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FIRE RESISTANCE OF BOILER ROOM BUILDING STRUCTURE FOR LIQUID AND GASEOUS FUELS

OTPORNOST PREMA POŽARU NOSEĆE KONSTRUKCIJE OBJEKTA KOTLARNICA NA TEČNO I GASOVITO GORIVO

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- fire risk
- fire load
- fire resistance time of structures

Abstract

Significant limitation of the methodology for determining the class of fire resistance, defined by the group of standards DIN 18230, is its inapplicability to industrial facilities in which energy is produced or distributed. The aim of this paper is to define new methodology for determining the necessary fire resistance of the building structure of a boiler room where liquid or gaseous fuels are used.

Ključne reči
- požarni rizik
- požarno opterećenje
- otpornost konstrukcije prema požaru

Izvod

Bitno ograničenje metodologije za određivanje stepena otpornosti prema požaru definisane grupom standarda DIN 18230, je neprimenljivost na industrijske objekte u kojima se proizvodi ili distribuira energija. Cilj ovog rada je definisanje nove metodologije za određivanje neophodne otpornosti prema požaru noseće konstrukcije objekta kotlarnica na tečno ili gasovito gorivo.

INTRODUCTION

W. Halpaap has developed methodology for determining the necessary fire resistance class for industrial building structures based on previous research for metallic structures 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 /1/. This methodology is 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 are standardized based on the research of the Swiss engineer Gretener (references are found in /3/) which are carried out in the period from 1961 to 1968: (1) The Swiss Society of Engineers and Architects (SIA) published SIA81 method in 1981 and SIA 2007 in 2007; (2) The Austrian Fire Brigade Association published TRVB 100 Technical Recommendation in three versions issued in 1975, 1987, and in 2010, /4/. Using the results of Gretener's research, author Purt /5/ recommended a new methodology in 1972, which is standardized by the European Fire Alarm Manufacturers Association (Euroalarm). More details on the methodology can be found in /6-9/.

A significant limitation of the DIN18230:2010 standard is its inapplicability to facilities in which energy is produced or distributed.

The aim of this paper is to determine the necessary fire resistance of the building structure (FR) of a boiler room in which liquid or gaseous fuels are used. 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 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:
- installation of an automatic fire alarm system;
- constant presence of the person on duty next to the fire control panel;
- sufficient number of fire extinguishers before the arrival of the fire brigade;
- existence of appropriate fire hydrant installation;
- professional fire brigade located up to 5 km from the building;
- 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 walls that border the fire sector.

Other assumptions include:
- mechanical ventilation system is applied, which provides adequate explosion protection, but without smoke and heat control system;
- 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;
- the boiler room is located on the ground floor;
- there are no other floors below and above the boiler room;

- the building in which the boiler room is accommodated is free-standing, or it is part of an industrial building;
- no combustible materials are built into the boiler room structure;
- installed boiler heating duty is less than 1 GW;
- no fuel is stored in the boiler room.

SPECIFIC FIRE LOAD AND FIRE RISK CLASS

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 structure 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 the boiler room area (m^2).

Based on the adopted assumptions, the value of parameter t_w can be determined as:

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

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

PURT METHOD

For the application of the Purt method it is necessary to determine two parameters: fire risk of the structure and fire risk of the structural 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 smoke effectiveness coefficient. In this case study, $H = 1$, because there is no expected harm for people; $D = 2$, 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 $F = 1$, because there is no danger of smoke and corrosive gases.

Hence, the fire risk of the structure contents $R_s = 2$, meaning that installation of fire alarm system, is necessary in the boiler room, except in 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 is a coefficient that qualitatively shows the hazard for the building structure and is calculated using the form:

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

where: P_0 is the structure content fire burden coefficient; C is the structure content combustion coefficient; P_k is the structure 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 structure's carrier fire resistance coefficient; and R_i is the fire risk reduction coefficient.

Based on the introduced assumptions, it follows that $S = 1.6$, because of the adopted fire hazard class I; $P_k = 0$, because $Q_i = 0$; $B = 1$, because the boiler room is located at the ground floor and with area less than 3000 m^2; $L = 1.1$, because the nearest professional fire brigade is 5 km away. If the width of the boiler room is less than 20 m, $S = 1$, otherwise $S = 1.1$. For the safety margin 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 Table 1, in which the last row gives the values of the necessary fire resistance of the building structure (*FR*).

Table 1. Fire resistance of building structure with width over 20 m.

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, $S = 1$. Thus, from Eq.(6) one can derive results given in Table 2.

Table 2. Fire resistance of building structure with width ≤ 20 m.

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

GRETENER METHOD

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

$$S_G \cdot F_G = \frac{(G + 4.42) B_G}{6.25}, \tag{7}$$

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:

$$G = \frac{A \cdot b}{10^5}, \quad (8)$$

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

$$S_G F_G = 0.84 B_G \quad (9)$$

where: B_G is specific fire hazard factor calculated from:

$$B_G = Q_G C_G R_G K_G A_G P_G E_G H_G, \quad (10)$$

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 = 1.6, because of the adopted fire hazard class I; $R_G = K_G = P_G = A_G = 1$. Factor H_G = 1 because the boiler room is located on the ground floor and E_G = 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 based on the calculated value of the factor of preventive fire-fighting measures ($S_G F_G$) and 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:

$$B_G = Q_G 1.6 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 1 \cdot 0.83 = 1.328 Q_G. \quad (11)$$

The results of Eq.(11) are shown in Table 3.

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

Q_m (MJ/m^2)	0-200	201-300	301-400	401-600	601-800	801-1300	1301-1700	1701-2500
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

EXAMPLES

In the paper several boiler rooms with different sizes and installed power duties are considered as shown in Table 4.

Table 4. Dimensions and power duties of case study boiler rooms.

Type	*a* (m)	*b* (m)	*A* (m^2)	*P* (MW)
J1	10	5	50	1
J2	15	8	120	10
J3	20	10	200	30
J4	30	20	600	100
J5	40	30	1200	400
J6	50	30	1500	800
J7	50	40	2000	1000
J8	60	40	2400	1000
J9	75	40	3000	1000

In Table 4, a is length of the boiler room, b is width of the boiler room, A is the surface of the boiler room, and P is installed boiler power duty.

The results obtained by applying the Purt's procedure are shown in Table 5. The values shown in the last column are necessary fire resistance of the building structure.

Using the Gretener's procedure, the results are shown in Table 6, in which the last column gives the necessary fire resistance of the building structure.

CONCLUSION

In Central Europe the usual methodology for assessing the fire resistance of building structures of industrial facilities is given by the technical standard DIN18230: 2010. A significant limitation of the DIN18230:2010 standard is its inapplicability to facilities in which energy is produced or distributed. This paper presents one possibility for assessing the fire resistance of the building structure of a boiler room that accommodates boilers fired with liquid or gaseous fuel. Standardized Purt's and Gretener's procedures are used to assess fire risks.

Table 5. Fire resistance of building structure based on Purt's method for case study boiler rooms.

Type	P_0	C	P_k	B	L	S	W	R_i	R_0	H	D	F	R_s	*FR* (min)
J1	1.0	1.6	0	1.0	1.1	1.0	1.0	1.0	1.75	1	2	1	2	< 30
J2	1.2	1.6	0	1.0	1.1	1.0	1.0	1.0	1.75	1	2	1	2	< 30
J3	1.2	1.6	0	1.0	1.1	1.0	1.0	1.0	1.75	1	2	1	2	< 30
J4	1.2	1.6	0	1.0	1.1	1.0	1.0	1.0	1.75	1	2	1	2	< 30
J5	1.4	1.6	0	1.0	1.1	1.0	1.3	1.0	1.57	1	2	1	2	30
J6	1.4	1.6	0	1.0	1.1	1.1	1.3	1.0	1.57	1	2	1	2	30
J7	1.4	1.6	0	1.0	1.1	1.1	1.3	1.0	1.57	1	2	1	2	30
J8	1.4	1.6	0	1.0	1.1	1.1	1.3	1.0	1.57	1	2	1	2	30
J9	1.4	1.6	0	1.0	1.1	1.1	1.3	1.0	1.57	1	2	1	2	30

Table 6. Fire resistance of building structure based on Gretener's method for case study boiler rooms.

Type	*a* (m)	*b* (m)	*A* (m^2)	G	Q_G	C_G	R_G	K_G	A_G	P_G	E_G	H_G	B_G	$S_G \cdot F_G$	*FR* (min)
J1	10	5	50	0.00	1.2	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.59	1.12	< 30
J2	15	8	120	0.01	1.2	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.59	1.13	< 30
J3	20	10	200	0.02	1.3	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.73	1.23	< 30
J4	30	20	600	0.12	1.3	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.73	1.26	< 30
J5	40	30	1200	0.36	1.3	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.73	1.32	< 30
J6	50	30	1500	0.45	1.5	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.99	1.56	< 30
J7	50	40	2000	0.80	1.5	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.99	1.99	30
J8	60	40	2400	0.96	1.4	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.86	1.60	30
J9	75	40	3000	1.20	1.3	1.6	1.0	1.0	1.0	1.0	0.83	1.0	1.73	1,56	< 30

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 with fire loads less than 500 MJ/m^2 it is sufficient to provide fire resistance of the building structure in 30 minutes. In addition, it can be recommended to the designers of boiler rooms to provide access for fire-fighting on at least three of four sides of the facility. What is more, the preferable width of the facility should not exceed 20 m.

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