency evacuation.

How do you establish evacuation routes and exits?

Designate primary and secondary evacuation routes and exits when preparing your emergency action plan. To the extent possible under the conditions, ensure that evacuation routes and emergency exits meet the following conditions:

- Clearly marked and well-lit;
- Wide enough to accommodate the number of evacuating personnel;
- Unobstructed and clear of debris at all times; and
- Unlikely to expose evacuating personnel to additional hazards.

If you prepare drawings showing evacuation routes and exits, post them prominently for all employees.

How do you account for employees after an evacuation?

Accounting for all employees following an evacuation is critical. Confusion in the assembly areas can lead to delays in rescuing anyone trapped in the building or unnecessary and dangerous search-and-rescue operations. To ensure the fastest, most accurate accountability of your employees, you may want to consider including these steps in your emergency action plan:

- Designate assembly areas where employees should gather after evacuating;

- Take a head count after the evacuation. Identify the names and last known locations of anyone not accounted for and pass them to the official in charge;
- Establish a method for accounting for non-employees such as suppliers and customers; and
- Establish procedures for further evacuation in case the incident expands. These procedures may include sending employees home by normal means or providing them with transportation to an offsite location.

How should you plan for rescue operations?

It takes more than just willing hands to save lives. Untrained individuals may endanger themselves and those they are trying to rescue. For this reason, it is generally wise to leave rescue work to those trained, equipped, and certified to conduct rescues.

Suppose you have operations that take place in permit-required confined spaces. In that case, you may want your emergency action plan to include rescue procedures that specifically address entry into each confined space.

What medical assistance should you provide during an emergency?

If your company does not have a formal medical program, you may want to investigate ways to provide medical and first-aid services. If medical facilities are available near your worksite, you can make arrangements for them to handle emergency cases. Provide your employees with a written emergency medical procedure to minimize confusion during an emergency.

If an infirmary, clinic, or hospital is not close to your workplace, ensure that the onsite person(s) have adequate training in first aid.

Consult with a physician to order appropriate first-aid supplies for emergencies. Medical personnel must be accessible to provide advice and consultation to resolve health problems in the workplace. Establish a relationship with a local ambulance service, so transportation is readily available for emergencies.

What role should employees play in your emergency action plan?

The best emergency action plans include employees in the planning process, specify what employees should do during an emergency, and ensure that employees receive proper training for emergencies. When you include your employees in your planning, encourage them to offer suggestions about potential hazards, worst-case scenarios, and appropriate emergency responses. After you develop the plan, review it with your employees to ensure everyone knows what to do before, during, and after an emergency.

Please keep a copy of your emergency action plan in a convenient location where employees can access it, or provide all employees a copy. You may communicate your plan orally if you have ten or fewer employees.

What employee information should your plan include?

In an emergency, it could be important to have ready access to important personal information about your employees. This measure includes their home telephone numbers, the names and telephone numbers of their next of kin, and medical information.

What type of training do your employees need?

Educate your employees about the types of emergencies that may occur and train them in the proper course of action. The size of your workplace and workforce, processes used, materials handled, and the availability of onsite or outside resources will determine your training requirements. Be sure all your employees understand the function and elements of your emergency action plan, including types of potential emergencies, reporting procedures, alarm systems, evacuation plans, and shutdown procedures. Discuss any special hazards you may have onsite such as flammable materials, toxic chemicals, radioactive sources, or water-reactive substances. Clearly communicate to your employees who will be in charge during an emergency to minimize confusion.

General training for your employees should address the following:

- Individual roles and responsibilities;
- Threats, hazards, and protective actions;
- Notification, warning, and communications procedures;
- Means for locating family members in an emergency;
- Emergency response procedures;
- Evacuation, shelter, and accountability procedures;

- Location and use of common emergency equipment; and
- Emergency shutdown procedures.

You also may wish to train your employees in first-aid procedures, including protection against bloodborne pathogens; respiratory protection, including the use of an escape-only respirator; and methods for preventing unauthorized access to the site.

Once you have reviewed your emergency action plan with your employees and everyone has had the proper training, it is a good idea to hold practice drills as often as necessary to keep employees prepared. Include outside resources such as fire and police departments when possible. After each exercise, gather management and employees to evaluate the drill's effectiveness. Identify the strengths and weaknesses of your plan and work to improve it.

How often do you need to train your employees?

Review your plan with all your employees and consider requiring annual training in the plan. Also, offer training when you do the following:

- Develop your initial plan;
- Hire new employees;
- Introduce new equipment, materials, or processes into the workplace that affect evacuation routes;
- Change the layout or design of the facility; and
- Revise or update your emergency procedures.

What does your plan need to include about hazardous substances?

No matter what kind of business you run, you could potentially face an emergency involving hazardous materials such as flammable, explosive, toxic, noxious, corrosive, biological, oxidizable, or radioactive substances.

The source of the hazardous substances could be external, such as a local chemical plant that catches on fire or an oil truck that overturns on a nearby freeway. The source may be within your physical plant. Regardless of the source, these events could directly impact your employees and your business and should be addressed by your emergency action plan.

Suppose you use or store hazardous substances at your worksite. In that case, you face an increased risk of an emergency involving hazardous materials and should address this possibility in your emergency action plan.

What special equipment should you provide for emergencies?

Your employees may need personal protective equipment to evacuate during an emergency. Personal protective equipment must be based on the potential hazards in the workplace. Assess your workplace to determine potential hazards and the appropriate controls and protective equipment for those hazards. Personal protective equipment may include items such as the following:

- Safety glasses, goggles, or face shields for eye protection;
- Hard hats and safety shoes for head and foot protection;
- Proper respirators;
- Chemical suits, gloves, hoods, and boots for body protection from chemicals;
- Special body protection for abnormal environmental conditions such as extreme temperatures; and
- Any other special equipment or warning devices necessary for hazards unique to your worksite.

How do you choose appropriate respirators and other equipment?

Consult with health and safety professionals before making any purchases. Respirators selected should be appropriate to the hazards in your workplace.

Respiratory protection may be necessary if your employees must pass through toxic atmospheres of dust, mists, gases, vapors, or oxygen-deficient areas while evacuating.

Who should you coordinate with when drafting your emergency action plan?

Although there is no specific requirement to do so, you may find it useful to coordinate your efforts with any other companies or employee groups in your building to ensure the effectiveness of your plan. In addition, if you rely on assistance from local emergency responders such as the fire department, local HAZMAT teams, or other outside responders, you may find it useful to coordinate your emergency plans with these organizations. Coordination ensures that you are aware of the capabilities of these external responders and that they know what you expect of them.

CHAPTER 9

SUPPRESSION OF INDUSTRIAL FIRES

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SUPPRESSION OF INDUSTRIAL FIRES

1. Introduction

Fires in industrial plants are likely to lead to an extensive loss of life and property, depending on the properties of the plant. Incidents may also occur, which brings about the necessity of a fast evacuation that will cover not only the inner of the plant but also its surroundings and sometimes wide settlement units. For this reason, it is an obligation to take the necessary precautions by accurately evaluating the hazards and risks for the establishment of fire safety in such a way that is more preferential than extinguishing fire in industrial plants.

Within this framework, it is required to mention the concepts of risk and hazard shortly. A hazard describes an adverse condition towards the property or life. Risk is a quantitative identification of any hazard and evaluation its probability of occurring. A hazard is a physical condition that potentially damages life, property, and the environment. Risk is the possibility of any unintended incident being present under particular circumstances within a definite period.

The main objectives and priorities of fire safety are given below:

a. To provide the life safety of people,

b. To protect the properties (plants and assets),

c. To keep the fire protection procedure and functions in working condition to ensure that fire never breaks out or fire does not repeat.

Life safety is also the priority in fires, as in all emergencies. Because of this priority, it is required to make evacuation planning and training. Planning and training are a must for a healthy evacuation. The safety of the employees cannot be ignored in fire suppression activities.

One of the following probabilities is in question once it is possible to intervene in the fire in the industrial plants (Rasbash et al., 2004).

- Fire suppression may be performed by employees in the early and beginning phase of the fire using portable/mobile extinguishers,
- Fire intervention by automatic extinguishing systems,
- Suppression activities by the fire brigade.

Any fire outbreak must be noticed immediately to extinguish it easily and effectively. It is accomplished either by various detectors or human observation. The ability of people to detect a fire usually leads to delays in fire interventions. For this reason, the most effective way is to notice the fires through various fire detectors. After the fire is detected, people should be warned. In case of failure to warn people, the toll of the delay in the evacuation may be heavy. The third and crucial point is to call the fire brigade. Starting the extinguishing process without completing these three procedures may lead to mistakes and unintended consequences. Following these phases, it should be attempted to intervene in the fire with the available facilities and principally through mobile extinguishers.

It is required to engage in a good selection and coordination of the hazards being special to the industrial plants, ignition sources, type of the fire, and proper extinguisher substances to perform the intervention activities to be completed by the personnel or fire brigade smoothly and effectively. These subjects, notably ensuring life safety in the fires, will be discussed in this part.

2. Ensuring Life Safety in Fires, Evacuation, and Coordination with Fire Brigade

2.1. General Rules Intended for Ensuring the Life Safety

Ensuring life safety is the key issue of the fire safety subject. All the other problems are of secondary importance compared to life safety. It is required to take precautions about the below-mentioned issues regarding the safety of life in the fires.

Fire exits should be available at an adequate number in case of a building fire. The sufficient number of exits is determined by taking such factors as the occupancy of the building, the number of persons present at the facility, characteristics of those people, and construction type into consideration. It must act following the national and international legislation in this regard.

The fire exits should also be used in an accessible way. The routes and corridors going to the exit and after-exit area should also be cleaned of obstacles. In terms of the safety of property or the escape routes used for storage purposes, the locked escape doors are the malpractices encountered in this regard.

People who know or do not know the building should easily turn towards the escape routes through the signs placed to evacuate the structure easily. For this reason, illuminated or non-illuminated signs should be posted and placed in a manner that will be clearly and easily understandable in emergencies. An emergency illumination should be constructed considering possible power blackouts in emergency cases. The emergency illumination should be designed in a way that will be supported for 90 minutes from the power blackout.

The conditions may get worse in emergency cases and the time given for evacuation may be restricted. For this reason, alarm and control systems should be installed to increase the time given for escape and be kept operating. The sooner the fire is detected, the more the evacuation period is increased. In addition, the active and passive systems preventing the growth or spreading of the fire also increase during this period. Once the fire is detected, it should be provided to warn those in the building of the evacuation. For this purpose, giving the personnel training regarding intervention and evacuation in emergencies is one of the precautions that will minimize the loss of life and property. Any person can make the correct decision in an emergency thanks to their training. Through this decision, the person can choose the way which will enable him/her to be helped by waiting in the place where he/she stands, turning towards the most proper exit, or intervening in the fire. However, evacuation is essential if appropriate.

The number and position of the exits which will enable the escape from the fire in the building are important. At least two exit doors should be available in the collectively used facilities. In calculating the adequacy of the exits, the capacity of the exit, the number of those who are present in the building, and escape distances are considered. The coefficients that are appropriate for the hazard classification are used while calculating.

2.2. Evacuation Planning

The evacuation plans should contain the methods which will enable those in the building at the emergency moment to get out of the building and take the roll. The issues related to the emergency notification, evacuation, necessary energy sources, and interruption of the machinery should be clearly and explicitly in the emergency action plans to be prepared within this framework. The evacuation and emergency plans should be designed in writing, the personnel should be informed, and the implementation should be tested through the drills. Also, assignments and responsibilities related to taking the role in assembly areas, rescue and first aid, and extinguishing activities should be specified in these plans.

The factors affecting the evacuation are the human factor, structural and technical characteristics of the building, and the fire itself. The type and diameter of the fire is the most important element affecting the evacuation. The legal regulation containing detailed provisions on evacuation in our country is the 'Regulation on Fire Protection of Buildings' (Açıl et al., 2018).

The below-listed items should be periodically controlled in terms of the safety of life in case of fires (Schroll, 2002):

- Whether there are two exit doors from all working areas or not,
- Whether any exit from any area takes people to any area containing hazardous substances or not,
- Whether the escape corridors are accessible and without obstacles or not,
- Whether the evacuation alarm is heard in all areas or not,
- Whether the voice call system is heard in all areas or not,
- Whether the emergency notification numbers are available on all phones and at visible points in the proper locations or not,
- Whether the evacuation diagrams are posted in the necessary areas or not,
- Whether the assembly areas are kept clean and without obstacles or not.

The general behavior of people during any fire should also be considered in training to be held. As a result of the research carried out by Surrey University in 1980, five basic points of view related to people's behaviors in fires have been suggested. Accordingly (Thomson, 2001);

- The fire-related behaviors of people in the fires vary depending on to what extent they see their behaviors are associated with their responsibilities.
- People prefer to use the route they are well aware of for evacuation in case of fires.
- People are disposed to ignore fire alarms.
- People prefer to stay at the building to get more information instead of starting the evacuation even though the first signs of the fire are seen, like fume.
- People could not act properly during the fires, and they generally panicked.

2.3. Providing Coordination With Fire Brigades

The fire brigades have to conduct preliminary work concerning the matters such as the location of the industrial plants in their region, plant plan, fire hazards, extinguishing sources, number of personnel, and evacuation capacities. This case is valid for industrial plants and for all structures posing a risk in terms of the use of the building and carrying extraordinary characteristics. Industrial plants are building their detection, alarm, and extinguishing systems to their plants by considering processes and legal obligations. Notwithstanding the exceptions, they are creating a safety organization depending on the number of personnel and planning to use this organization or any unit trained in fire intervention for first response.

Reporting the fire to its emergency system as soon as possible facilitates the fire brigade's work and minimizes the losses of property and life arising from the fire. For this reason, the personnel should be instructed to call the fire brigade. Apart from this, good collaboration is needed for directing the fire brigade personnel who arrive at the plant to the correct point, making the water supply sources easily accessible, keeping the extinguishing systems in operating state, and identifying the rescue need clearly by taking the roll of the evacuees. The responsibilities of fulfilling these procedures should be specified and clarified in the emergency plans.

It should be encouraged to perform planned plant visiting, joint evacuation, first-aid, extinguishing, and rescue drills in collaboration between the fire brigade and industrial businesses.

3. Extinguishing Systems in the Industrial Plants and Their Activities

The fire safety measures in the buildings can be discussed under two headings as active and passive measures. The operational measures include the systems related to detecting, controlling, and extinguishing fires, providing the efficiency of the fire brigade and awareness and training of the personnel about the fire. The passive measures include the precautions taken to prevent the fire's growth or spread by using such methods as division, separation, and removal in the buildings (Rasbash et al., 2004). The passive systems are designed as an integral part of the building. Firewalls can be given as an example of passive systems. The active systems are designed to be activated mechanically in an emergency, such as sprinkler systems. Both active and passive systems are critical in terms of fire safety. The firewalls are designed to be fire-resistant, generally for 4 hours, and are constructed so that they will extend onto the roof. Fire detection and alarm systems may be designed manually or automatically. Detectors such as fume or heat detectors are used in detecting fire, and the detection systems can be designed to activate the fire-extinguishing systems.

The first thing preferred in providing fire safety is eliminating the hazard, if possible. If not, it can be tried to minimize the hazard by substitution. Using a less-flammable substance in the industrial processes is an instance. If it is not applicable, hazard isolation may be tried. This way, any substance or process containing a fire hazard can be taken to another controlled area isolated from the other processes or implications. The engineering control practices also provide the minimization of the risks. Systems such as automatic valves can eliminate the risks caused by human errors. The systems being activated once ambient reading devices detect hazardous gas/air mixtures may be given as an example. Automatic detection and extinguishing systems are the engineering practices that ensure fire safety. Such systems should be kept operating, and their maintenance should be regularly carried out for the engineering practices to be effective. Another way to implement the elimination of hazards is through administrative rules. The organizational practices are policy, procedure and training prepared and issued to ensure fire safety. Appropriate personal protective equipment and materials should also be used to protect from hazards, as in the practice of personnel who work in petroleum refineries and wear fire-resistant clothing. The installed fire-protection systems protect when people are not present at the plants. Also, they do not lead to negative consequences arising from human errors. These systems are reliable. It should be decided whether they will be installed by considering their costs (Rasbash et al., 2004).

The installed systems save fire and rescue activities time by detecting the fire, warning people, and intervening automatically. They make significant contributions to ensuring life safety. The fire brigade prefers to maintain the operation of these systems while it continues its extinguishing activities.

It is required to use the appropriate extinguishing substances for the burning materials either in the fire and rescue activities or in the automatic extinguishing systems. This part will discuss the extinguishing substances and the fixed extinguishing systems.

3.1. Fire Classification and Extinguishing Substances

The characteristics of the burning materials classify fires. The extinguishing substances are used in conformity with the classification of the fire. According to the definitions at international standards, the fire classes are as follows (NFPA 10, 2022):

Class A fires; Fires where solid materials such as wood, paper, and clothing burn out. Such fires leave ashes.

Class B fires; Fires where flammable and combustible liquids and gases burn out. Such fires can develop and spread quickly.

Class C fires: These are the fires where there is electric power at its source. It is not a classification based on what burns out. After the electric power is turned off, the fire is regarded as a fire belonging to the class of the existing fuel type.

Class D fires; Fires where combustible metals such as magnesium, titanium, and zirconium burn out fall into this class. It is difficult to ignite such metals; however, it is difficult to extinguish these fires after the ignition.

Class K fires; are the fires of oil used for cooking, particularly in industrial kitchens.

The primary extinguishing substance is water in Class A fires; foam, dry chemicals, halogens gases, carbon dioxide, and clean gases in Class B fires; dry chemicals, carbon dioxide, halon, and clean gases in Class C fires; metal-specific dry powders in Class D fires and wet chemicals in Class K fires (Ceasefire, 2022).

The extinguishing of any fire is accomplished by removing one or several of the fuel, oxygen, heat, or chemical reaction.

Extinguishing the fire by removing oxygen is the basic method to extinguish flammable liquid fires. The combination of oxygen and fuel can be physically prevented or moved away from confined spaces by using rare gases.

If the oxygen level drops below 12% in confined spaces, the development of flames becomes impossible. It is required to fill about 60% of any confined space with carbon dioxide to extinguish the fire in this space. The most effective substance used in extinguishing a fire by cooling is water. Water has a unique heat absorption capacity. As the size of the droplets shrinks, water absorbs more heat from the atmosphere since total surface areas increase. Dry chemical powders and halon gas extinguish the fire by interrupting the chemical reaction by absorbing the energy in the molecules enabling the flame to develop (Thomson, 2001).

Some substances, such as chlorine, ammonium nitrate, and oxygen in the air, are oxidizing due to their structures. While the mass/surface rate in the solid materials increases, the ignition of that material becomes more difficult. As this rate decreases, the ignition occurs more easily. Liquids ignite more easily than solids, and gases ignite more easily than liquids since they burn out at the gas phase regardless of the burning material.

The ignition sources can be classified under four main headings mechanical, electrical, chemical, and nuclear. Heat emerges through friction or pressure by mechanical means. It can occur by resistance, short circuit, static electricity, or any natural event such as a stroke of lightning in electrical ways. Heat accumulation is realized through combustion, decomposition, spontaneous heating, or mixtures producing heat in chemical ways. Heat production occurs by atomic nucleus fission or fusion in nuclear ways (Schroll, 2002).

The combustion products are flame, heat, fumes, and fire gases. Although flames attract more attention in fires, high temperatures and fume are more dangerous in terms of life safety. The smoke can obstruct the field of vision at the fire site and complicate the evacuation. There is plenty of fire gases in all fires, and they pose a danger to human life. Carbon dioxide, carbon monoxide, hydrogen cyanide, hydrogen chloride, ammonia, sulfur dioxide, nitrogen dioxide, phosgene, and acrolein may be ranked among these gases. Another danger in the fire site is decreased ambient oxygen due to smoke and fire gases. The oxygen decrease poses a danger due to the air people inhale and creates an impact that increases the production of carbon monoxide (Küçük, 2001).

The extinguishing substances and their characteristics are listed as follows (Schroll, 2002).

a. Water: It is the mostly used extinguishing material. It is used in extinguishing using portable devices, hoses, foam systems, or automatic extinguishing systems. The heat absorption capacity of the water is quite high. Water absorbs maximum heat in its evaporation phase. The water sprayed on the fire does not fully evaporate.

b. Dry Chemicals: Dry chemicals cut the contact of the combustible material with the air by covering its surface and realize the extinguishing process with the decomposition of the chemical substances in its structure (Mammacıoğlu, Coşkun, and Soyhan, 2017). Dry chemicals are the various chemicals produced in the form of fine powder. Dry chemicals are available in two types; normal and multi-purpose dry. Normal dry chemical extinguishers contain sodium bicarbonate and are used in Class B and C fires. The multi-purpose dry chemical extinguishers contain mono-ammonium phosphate and may be used in Class A, B, and C fires. The multi-purpose dry chemicals are effective by adhering to the surface of the combusting materials. Dry chemicals are the extinguishing materials that extinguish flammable liquid fires in the fastest and most efficient way. Dry chemicals highly effective in big flammable/combustible liquid fires known as Purple K contain potassium bicarbonate. These dry chemical extinguishers can be used utilizing portable or wheeled mobile devices, hose systems installed on vehicles, or systems.

c. Halon: Halogenous hydrocarbon agents are highly effective gases in extinguishing fires. Halon 1211 and Halon 1301 are the most popular ones. Halon 1211 is generally used in mobile extinguishers, and Halon 1301 is used in fixed extinguishing systems. Halon agents extinguish the fire by interrupting the chemical reaction. Their greatest advantage is not to leave residuals. They can be used in Class A, B, and C fires. It is a colorless and odorless gas. A 5-7% concentration is sufficient for extinguishing (Öner, 2009). They are kept in liquid under pressure. It is ranked between dry chemicals and carbon dioxide in terms of extinguishing speed. The disadvantageous aspects are its cost and adverse environmental effects. According to the Montreal Protocol, the production of Halon 1211, 1301, and 2402 was banned in the USA due to its negative impact on ozone layers as of January 1, 1994. However, the use and sale of the products produced and stocked before this date were allowed. Halon may be applied utilizing mobile extinguishing devices, wheeled extinguishing devices, onboard or building hose systems, or automatic extinguishing systems.

d. Carbon dioxide: Carbon dioxide is stored in the liquefied form in high-pressure steel cylinders or by cooling up to –20 ° C in the low-pressure vessels in the fixed fire extinguishing systems. Since the carbon-dioxide is harmful to health at high concentrations, special protective measures should be taken if the limit value above 5% is exceeded in the atmosphere (Yılmaz, 2018). The carbon-dioxide gas is an extinguishing substance used to extinguish Class B and C fires. It is not an electric conductor and does not leave waste. It is cheap; however, it is not as effective as halon agents. It extinguishes the fire by blocking the oxygen. It bears the risk of dropping the oxygen level below the limit values regarding life safety in the space used. They are used in extinguishing the fire using mobile, wheeled extinguishing devices, onboard or in-building hose systems, or automatic extinguishing systems.

e. Foam: Foam creates a cover onto the burning material and prevents it from combining with oxygen. The water in it drops the temperature of the burning material by functioning as a coolant and slows down the reaction speed. For this reason, foam is an appropriate extinguisher for fuel oil fires. Also, the proper dry chemicals are used as supplementary material together with the foam (Türkel, 2020). The foam can be used utilizing mobile or wheeled devices, hose systems, or automatic extinguishing systems. The foam can be generated chemically or mechanically. In firefighting, the foam generally produced mechanically is used. Foam is a final extinguishing material produced by putting air into the solution obtained by mixing the concentrate with water at particular proportions. While the foam is used to extinguish the Class A and B fires, it has been essentially designed to extinguish the Class B fires efficiently. It extinguishes the fire by separating the fuel from the oxygen and cooling the fuel. The mixture ratio and expansion characteristics are important in the foam. The concentrates are used in a mixture ratio of 1%, 3%, 6%, or 9%. The mixture ratio represents the water-concentrate mixture ratio of the solution. The foams are classified as light, medium, and heavy in terms of expansion. The low expansion foam ratio is 10:1, and medium and high expansion foams expand at a percentage of 100:1 and 1000:1. This ratio represents the ratio of this solution to the foam obtained after air is mixed. In heavy foam with a ratio of 10:1, a water-concentrate mixture of 1 liter turns into the foam with a volume of 10 liters after the air is added. The light foams extinguish fires in inaccessible confined spaces by applying effective ventilation.

The quality of the foam must conform to a set of criteria. Firstly, the foam should easily flow over the flammable liquid and quickly cover the fuel. The foam should not release the water in it quickly. The slower it releases the water, the longer the cover integrity on the fuel may be protected. Also, the foam should resist high temperatures and not decompose easily. It should not contaminate the fuel or hold the fuel on it.

The foams are made of natural and synthetic materials. Protein foams are mechanical foams produced from raw materials. Its heat resistance and covering characteristic are high, but its fluidity is low. Its fire-extinguishing rate is relatively lower. Also, the protein foams cannot be used together with dry chemicals. The developments in synthetic foams have reduced the use of protein foam. The shelf life of protein foams is about ten years.

Synthetic AFFF foam is the foam type that is mostly used in firefighting. They can extinguish fire in a faster and more efficient manner compared with other types of foam. They can be used together with dry chemicals. Such a dual-use provides a more efficient fire-extinguishing because dry chemicals are more effective than foam. Since the foam cools the fuel, its extinguishing effect increases incrementally. Alcohol-resistant AFFF foams are used to extinguish fires where polar solvent flammable liquids such as water-soluble alcohol, methyl ethyl ketone, and thinner. The shelf life of the AFFF foams is 25 years.

f. Dry Powders: These extinguishing substances are used to extinguish metal fires. The most commonly used extinguishers in this category are G-1 and Met-L-X products. Dry powders prevent combustion by forming a shell on the burning metal. The shell should fully cover the surface of the combusting metal to extinguish the combustion. Dry powders are generally applied on the fire by shovel or mobile extinguishers. Graphite and sodium chloride are used in the production of dry powders.

g. Wet Chemicals: Wet chemical extinguishers are produced from potassium acetate and are used to extinguish oil fires in industrial kitchens. Once applied, they produce thick, soapy foam and function by interrupting the connection of fuel with oxygen. The wet chemicals may be used employing portable extinguishers or installed systems.

h. Halon-Substitute Clean Gases: The substitute products produced due to the environmental concerns related to halon gas are also effectively used in firefighting. The Inergen brand is one of these products. This product is produced by Ansul and consists of nitrogen, argon, and carbon-dioxide composition. This product drops the oxygen level to 12,5% in the fire atmosphere and raises the carbon-dioxide level to 4%. The most popular ones among the other halon-substitute gases are FM-200 and FE-36 products. FE-36 is a clean gas used in portable extinguishing devices to substitute Halon 1211. This gas is also used in fixed blast suppression systems.

3.2. Fixed Extinguishing Systems in the Industrial Plants

The most effective systems for ensuring fire safety in industrial plants and extinguishing fire outbreaks by blocking their growth and spreading are the detection, alarm, and extinguishing systems used and operating manually or automatically. The information related to these systems by the extinguishing substances used in the systems is given below (Schroll, 2002).

a. Fixed Water Pipes: Fixed water pipes may be installed to facilitate the fire intervention with water in the industrial plants. These systems can be suitably designed for the use of both personnel and firefighters. These systems save time to be lost by laying out a hose and facilitate the capacity of the personnel in firefighting with water through the training they receive.

b. Automatic Water Sprinkler Systems: Water sprinkler systems are installed by taking the following details into account; combusting material, whether there is freezing risk or not, whether there is a shelving system or not, risk group and adjusted flow rate, pipeline, whether it is located at the earthquake zone or not. In this context, a nozzle model is selected, and the explosion temperature of the nozzle is calculated (Yıldız, 2021). The automatic sprinkler systems used to extinguish the fire can be designed in four ways. These are the wet-pipe, dry-pipe, pre-warning, and deluge-type automated sprinkler systems. Each of these systems has specific advantages and disadvantages.

In the wet-pipe sprinkler systems, each head is sealed with a thermo-fusible material, and the pipe has water. Each sprinkler head operates individually. Thus, the water is only be applied on the site where fire breaks out. Due to the freezing risk of the water, it is only used in air-conditioned areas.

The design and operation of the dry-pipe system show similarity with the wet system. The most important difference is not to keep water up to the control valve in the pipes. Thanks to this feature, it can also be used in air-conditioned areas.

Pre-warning sprinkler systems are systems designed by combining particular properties of the wet and dry-pipe systems. In this system, the air is on the top of the control valve in the pipes. The opening of the control valve is associated with the precision detection devices detecting the fire. Thus, water reaches this head until the sealing material of the sprinkler heads melts, and the loss of time is prevented.

Deluge systems are generally installed in atmospheres containing extra hazards. The distinctive difference is that the sprinkler heads are open. Water discharges from all sprinkler heads once the control valve is opened, as in the pre-warning system. This system is used in areas such as aircraft hangers or painting areas where fire can quickly spread.

c. Water Mist Applications: Water mist systems are designed at different pressure classes and nozzle types. In high-pressure systems, particle sizes of 50-100 microns can be achieved under the operating pressure of 120 bars. In conventional sprinkler systems, the particle sizes are above 1000 microns. The water mist systems are highly effective in extinguishing (Şiranlı & Turanlı, 2019). The water mist systems are the unique systems through which the water is sprinkled onto the fire site in the form of very fine droplets. These systems resemble the deluge systems in terms of their sprinkler head. Water discharge application would have been started from all sprinkler heads in the related site at the time of the application. The water mist applications are used in the areas where three-dimensional protection is required and areas where high-speed water flow is needed. The water mist is applied under high pressure. They protect the large transformers, propane storage tanks, or openings passing through the firewalls.

d. Automatic Foam Extinguishing Systems: These are the systems installed in the areas where inflammable liquid fires are expected. In these systems, low and high-expansion foam can be used. The low-expansion foam may be sprinkled into the atmosphere utilizing special sprinkler heads or monitor nozzles in these systems. The high-expansion foam is applied through foam generators mounted at the ceiling level. The foam extinguishing systems protect the extra hazardous areas like aircraft hangers and flammable liquid storage.

e. Water Supply Systems: Automatic watery extinguishing systems should be supported by an adequate intended water resource. The water supply capacity is calculated by considering the time required for the system's operation and design flow rate. According to this calculation, a water reservoir should be constructed in such a volume, and the water should be transmitted to the system under the required pressure.

f. Automatic Carbon-dioxide Extinguishing Systems: There are two types of carbon-dioxide extinguishing systems. First of which is the local application, and the second is the bulk overflow system. These systems can be designed as high-pressure or low-pressure. The systems with carbon dioxide are used to protect the machinery, equipment, or environments in which combustible/flammable liquids are used and are preferred since they do not leave any waste. They are cheaper than the halon types. They should not be used in the protection of areas in which people could not evacuate quickly against the fire. Also, they should not be used to protect the areas where pyrophoric substances and reactive metals are stored and kept. Low-pressure systems operate under the design pressure at about 20 bars, and high-pressure systems at a level of about 58 bars. The system is activated by means of heat or flame sensors. A pre-warning alarm system should be installed to allow the people on the site where the application will be performed to move away. If an adequate time as long as people will escape with the pre-warning alarm is not created, an important life-threatening risk arises. Since the ambient carbon dioxide is required to be protected in the bulk overflow systems, the door or ventilation wells in the building must be closed automatically. The activation of the system may be designed automatically or manually. The carbon dioxide may be used in fire extinguishing through hoses. After the carbon dioxide is poured into the environment, it accumulates close to the ground, and these areas suffer from the lack of oxygen for a long time.

g. Halon Systems; Halon systems are used to protect the computer rooms and areas where electronic equipment is kept against fire. The fixed extinguishing systems are generally designed as the bulk overflow. In the bulk overflow application, the gas is fully discharged into the area planned to be protected. The halon systems are activated using smoke detectors positioned based on the dual-zone principle. In the dual-zone system, the smoke detectors should detect the fire on both sides to discharge the gas. Once the halon is applied, it does not leave any waste and does not contain any serious risk in terms of life safety. Its disadvantage is its cost and environmental concerns.

h. Fixed Systems in which Halon Substitutes are used: There is not too much difference between the halon substitutes and halon systems in practice. In these systems, the extinguisher is stored within cylinders and applied through nozzles positioned at the strategic points.

i. Fixed Systems in which Dry Chemicals are used: The systems in which dry chemicals are used are designed in such a manner that will perform the local application. In the local applications, the extinguishing substance is placed in such a manner it will be applied on the site or device intended to be protected by proper nozzles. The system is activated by means of heat sensors. The dry chemicals enable the flammable liquid fires to be extinguished quickly and effectively. The disadvantage is that the cleaning activities following the application are difficult and expensive. For this reason, the use of dry chemicals is not preferred in the protection of sensitive materials.

j. Flammable Vapor Detection Systems: Flammable vapor detection systems are the systems used to control the processes bearing the potential of creating an explosive atmosphere. In this control process, there are two stages. In the first stage, the system alarms once 25% of the lower explosive limit is reached in the atmosphere. In the second stage, 50% of the lower explosive limit is reached; the system automatically shuts down the process and Works under the protection. The control points at these stages may be adjusted to the need of the user.

k. Explosion Ventilation and Suppression Systems: Explosions may be experienced in the plants where industrial activities are carried out due to the combustible/flammable liquids, gases, and powders. Explosions are sudden ignition processes. The pressure wave in the explosions experienced with a sudden ignition of flammable/combustible gases, liquid vapors, and powders quickly proceeds below the acoustic velocity. In detonation, the velocity of the pressure wave realizes above the acoustic velocity. The pressure wave leads to more damage in confined spaces. As in the fires, all explosions need fuel, heat, oxygen, and chemical reaction components. One of the methods applied for absorbing the explosion effect and minimizing the damage is ventilation. This method ensures that a weak component incorporated into the process channelizes the pressure wave and fires towards a controlled and planned direction with the explosion's impact. The explosion suppression systems run with the logic of explosion prevention by detecting the indications before the explosion too quickly in similar environments and rapidly discharging the extinguishing substance into the site. It is aimed to detect the pressure increase or flame quickly as the indications of the explosion. Dry chemicals, gas, or fast evaporative liquid extinguishers are used as extinguishers/suppressors within the vessels placed at strategic points by the means and processes controlled in these systems.

3.3. Various Applications in Intervention into the Industrial Fires

a. Preventing the Spread of Fire and Smoke Discharge

The spread of the fire and its impacts can be prevented by the active systems installed in the building. Pressurization applications, smoke control doors, dampers in the ventilation pipes, automatic roof ventilation covers, and fire doors may be given as examples of these systems. Deaths experienced in the fires are caused by the smoke's impact rather than the buildings' collapse. The smoke prevents vision and its toxic effect, it leads to death by inhaling the hot air, and it causes people not to do any action they can easily achieve under normal conditions. Fires affecting buildings pose risks in two different ways. The first is to experience collapses after the fire damages the structural elements carrying the building. The second is that the fire spreads, bypassing the doors, chimneys, service cavities, or non-fire-resistant walls (Rasbash et al., 2004).

b. Explosions and Intense Flame

Production plants have to make flammable liquids and gases available in significant amounts due to the nature of their Work in their plants. In case of any release of such flammable substances into the atmosphere, a critical fire disaster may occur. This disaster emerges in three different ways: the first is a "boiling liquid expanding vapor burst" (Bleve), the second is an inflammable cloud burst, and the third is getting agitated of the boiling flammable liquid" (Boilover). As a result of these incidents, it may be faced with giant flames.

The Bleve phenomenon is the bursting of the flammable gas liquefied under pressure severely due to heating after the cylindrical or global tanks in which such gas is kept are subjected to fire since they cannot stand excessive pressure. In the meantime, the flammable liquid evaporates quickly and creates a fireball with a diameter of hundreds of meters once it ignites. Bleve is a sudden release of overheated, pressurized fluid into the atmosphere. The reason for such sudden releases results from fires surrounding the tank, corrosions, and in-tank overheating (Vatansever, Kırtaş, and Barışık, 2021).

A combustible cloud burst occurs in case of plenty of gas, vapor, or mist accumulates in open space. The combustible gas/air mixture not ignited with a powerful explosive resource in an open space does not produce any excess pressure under normal conditions; however, an intense flash is experienced. Besides, suppose there are many obstacles or compartments in the open space where combustible gas/air mixture is kept. In that case, an ignition that can create pressure under about 1 bar due to a small igniter occurs. This pressure is such a pressure that it is capable of demolishing buildings.

The Boilover phenomenon is an incident where the crude oil or certain fuels ignite within an open vessel. In such types of fire, a zone with a temperature of 200°C forms above the liquid. This temperature proceeds towards the lower levels of the liquid over time. Once the water is retained within the tank and is subjected to such temperature, it quickly evaporates, expands, and scatters the combustible liquid to a wide area in the form of an explosion. This sudden development leads to the fast spreading of fire and injuries, and deaths. Similar explosions are experienced when water is mixed with melted metal (Rasbash et al., 2004).

Dust explosion occurs once the accumulative combustible dust emerges in the industrial processes, leading to a destructive explosion by ignition with the emergence of the required conditions. Factors affecting the ability of the dust to lead to an explosion may be gathered under four main headings. The first of which is the existence of any combustible substance. It is not possible for any non-combustible air-dust mixture to ignite. The second factor is the size of the dust particles. The smaller the dust particles are, the higher the surface/mass ratio is and the easier the ignition happens. The third factor is that the dust/air mixture is in a proper ignition range depending on the physical characteristics of the material being in the form of dust. The fourth factor is the existence of any ignition source with adequate energy. A minimum of 5 mJ of energy is needed to ignite the most explosive dust (Thomson, 2001).

Phases of a typical dust explosion occur as explained below:

- A cloud of proper and adequate dust accumulates on the machinery or different surfaces.
- The dust layer is exposed to an ignition source.
- Dust ignites, and the combusting layer develops quickly. This stage is called the first explosion.
- Dust being close to this point, flow due to the first explosion and get mixed with the air.
- Dust mixed with the air with the impact of the heat from the first explosion re-ignites. This ignition is called a secondary explosion.

If the particle diameter of the combustible solids in the form of dust or fiber is smaller than 0,5 mm, it can explode by reacting with the airborne oxygen if there is an ignition source. As the particle diameter shrinks, the explosion opportunity increases. While it varies depending on the type of combustible dust and the particle size, the lower explosive limit's concentration is 30-60 g/m3 (Mevlevioğlu, Kadırgan, and Çiftçioğlu, 2019).

Dust explosions can occur in the plants where the following processes are performed:

- Plants where the aluminum powder is processed,
- Plants where there are the processes in which sugar, flour, and starch products are produced and used,
- Places where grains are processed,
- Workplaces where many woodchips accumulate due to the activities such as sandpapering, cutting, and grinding.

A careful fire risk assessment should be conducted in the related plants in order not to experience any dust explosions. The probable ignition sources should be brought into a condition that will not pose any risk through the precautions to be taken. In case of failure to eliminate the ignition sources, dust formation or access to a proper dust-air mixture should be prevented (Thomson, 2001).

c. Spontaneous Combustion

Some substances produce heat by reacting with the air or humidity. The heat produced in this way accumulates if it is not conducted fast enough. It can lead to ignition by increasing the temperature up to the spontaneous temperatures of that substance. Reactive metals, pyrophoric gases (diborane, phosphine, etc.), and substances reacting with water and phosphor may be examples of these substances (Thomson, 2001).

d. Extinguishing of Combustible/Flammable Liquid Warehouse Fires

Foam systems are the most commonly used systems to extinguish petroleum product combustible tank fires. Although mobile foam systems can be comfortably used, fixed systems are preferred because the extinguishing substance is limited, its application time is short, and it is harder to use. The foams with an expansion ratio of 5:1-10:1 at a rate of 3% water-concentrate are used in most warehouse fire interventions. The application ratios vary between 2.5 and 5 liters/minute-m2. Another foam application technique is extinguishing the fire by injecting foam beneath the liquid in the fixed roof warehouses (Zalosh, 2003).

e. Protection of Transformers from Fire and Intervention

Transformers are devices where voltage is conducted by increasing or decreasing due to various reasons. Water mist may be used on the condition of strictly conforming to the design rules set out in the related standards (NFPA 15) on protecting transformers against fire. Using water mist in the transformers is still disputed and is also regarded as risky due to the electric energy. Also, in the case of using water mist in transformer oil fires, the splashing hazard of the hot oil is available. It is not appropriate to use the turbo fire hose nozzles employed in the fire department in the fires of transformer oils (Zalosh, 2003).

f. Reactive metals

Metal fires are extinguished by using unique dry powders. Being familiar with the behaviors of the metals acting reactively in contact with the water or being exposed to the heat under these pressures is important in terms of life safety. The information about reactive metals is below (De Haan, 2007).

*** Sodium**

Sodium is a soft metal. It is normally stored within a paraffin or oil bath since it develops strong reactions with its strain in the air or human skin. It releases too toxic oxide when it is exposed to the heat, and it automatically inflames once it is exposed to the air during the fire. Its ignition temperature is about 115°C. It produced plenty of combustible/explosive hydrogen gas and caustic sodium hydroxide in contact with water. For this reason, it exhibits a severe exothermic reaction and splashes the flame, alkaline solution, and melted sodium around severely.

*** Potassium**

Potassium is less used in the chemical synthesis processes. It contains similar hazards to sodium. Its pure state is a silvery metallic crystal. In contact with water, it produced hydrogen gas, potassium hydroxide, and excessive heat. Also, it produced peroxides and superoxide, having an explosive characteristic by reacting with airborne oxygen. It builds a yellow-colored layer on the superoxide metal, and it can lead to detonation by friction. It can automatically ignite due to the heat it produces by reacting with the airborne humidity.

*** Phosphor**

It has a structure like wax. It has two types; white and red phosphor. The White phosphor flares up once it contacts the air. It is stored under petroleum distilled liquid. Its ignition temperature is 30°C. It produces highly toxic oxide by reacting with many oxidizers. The red phosphor is a more stable substance. It does not flare up once it comes into contact with the air. Its ignition temperature is 360°C. It combusts with strong oxidizers, severely reacts, and even it can lead to an explosion.

*** Magnesium**

The flame of the flaming magnesium can reach up to 3000°C. It is hard to ignite once it is in the form of a mass having a small surface area. However, it can be ignited by a match in the form of a woodchip, powder, or strip. It produces flammable hydrogen gas or heat by reacting with water.

4. Types, Performance Characteristics, and Usages of Portable Fire-Extinguishers

Various types, performance characteristics, and modes of usage of portable extinguishers are given below (Schroll, 2002).

a. Portable Water Extinguishers

It has two types in terms of the working principle. The first is a pumped extinguisher, and the second is an air-pressurized extinguisher. The pressurized ones are preferred. They are used in incidents where water extinguishing is applicable. Its capacity is about 9,5 liters, and the Access distance is about 9 meters. The application time is about 1 minute. Extinguishers are pressurized at a level of about 7 bars. These devices' use and training of the personnel **are easy, the extinguishing substance is cheap, and its cleaning is simple. The** disadvantageous aspects of these extinguishers are that they are used only in Class A fires, are heavy, are not kept in unheated areas, and pose a hazard in non-Class A fires. The portable extinguishers forming water mist may be used to fight Class A and C fires. Such extinguishers are designed for a capacity of 6.6 and 9.5 liters. The Access distance is about 3-3.7, and the application time is 72-80 seconds.

b. Portable Foam Extinguishers

These extinguishers are available in two types. In the first group, the extinguishers have a mixture of water and concentrate and are applied by an air mixer nozzle. The second group of extinguishers has only water. Once the application is started, the water turns into a final product through nozzle ventilating by passing through a cartridge in which there are tablets producing foam once they get mixed with water. They are similar to water extinguishers in terms of working principle. The capacity of these extinguishers is 9.5 liters, which are used in Class A and B fires.

The Access distance of the extinguishing substance is 9.2 meters, and the application time is about 1 minute. They are pressurized with compressed air of about 7 bars. It is easy to carry out their maintenance, prepare them for operation after use, and give instructions about their use. It is cost-efficient. The disadvantageous aspects of these extinguishers are that they are not recommended to be used in Class C and D fires; they are heavy extinguishers and have freezing probabilities. One hundred twenty-five liters of wheeled models are available.

Use of Portable Foam Extinguishers: The hose should be held at a proper angle and ensure that the foam falls onto the scattering fuel in a curved manner. It can be provided that the foam flows onto the flammable liquid by striking obstacles in the site. Or, the foam may be enabled to flow and cover the flammable liquid by directly hitting the pre-flammable liquid points.

c. Portable Extinguishers Containing Dry Chemical

Portable extinguishers with dry chemicals are divided into two types. Tubes containing dry chemicals in the first group are generally pressurized with nitrogen. While these extinguishers weigh up to 1.3.6 kilograms, the extinguishers weighing 4,5 kilograms are mostly used. Whereas the application times of the extinguishers vary between 8-20 seconds, their access distance elevates up to 9.2 meters. The second group of portable extinguishers containing the dry chemical is those with cartridges. In the tubes with cartridge, there is only dry chemical within tubes, and tubes are not pressurized. Instead, there is propellant gas within the cartridge. At the time of application, the gas in the cartridge is provided to be pressurized by opening the valve. The application time and access distance have similarities with the preceding group. These extinguishers have either normal or multi-purpose dry chemicals. The portable extinguishers with normal dry substances are used in intervention into Class B and C fires; the extinguishers with multi-purpose dry substances are used in intervention into Class A, B, and C fires. The portable wheeled extinguishers containing dry chemicals weigh up to 159 kilograms. The access distances are maximum of 1,37 meters, and the application time is a maximum of 150 seconds. This group of portable extinguishers can extinguish particularly Class B fires quickly and effectively. They do not freeze. It is easier and cheaper to make the cartridge types ready for the service. The disadvantage is not cooling down in the Class A fires. Also, they create too much pollution on the site where they are employed.

Use of the Portable Extinguishers containing Dry Chemical:

- These extinguishers are very effective in combustible/flammable liquid fires. The safety pin is pulled into the pressurized tubes, the hose is removed from its housing, and the extinguisher is ready for use. The cartridge safety pin would have been opened while removing the hose from its housing on the cartridge. The cartridge opening valve is opened, and thus, the extinguisher is pressurized.

- In the intervention into the flammable liquid scattering, the fire should be intervened by sweeping to the right and left, starting from the point closest to the user. The sweeping motion is performed to slightly exceed the right and left ends of the fire at an average speed. It is continued as the fire is extinguished. If it is not reached the end of the scattered liquid from the point where it stands, the intervention is continued by passing to the right edge from which Access is possible.

- If there is an obstacle in the scattering area, the intervention of two persons is more effective. However, it should be acted on coordinately.

- If the extinguishing substance is administered into the liquid directly, it may lead to the scattering and spread of the fire. For this reason, the angle should be adjusted to the surface.

- In three-dimensional fires, in other words, in the fires in which the flammable liquid drops by flowing from a point, the intervention should be started from the ground. A sweeping motion should be applied while extinguishing the scattering on the floor. Once it is turned to the upper source, it should be climbed upwards slowly without sweeping. Once the source is accessed, the sweeping motion may be applied by the size of the fire.

- Fires caused by the pressurized flowing of flammable liquids can be divided into two groups; the fires arising from the liquids flowing from top to down in a pressurized way and from the flammable liquids spurting in a pressurized way from the bottom to top. What is essential in both of these is to interrupt the flow. If it is not possible, it may be attempted to extinguish by using portable extinguishers. It is firstly intervened at the point where the leakage is present in the fires of the pressurized spurting liquids from top to down. Afterward, the flowing liquid is pursued, and the fire is extinguished with a slow sweeping motion towards the scattered fuel on the ground by going down slowly. If the sweeping movements are applied too widely and quickly, the fire can reach the source again. In such a case, it is required to repeat every work. If the pressurized leakage is on the ground and spurts upwards, a continuous application should be made on the source point. Then, it should be acted to cover the whole scattering site with an extinguisher and the ever-expanding sweeping motions. Simultaneously using more than one extinguisher provides more effective extinguishing in both incidents.

- Gas fires can be effectively extinguished by portable extinguishers containing dry chemicals. The gas fires should not be intervened if it is not intended to get access to the cut-off valves or are life-saving. Otherwise, an explosion risk arises due to the leaking gas even if the fire is extinguished. What is essential in the intervention into the gas fires is to cut the gas flow. If the fire is to be extinguished with the need for life-saving or valve Access, the dry chemical should be held and administered stably onto the flowing gas.

d. Portable Extinguisher containing Carbon-dioxide

These extinguishers contain carbon-dioxide liquefied with pressure. There are models at different weights. The application time is 8-30 seconds. The Access distance is in the range of 1,5 and 2,4 meters. An extinguisher-specific application nozzle is available. There are also wheeled models. They can be used in Class B and C fires. They do not freeze and leave any waste. They are not suitable for being used in Class A fires. Since static electric charge may accumulate during the application, they can pose a risk theoretically in explosive atmospheres. Special tools are needed for refilling and making it ready for use.

Use of the Portable Extinguishers containing Carbon-dioxide:

- These extinguishers may effectively extinguish electric and small-scaled combustible/flammable liquid fires.

- The safety pin is pulled for the application, and the fire hose nozzle is removed from its housing. The fire hose nozzle is fixed in small models; it is at the tip of the hose in large models.

- It should be ensured that the whole site is covered with carbon dioxide through the sweeping motions to right and left and up and down while administering gas to fight switchboard fires.

- The fire is intervened by applying sweeping motion in the small flammable liquid fires.

e. Portable Extinguishers containing Halon

These extinguishers contain halogenous hydrocarbon liquefied with pressure. The most commonly used halon agents are Halon 1211 and Halon 1301. They can weigh up to 10 kilograms. The application time is 8-30 seconds. The access distance is a maximum of 4,6 meters. There are also wheeled models and large types weighing 68 kilograms. The Access distance of these models increases up to 5,5 meters. Halon is used in the intervention in Class B and C fires. It is deemed suitable to use the large units in Class A fires. They do not leave any waste. They do not freeze. It is a more efficient extinguishing agent compared with carbon dioxide. However, this gas is expensive. It is ranked among the gases leading to ozone layer depletion and poses an environmental risk. Thus, portable extinguishers containing halon-substitute gases have been started to be used. Halotron and FE-36 are some of these gases.

Use of the Portable Extinguishers Powered by Halon and Halon-Substitute Gases:

These extinguishers are used particularly to protect precision and expensive electronic equipment. Their use resembles the use of portable pressurized extinguishers containing dry chemicals.

Once the safety pin is pulled, and the hose is removed, it is ready for use. If it is to be used in a limited area, it can be sprayed to fill the whole atmosphere. It is applied by quick motions to right and left or in such a way that will create an '8' figure in the non-limited areas, for example, in flammable liquid scattering.

f. Portable Extinguishers containing Dry Powder

Portable extinguishers containing dry powder are only used in the intervention into Class D fires, and extinguisher fitting to each combusting metal should be used. They are designed as pressurized tubes or extinguishers with a cartridge. They weigh 13.6 kilograms. The extinguishing substance is also used by shovels in the extinguishing process manually. The access distance of those pressurized is 2.4 meters. The wheeled extinguishers can weigh up to 159 kilograms. The after-use filling is easy.

Use of Portable Extinguishers containing Dry Powder:

- Dry powders are kept in buckets or portable extinguishers.
- The extinguishing substance should be applied in soft motions to cover the combusting material to succeed in extinguishing.
- Using portable extinguishers with cartridges and dry powder shows similarity with those with dry chemicals.
- The Access distance of the portable extinguishers with dry powder is too short. For this reason, it may be required to approach the combusting material too closely.

- Dry powder should be slowly applied in such a way that it will create a layer on the combusting material.

g. Portable Extinguishers containing Wet Chemical

These extinguishers are used to extinguish cooking oil fires in kitchens (Class K fires). They are generally needed in the food sector. These extinguishers or systems are required in industrial plants if the food for personnel is cooked in those plants simultaneously.

General Rules related to the Safe and Effective Use of Portable Extinguishers

General rules relating to the safe and effective use of portable extinguishers may be summarized as follows (Schroll, 2002):

The first thing to be done by any person who sees the fire is to warn other people. The warning signal is the priority for human life and the obligation to start the evacuation immediately. The second thing to be done is to call the fire department. The unnecessary time loss in these procedures' performance makes evacuation and extinguishing processes difficult. After the fire department is called, it can be attempted to extinguish the fire with portable extinguishers. They control the extensions of the fire and return to normal by checking whether the extinguishing process is properly realized or not. Delaying the calling of the fire department without complying with the previous sequence and spending priceless moments with the attempt to extinguish by portable extinguishers may lead to disaster. It is worth emphasizing this issue in the fire training of the personnel. What is ideal behavior is to call other persons while engaging in the extinguishing processes with portable extinguishers.

Several factors affect the decision to use portable extinguishers. First, it should be a ready extinguisher that fits into the use. The second factor is the size and intensity of the fire. No person should lead the injury of himself/herself or another person by using a portable extinguisher. If the fire is too big or it quickly develops and spreads, it should not be attempted into intervention by portable extinguishers. Fire products can turn the area to be intervened into a fatal environment in a short time.

If a trained person decides on using a portable extinguisher by taking these issues into account, it should be attempted to extinguish by taking a proper extinguisher. The selected extinguishing substance should be compatible with the fire class. Life safety is more important than rapid intervention. The extinguishing person should choose his/her position so that an exit door is located just behind him/her for the escape. He/she should not get a position in such a manner that it will be between the fire extinguisher and the exit door. In the fires out of the building, the wind direction must be considered within the same framework.

The user should determine the distance with the fire as a safe distance, about 3 meters. Afterward, the safety pin should be pulled and tested to determine whether the extinguisher operates or not, and the extinguishing process should be started. The area should be abandoned against the ignition risk after the application is completed and extinguishing is realized.

The use of the wheeled portable extinguishers may require special training. However, its use is the same as the techniques used in smaller extinguishers. The most popular of the standards recognized internationally concerning the maintenance and control of portable extinguishers is NFPA standard numbered 10. It is guaranteed with the periodical controls and hydrostatic tests that the portable extinguishers are ready for use. Test periods vary by type. In-tube examination and hydrostatic test period are five years for the portable extinguishers containing water, foam, and carbon dioxide. In-tube control period is six years and the hydrostatic test period is 12 years for portable extinguishers containing dry chemical, halon, and halon-substitute. The periodical maintenance and test results should be recorded.

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INNOVATIVE AND EFFECTIVE APPROACHES TO THE PREVENTION AND INTERVENTION OF INDUSTRIAL FIRES

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