INTERNATIONAL SCIENTIFIC AND PROFESSIONAL CONFERENCE
POLITEHNIKA 2023
Belgrade, 15th December 2023

ENVIRONMENT AND SUSTAINABLE DEVELOPMENT. MECHATRONICS. OCCUPATIONAL SAFETY AND HEALTH AND FIRE SAFETY. SMART MANAGEMENT SYSTEMS. GRAPHIC ENGINEERING. DESIGN. TRAFFIC ENGINEERING. BIOTECHNOLOGY AND HEALTHCARE. MECHANICAL ENGINEERING. ECOTOURISM AND RURAL DEVELOPMENT.

FIRE RESISTANCE OF BOILER ROOM THE BUILDING STRUCTURE

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Abstract: *This A significant limitation of the methodology for determining the class of fire resistance, defined by the group of standards DIN 18230, is the inapplicability to industrial facilities in which energy is produced or distributed. The aim of this paper is to define a new methodology for determining the necessary fire resistance of the building structure of a boiler room.*
Keywords: fire risk; fire load; fire resistance time of structures.

1. INTRODUCTION

W. Halpaap was developed methodology for determining the necessary fire resistance class for industrial building structures based on the previous research for metal constructions made by Gellinger and Boe in the period from 1959 to 1964. A historical overview of the methodology and more references can be found in paper [1]. This methodology was standardized in the form of German technical standard DIN 18230 [2], which was modified several times in the period from 1964 to 2010.

Two methods for fire risk assessment were standardized based on the research of the Swiss engineer Gretener (references can be found in paper [3]) which were carried out in the period from 1961 to 1968: (1) The Swiss Society of Engineers and Architects (SIA) published SIA81 method in 1981 and SIA2007 in 2007; (2) The Austrian Fire Brigade Association published TRVB 100 Technical Recommendation in three versions issued in 1975, 1987 and 2010. Using the results of Gretener's research, author Purt [4] recommended a new methodology in 1972, which was standardized by the European Fire Alarm Manufacturers Association (Euroalarm).

A significant limitation of the DIN18230:2010 standard is its inapplicability to facilities in which energy is produced or distributed. In paper [5] a new approach is presented in order to determine the necessary fire resistance of the building structure of a boiler room where liquid or gaseous fuels are used. This results was extended to boiler room where solid fuels are used in [6].

The aim of this paper is to determine the necessary fire resistance of the building structure (FR) of a general boiler room. The analysis will include boiler rooms with boilers that use gaseous fuels such as mixtures of methane and other gases (i.e. natural gas, city gas or landfill gas) or LPG, liquid fuels such as oil fuels and alcohol-based fuels, solid fuels and cases in which one type of fuel is primary and the other is alternative. The proof of the adequacy of the class of fire resistance for building structure will be given independently using the Purt methodology (according to the Euroalarm standard) while the obtained results will be verified by using the Gretener methodology (according to the TRVB 100:2010 recommendations).

Assumed fire prevention and protection measures include:

1.1. Installation of an automatic fire alarm system;
1.2. Constant presence of the person on duty next to the fire control panel;
1.3. Sufficient number of fire extinguishers before the arrival of the fire brigade;

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1.4. Existence of appropriate fire hydrant installation;
1.5. Professional fire brigade located up to 5 km from the building;
1.6 Access to the boiler room is provided from three sides for the purpose of fire-fighting, i.e. there is at least one opening that can be used for fire-fighting purpose on every 20 m of the walls that border the fire sector.

Other assumptions include:
2.1. Mechanical ventilation system is applied, which provides adequate explosion protection, but without smoke and heat control system;
2.2. The boiler room is rectangular shape with single fire compartment, which is less than 40 m wide, and with an area of less than 3000 m^2 in which there are no other facilities;
2.3. The boiler room is located on the ground floor;
2.4. There are no other floors below and above the boiler room;
2.5. The building in which the boiler room is accommodated is free-standing or it is part of an industrial building;
2.6. No combustible materials are built into the boiler room construction;
2.7. Installed boiler heating duty is less than 1 GW;
2.8. No fuel is stored in the boiler room.

2. SPECIFIC FIRE LOAD AND FIRE RISK CLASS FOR BOILER ROOMS WITH LIQUID OR GASEOUS FUELS

In Euroalarm tables, only boiler rooms that use solid fuels are considered. Tables given in TRVB 126:1987 do not define which type of fuel is used in the boiler room, but based on the adopted coefficient of fire risk class S = 1, it can be concluded that these are fuels of class IV fire hazard, i.e. solid fuels. Since no combustible materials are built in the construction of the fire sector in which the boiler room is accommodated, it follows that the fixed specific fire load is $Q_i = 0$. It also can be assumed that fuel amount that can be found in the boiler room is sufficient for no more than 15 minutes of operation and that the boiler efficiency is higher than 50%. Based on the above assumptions, the total specific fire load can be calculated using the following equation:

$$Q = Q_m = \frac{P \cdot t_w}{A} \tag{1}$$

where Q is specific fire load [MJ/m^2], Q_m is movable specific fire load [MJ/m^2], P is installed boiler heating duty [MW], t_w is total combustion time and A is boiler room area [m^2]. Hence

$$t_w = 2 \cdot 15 \cdot 60 \text{ s} = 1800 \text{ s}. \tag{2}$$

In this study the fire hazard class I (for gaseous fuels), is adopted because this is the most unfavorable case.

3. PURT METHOD.

3.1 Purt method for boiler rooms with liquid or gaseous fuels

For the application of Purt method it is necessary to determine two parameters: fire risk of the structure construction and fire risk of the structure contents. The fire risk of the structure contents is a coefficient that qualitatively shows the harm to people and equipment. It is calculated using the equation:

$$R_S = H \cdot D \cdot F \tag{3}$$

Where H is the harm to people coefficient, D is the harm to property coefficient and F is the smoke effectiveness coefficient.
In this case study, H equals to 1 because there is no expected harm for people, D equals to 2 because expensive equipment is installed in the boiler room and because interruption of the boiler operation causes stoppage of the supply of thermal energy to consumers, and F equals to 1, because there is no danger of smoke and corrosive gases.
Hence, the fire risk of the structure contents (R_s) equals to 2, which means that installation of fire alarm system, is necessary in the boiler room, except in the case of installation of the fire extinguishing system, which is a technically unacceptable solution due to the large area and height of boiler rooms.
Fire risk of the structure construction is a coefficient that qualitatively shows the hazard for the building construction and is calculated using the form:

$$R_0 = \frac{[(P_0 \cdot C) + P_k] \cdot B \cdot L \cdot S}{W \cdot R_i} \tag{4}$$

where P_0 is the structure content fire burden coefficient; C is the structure content combustion coefficient; P_k is the structure construction material fire burden coefficient; B is the size and position of the fire sector coefficient; L is the extinguishing start delay coefficient; S is the fire sector width coefficient; W is the structure's carrier construction fire resistance coefficient; and R_i is the fire risk reduction coefficient.
Based on the introduced assumptions, it follows that S equals to 1.6, because of the adopted fire hazard class I; P_k equals to 0, because Q_i equals to 0; B equals to 1, because the boiler room is located at the ground floor and with area less than 3000 m^2, L equals to 1.1 because the nearest professional fire brigade is 5 km away. If the width of the boiler room is less than 20 m, S equals to 1, otherwise S equals to 1.1. For the margin of safety in this paper the following values are adopted: S = 1.1 and R_i = 1.
Since the installation of a fire extinguishing system is not a technically acceptable solution, it is necessary to choose the coefficient W so that $R_0 < 2$ as follows:

$$\frac{P_0 \cdot 1.94}{W} < 2, \tag{5}$$

that is

$$P_0 \cdot 0.97 < W. \tag{6}$$

Based on the previous inequality, the results are shown in the table 1, in which the last raw gives the values of the necessary fire resistance of the building structure (FR).

Table 1. Fire resistance of the building structure with width more than 20 m

Source: [5]

Q_m [MJ/m^2]	0÷ 251	252÷502	503÷ 1004	1005÷ 2009	2010 ÷4019
P_0	1.0	1.2	1.4	1.6	2.0
W	1.0	1.3	1.5	1.6	2.0
FR [min]	<30	30	60	90	240

If we assume that the boiler room is less than 20 m wide, S equals to1. Thus, from equation (6) one can derive results given in table 2.

Table 2. Fire resistance of the building structure with width equal or less than 20 m
Source: [5]

Q_m [MJ/m^2]	0÷ 251	252÷502	503÷ 1004	1005÷ 2009	2010 ÷4019
P_0	1.0	1.2	1.4	1.6	2.0
W	1.0	1.3	1.3	1.6	1.8
FR [min]	<30	30	60	90	180

3.2 Purt method for boiler rooms with solid fuels

From tables given in EUROALARM standard P_0 equals to 1, because movable specific fire load Q_m equals to 251 MJ/m^2 for boiler rooms and C equals to1.2 because the fire hazard class III (for solid fuels) is adopted. Since no combustible materials are built in the construction of the fire sector in which the boiler room is accommodated, it follows that the fixed specific fire load is Q_i = 0 thus P_k equals to 0. Coefficient L equals to 1.1 because the nearest professional fire brigade is 5 km away. If the width of the boiler room is less than 20 m, S equals to 1, otherwise S equals to 1.1. For the margin of safety in this paper the following values are adopted: S = 1.1 and R_i = 1.
Since the installation of a fire extinguishing system is not a technically acceptable solution, it is necessary to choose the coefficient W so that R_0 <2 as follows:

$$\text{for } R_i = 1: \frac{1{,}45 \cdot B}{W} < 2, \text{ for Ri = 1,2: } \frac{1{,}2 \cdot B}{W} < 2 \text{ and for Ri = 1,3: } \frac{1{,}12 \cdot B}{W} < 2, \tag{7}$$

which implies

$$\text{for } R_i = 1: 0{,}725 \cdot B < W, \text{ for Ri = 1,2: } 0{,}6 \cdot B < W \text{ and for Ri = 1,3: } 0{,}56 \cdot B < W. \tag{8}$$

From equation (8) it can be concluded than fire resistance of the building structure (FR) depends only on the area and height of the boiler room. The previous condition is met when W equals to 1, which is a case for all boiler rooms with area less than 10 000 m^2, from which it follows that it is sufficient to provide the supporting structure of the boiler room that is fire resistant for 30 minutes.

4. GRETENER METHOD

4.1 Gretener method for boiler rooms with liquid or gaseous fuels

The decision on the necessary fire-fighting measures is made on the basis of the calculated value of the factor of preventive fire-fighting measures ($S_G \cdot F_G$) and the estimated value of the fire resistance of the building structure (F_G). The following equation is used to determine the $S_G \cdot F_G$ factor:

$$S_G \cdot F_G = \frac{(G + 4.42) \cdot B_G}{6.25} \tag{9}$$

because there are no installed smoke and heat control systems in the building, where G is the geometry factor of the fire sector. Since the boiler room is provided with fire extinguishing access from three sides, i.e. there is at least one opening on the walls that limit the fire sector on every 20 m, G is calculated according to the equation:

$$G = \frac{A \cdot b}{10^5} \tag{10}$$

Where A is area of the fire sector [m^2] and b is width of the fire sector [m]. In this case the most unfavourable scenario is assumed: A = 2000 m^2 and b = 40 m when G = 0.8 it follows that

$$S_G \cdot F_G = 0.84 \cdot B_G \tag{11}$$

where B_G is specific fire hazard factor calculated from the equation:

$$B_G = Q_G \cdot C_G \cdot R_G \cdot K_G \cdot A_G \cdot P_G \cdot E_G \cdot H_G \tag{12}$$

where E_G is fire brigade intervention factor, A_G is the factor of fire activation, P_G is people harm factor, Q_G is specific fire load factor, C_G is factor of combustibility, R_G is smoke hazard factor, K_G is corrosion hazard factor and H_G is building height factor.
Based on the assumptions, in this case C_G equals to 1.6, because of the adopted fire hazard class I, $R_G = K_G = P_G = A_G = 1$. Factor H_G equals to 1 because the boiler room is located on the ground floor and E_G equals to 0,83 because the nearest professional fire brigade is 5 km away.
As mentioned before, the decision on the necessary fire protection measures is made on the basis of the calculated value of the factor of preventive fire-fighting measures ($S_G{\cdot}F_G$) and the estimated value of the estimated value of the fire resistance of the building structure (F_G).
Therefore, in this case specific fire hazard factor can be calculated as:

$$B_G = Q_G \cdot 1.6 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 0.83 = 1{,}328 \cdot Q_G \tag{13}$$

The results of equation (13) are shown in table 3.

Table 3. Fire resistance of the building structure based on Gretener's method

Source: [6]

Q_m [MJ/m^2]	200 <	300 <	< 400	< 600	< 800	<1300	<1700	<2500
Q_G	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
B_G	1.33	1.46	1.59	1.73	1.86	1.99	2.12	2.26
$S_G \cdot F_G$	1.12	1.23	1.34	1.45	1.56	1.67	1.78	1.90
FR [min]	<30	<30	<30	<30	<30	F30	F30	F30

4.2 Gretener method for boiler rooms with solid fuels

Based on the assumptions, in this case $Q_G = C_G = R_G = K_G = P_G = A_G = 1$. Factor H_G equals to 1 because the boiler room is located on the ground floor and E_G equals to 0,83 because the nearest professional fire brigade is 5 km away.
Therefore, in this case specific fire hazard factor can be calculated as:

$$B_G = 1.6 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 0.83 \cdot 1 = 0.83 \tag{14}$$

It follows that:

$$S_G \cdot F_G = 0.90 \cdot 0.83 = 0.75 \tag{15}$$

From the results it can be concluded that it is sufficient to provide the supporting structure of the boiler room that is fire resistant for 30 minutes.
If boiler room is with installed capacity lower than 500 kW or with area smaller than 150 m^2, factor G can be calculated from equation (10). In this case the most unfavourable scenario is assumed as A = 150 m^2 and b = 40 m when G = 0.06 it follows that

$$S_G \cdot F_G = 0.72 \cdot B_G \quad (16)$$

Based on previous result from equation (16) $B_G = 0.83$ and equation (14) follows that:

$$S_G \cdot F_G = 0.72 \cdot 0.83 = 0.6 \quad (17)$$

From the results it can be concluded that it is sufficient to provide the supporting structure of the boiler room that is fire resistant for 30 minutes, even in case where automatic fire alarm system is not installed in the boiler room.

5. CONCLUSION

Standardized Purt's and Gretener's procedures were used to assess fire risks. The differences between the applied methods are that Purt's procedure does not consider the approaches of fire engines and the probability of fire activation while Gretener's procedure does not consider the consequences of fires other than human losses. Considering the initial assumptions from the results it can be concluded that for boiler rooms where solid fuels are used for generating energy it is sufficient to provide fire resistance of the building structure of 30 minutes.

This research was supported by the Organization Name [grant number xxxxxx].

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