Testing the volume of HF, HCl, CH_4 gaseous air pollutants' emission for WR water grate boilers type – state of the polish heating industry

Badanie wielkości ładunku emisji spalin związków HF, HCl, CH_4 dla kotłów wodnorusztowych typu WR – stan polskiego ciepłownictwa

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DOI 10.36119/15.2020.12.1

Poland is one of the heaviest users of district heating systems in Europe, and those district heating systems are mainly coal-fired.
This study describes the correlation between emission of gaseous air pollutants and the combustion parameters of WR coal-fired water grate boilers (WR-25, WR-10, WR-8M). Air pollution emissions loads were measured during boiler work in conditions other than standard (start-up, extinction, load fluctuations).
A negative impact of compounds such as HCl, HF, CO and NH_3 in emission standards for various heat sources has been noted.
Keywords: emission, boiler, heating plant, air pollution, combustion, coal, heating

Polska należy do największych użytkowników systemów ciepłowniczych w Europie, które wciąż w większości opalane są węglem kamiennym.
W artykule opisano korelację pomiędzy emisją gazowych zanieczyszczeń powietrza i parametrami spalania węglowych wodnych kotłów rusztowych typu WR (WR-25, WR-10, WR-8M). Wielkości gazowych emisji zanieczyszczeń powietrza były mierzone podczas pracy kotłów w warunkach odbiegających od normalnych (rozruch, wygaszanie, zmiana obciążenia). Zaobserwowano negatywny wpływ związków, takich jak: HCl, HF, CO oraz NH_3.
Słowa kluczowe: emisja, kotły, ciepłownia, zanieczyszczenie powietrza, spalanie, węgiel, ogrzewanie.

Introduction

Globally, covering the energy needs of the society is one of the main causes of air pollution. This is particularly visible when energy is produced in sources that burn solid fuels (hard coal and brown coal).

During combustion, these fuels give the highest emissions of air pollutants per unit of energy obtained, mainly dust, SO_2, NO_x and CO_2 during normal boilers' operation conditions and additionally, pollutants such as HCl, HF, CO oraz CH_4 i NH_3 formed during incomlete and imperfect combustion, characteristic for the boilers' unstable operation conditons (different than normal). The analysis of the structure of covering the country's energy needs shows that this problem is particularly important in Poland.

The dominant fuel in domestic heat sources is still hard coal. The share of coal in heat production is approx. 75%. [1, 2]

According to estimates, about one third of energy consumption in Poland is spent on space heating. On average, more than half of the flats in cities are heated by heating networks, in some cities, such as Warsaw, even 75÷80%.

The amount of pollutants generated by the boiler depends mainly on the amount burned and the fuel characteristics, the type of furnace determining the temperature level in the combustion area and the oxygen concentration in the initial section of the flame [3, 4].

The considered coal combustion plants in WR type boilers without wet or semi-dry flue gas desulphurization (FGD) are considered to be the main source of hydrogen chloride emitted to the atmosphere. Chlorine compounds contained in flue gas are an additional corrosive factor for boiler elements and flue gas ducts, as well as a component of acid rain.

The main reason for the emission of hydrochloric acid is the content of chlorine in the coal supplied by the Polish coal mine.

It occurs in the form of inorganic salts – chlorides, and in the form of chloro derivatives of organic compounds that are components of coal, the content of the latter usually amounting to no more than 5% of the total amount of chlorine in the coal.

Chlorine derived from chlorides is contained in the brine that has not been removed from the coal after mining, and which is on the surface of its grains. The effective removal of these compounds takes place in the process of washing coal.

During combustion a part of chlorine is bound into slag and ash, then separated in dry dust collectors. The remaining chlorine leaves the power system either in the form of gaseous hydrogen chloride or as inorganic chlorine compounds contained in the finest grains of dust that has passed through the cyclones. The study [5] shows that the mass value of chlorine emission in the combustion flue gases from grate furnaces is comparable to the sulfur emission.

Like chlorine, fluorine is also a natural element found in fossil fuels. When using fossil fuels such as coal to generate power without usage of flue gases desulphurization (FGD), the fluorine is released into the exhaust gases. By combining with hydrogen it forms hydrogen fluoride and converts to hydrofluoric acid in the presence of moisture in the air. It has been observed that hydrogen fluoride can be emitted by "rotating" in a rotary heat exchanger and in a combustion air pre-heater [6, 7].

Very little information is available on the capture of halogens by electrostatic precipitators and fabric filters. Due to the nature of

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the gases, in the absence of sorbent, it is likely that they have little or no effect on the capture of halogens. The addition of a sorbent, such as lime, to the combustion zone can lead to the capture of halogens on or into the particles which can then be trapped by filtration systems. The actual removal efficiency of halogen emissions from combustion plants with a wet flue gas desulphurization plant varies widely. For chlorine (HCl) it varies between 87÷97%, for fluorine (HF) between 43÷97% [7, 8, 9]. The efficiency of halogen removal in a dry flue gas desulphurization installation is comparable to a wet installation. [7]. Chlorine and fluorine in the fuel most often combine with alkaline elements such as Na or K. At 850 C, chlorine and fluorine form into gaseous HCl and HF, which then react with CaO at a lower temperature. HF is trapped by excess limestone in the ash filter, the effectiveness is usually greater than 90%. On the other hand, the effectiveness of HCl may vary significantly, depending on the moisture content in the flue gas, excess limescale in the ash filter and the type of filter (electrostatic precipitators or bag filters), the HCl retention efficiency is between 20÷90%. Therefore, for fuels with high chlorine content, secondary means such as $Ca(OH)_2$ injection may be installed.

WR type boilers

Coal boilers can be divided into:

- ✓ grate,
- ✓ dust (water, drum, flow)
- ✓ fluid

WR type grate water boilers fired with fine coal (MI 20-0 mm or MII 10-0 mm assortment) are installed in heating plants and combined heat and power plants as well as in industrial plants as devices for generating heat.

Optimal load of a boiler stands at 85-95% of the nominal power. Then, the WR-type boiler reaches the highest installed power of 82%. These are conditions at which there is effective heat generation with minimum fuel consumption and stable parameters of furnace and dedusting system operation. Work with optimal load ensures the lowest (for a given combustion process) index of fuel consumption due to almost perfect and complete combustion, and the lowest air pollution emissions index per unit of heat generated [10]. In such cases, we actually have only emission of 3 particulates: SO_2, NO_x and CO_2. Other substances which are the result of incomplete and imperfect combustion: VOC, HF, HCl and NH_3, CO and others, are present only in trace volumes. However, combustion in substoichometric conditions leads to a clear increase in emissions of these substances.

Due to frequent external temperature changes, the boilers are often turned on and off, or operate at a load below the technical minimum. At that time, they generate higher unitary emissions of typical pollutants as well as those resulting from incomplete and imperfect combustion.

The analysis of the presented diagram shows a very high variability of the heating plant load during the heating period, depending mainly on the outside temperature. Of course, the presented graph is an ordered graph averaging the needs, and in fact, due to frequent temperature changes, the boilers existing in the heating plant are often turned on and off, or work at a load below the technical minimum. At that time, they generate higher unitary emissions of typical pollutants as well as those resulting from incomplete and imperfect combustion. Unstable parameters of the furnace operation also occur in emergency situations. Contrary to popular belief, the conditions under which the boilers operate under varying loads occur very often. Taking into account that there are as many as 769 WR type boiler units in active operation in Poland, tab. 1.1. the problem becomes serious [11].

Experimental measurements

The research was carried out in four heating plants supplying heating systems, hereinafter referred to as Objects A, B, C or D.

At present, the production units of the analyzed measuring objects generate heat by burning fine coal. The heating plants have WR type coal stoker boilers, used for the needs of central heating and domestic hot water in the heating and summer season.

Installed WR boilers are used to produce heating water for central heating and hot water in public utility buildings, in buildings of business entities and in residential buildings.

The heated water is sent to heat nodes of recipients. Circulation of water is provided by circulation pumps. The combustion of coal takes place inside the boiler, in the combustion chamber on a moving mechanical grate. Above the grate there is a combustion chamber with a secondary air duct. Under the grate, there is an under-grate box with blast zones and a duct supplying the atmospheric air necessary for combustion to the blast zones. All measurement facilities have exhaust gas dedusting systems (cyclones) with an average real efficiency of about 88%, but they do not have devices for flue gas desulphurization and denitrification. Measurements of gaseous pollutant emissions (NO_2, SO_2, CO_2, CO), general dust emissions and measurement of oxygen content in exhaust gases are carried out. The exhaust gases from the heating plant are discharged into the atmosphere through a chimney, in which there is a monitoring system for the emission of pollutants emitted into the air.

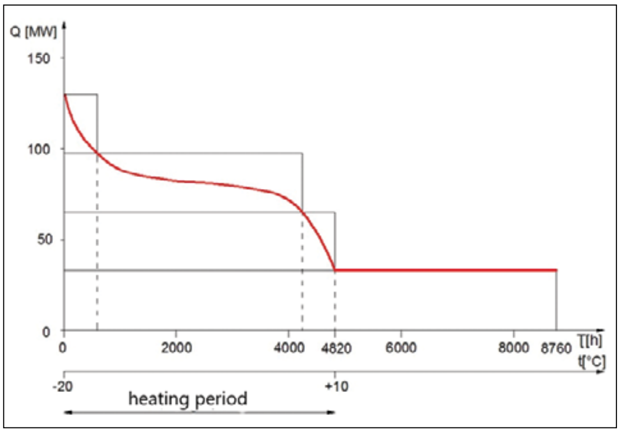
The Regulation [12] specifies the requirements for the measurement of emission levels. Continuous measurements are carried out for sources with a rated thermal power of not less than 100MW.

For other sources, periodic measurements of emissions to the air are carried out twice a year – once in the winter season (October – March) and once in the summer season (April – September), however, in the case of a source operating seasonally for a period not exceeding six months, the measurements emissions to air are carried out once a year during the operation of the source.

Tab.1.1. The WR water boilers summary in Poland [11]
Tab.1.1. Zestawienie kotłów typu WR w Polsce [11]

Boiler type	WR – 25	WR – 15	WR – 10	WR – 5	WR – 2,5	Different type of WR	Σ
Number of units	261	3	262	160	22	61	**769**

Fig. 1.
Typical ordered chart of heat production/heat consumption in central Poland
Rys.1. Typowy uporządkowany wykres produkcji ciepła/ zużycia ciepła w centalnej Polsce



In all four cases, the measuring probe was placed in the flue gas duct after the WR boiler, in a measuring cross-section that meets the relevant flow requirements for such measurements. The measuring probe was placed before the cleaning devices, Fig. 2.

Fig. 2.
Placing the probe during experimental research
Rys. 2. Umieszczenie sondy pomiarowej podczas badań eksperymentalnych

According to PN-ISO 10396: 2001 "Emission from stationary sources – Sampling for automatic measurement of the concentration of gaseous components", the measuring point should be located near the center of the measuring cross-section, located in 1/3 of the channel length. Such measurement, called the non-extraction method (the measurement process is continuous), allows to obtain the most representative concentration values. Prior to starting the measurements, non-extraction systems should be calibrated with calibration gases. Nitrogen was used for calibration in the experimental tests carried out.

According to the PN-EN 14181: 2010 standard „Emission from stationary sources – Quality assurance of automatic measurement systems", a zero point and span check should be performed using a reference path without waste gases before and after readjustment of AMS (automatic measurement system) and its reassembly at the place of measurement. These activities were performed prior to the planned commissioning of the boiler unit.

Measurements of pollutant concentrations were made with the GASMET DX-4000 gas analyzer, which allows for the simultaneous measurement of up to 50 chemical compounds present in exhaust gases, waste gases, process gases and air. The compounds that can be measured are: NH_3, CO_2, CO, CH_4, NO_2, NO, N_2O, SO_2, H_2O, HCl and HF, however, it is not possible to test noble gases (He, Ne, Ar…) and diatomic homonuclear gases (O_2, N_2, H_2, Cl_2…)). The main characteristics of the measuring device are:

- The lowest detectable concentration 0.2 ppm,
- Accuracy of 2% on the measuring scale,
- Precision 0.01% of the measuring scale,

There is no possibility of testing noble gases [13].

The measurement method, known as FT-IR (Fourier Transform Infrared), is based on the ability of polyatomic gas particles to absorb infrared radiation. The GASMET DX-4000 analyzer used in the research meets the PN-ISO 10396: 2001 standards.

Results

a) Object A

The heat plant Object A has four water-based WR type grate boilers, which achieve a nominal permanent power of 124MW, with a nominal power in fuel of 153MW. The individual boilers have a thermal power:

- K1 (WR-25) – 32MW;
- K2 (WR-25) – 29MW;
- K3 (WR-25) – 30MW;
- K4 (WR-25) – 33MW.

Measurements started around 9.30 am. The equipment was connected and measurements were started. At that time, the staff of the Heat Plant started the firing up procedure for boiler no. 1. At 10:10, an increase in air pollutant emissions can be observed, Fig. 3. An increase in carbon monoxide was recorded, over 700mg/Nm^3 (at a pressure of 101.325kPa and a temperature of 0°C) . Such a significant increase in CO emissions is related to semi-combustion. Most often it occurs in the absence of the optimal amount of air needed for the combustion. This process stabilizes with the stabilization of the furnace operation. The proper separation of air and fuel occurs when the boiler is operated under nominal load conditions – normal conditions.

Fig. 3 shows the emission of compounds such as methane, hydrogen chloride and hydrogen fluoride, which are not covered by emission limits from heat sources. The Regulation [14] only sets limits on HCl and HF for waste incineration plants and some waste co-incineration plants. Average daily limits are on the level of 10mg/m^3_u for HCl and 1mg/m^3_u for HF, this is determined for an oxygen content of 11% in the waste gas. As shown in the experimental studies, Fig. 3, HCl and HF also appear in the exhaust gases. Significant methane emission in the first stage of start-up proves insufficient amount of oxygen supplied to the combustion chamber. When the furnace operation slowly stabilizes, the level of CO and CH_4 emissions decreases. Around 1:15 p.m. the conditions stabilize and the boiler has a thermal load of 6.8 MW. For almost 2 hours, the conditions stabilize and reach the actual values for a given load. After stabilization of the combustion process and the heat load, the CO value is approximately 100mg/Nm^3 (at a pressure of 101.325kPa and a temperature of 0°C), which proves that the combustion process is not conducted properly. The emission limits which are set in [14] are not exceeded. It is important to show that the operation conditions of the WR-25 boiler with power of 7 MW is work at a low load (less than 30% of the nominal load with which the boiler works under stable conditions); that will generate the formation of harmful substances. (SO_2, NO_x, HCl, HF, NH_3, CH_4, CO)

The second stage was changing the boiler's thermal load. The measuring equipment was connected to the flue gas pipe downstream of the boiler, before flue gas cleaning during the operation of boiler no. 2. At that time the thermal load was 6.95MW. The conditions stabilized until 12:30 p.m.. The load was then changed from 7 to 3MW. In the case of the WR-25 boiler, the load is

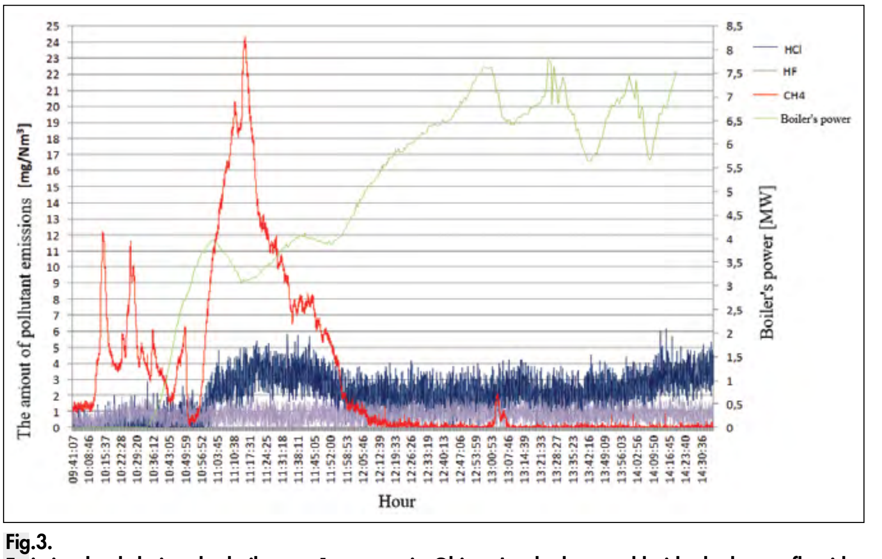


Fig.3.
Emission load during the boiler no. 1 start-up in Object A – hydrogen chloride, hydrogen fluoride, methane
Rys.3. Wielkość emisji zanieczyszczeń powietrza podczas rozruchu kotła nr 1 w Obiekt A – chlorowodór, fluorowodór, metan

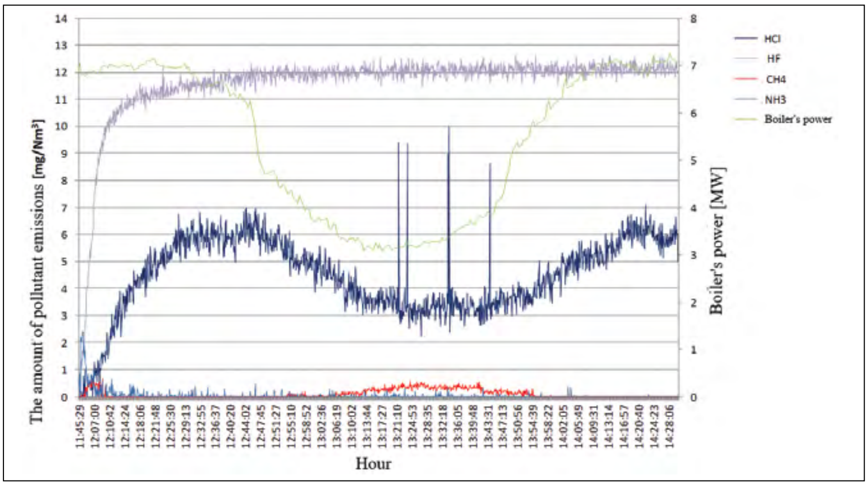


Fig. 4.
Emission load during power changes of the boiler no. 2 in Object A – hydrogen chlorine, hydrogen fluoride, methane, ammonia
Rys. 4. Wielkość emisji zanieczyszczeń powietrza przy zmianie obciążenia kotła nr 2 w Obiekt A – chlorowodór, fluorowodór, metan, amoniak

much below the permissible level (7.5MW), at which the boiler works optimally, from the combustion process and gaseous emissions point of view. Same situation was with start-up, carbon monoxide emissions increased during load reduction. This increase is due to insufficient amount of oxygen in the combustion chamber and results in semi-combustion.

After briefly setting the parameters at the level of approx. 3MW, the output load was returned to, which was achieved at approx. 14:10, fig. 4. Then the pollutant emission concentrations reached their initial values. Very worrying emission values were recorded for hydrogen fluoride, which since the beginning of the measurements has reached a constant value of approx. 12mg/Nm^3. Considering the permissible emission concentration for HF for waste incineration plants at the level of 1mg/m^3_u, this is a worrying emission level, Fig. 4. The amount of the HCl emission concentration was variable, dependent on the load, Fig. 4. A few single peaks may indicate temporary changes in the content of chlorine in the burned coal. Due to the fact that coal contains chlorine and fluorine compounds in its structure, it is probable that the burnt sample had a high content of it.

b) Object B

Combustion installation in Object B consists of 4 WR-10-011 water grate boilers. The total thermal capacity of the installation is 53.553MW. The individual boilers have thermal power of:

- K1 (WR-10) – 13,273MW;
- K2 (WR-10) – 13,571MW;
- K3 (WR-10) – 13,250MW;
- K4 (WR-10) – 13,403MW.

Measurements started around 3:45 p.m. The equipment was connected and measurements started. At that time, the Heating Plant staff started the firing up procedure for boiler no. 4. At 4:00 p.m., an increase in air pollutant emissions can already be observed, Fig. 5. At 4:30 p.m. the power of the boiler reached 4.2MW, at 5:30 p.m. the power started to stabilize at the level of 6.2MW. The highest increase was recorded by carbon monoxide, over 2600mg/Nm^3 (at pressure 101.325kPa and temperature 0°C). In the first stage of start-up, not entire coal burn out in due to low temperature in the combustion chamber, too much fuel or/and too fast grate advance. Fig. 5 shows the emission of compounds such as methane, hydrogen chloride and hydrogen fluoride, which are not covered by emission limits from heating sources. Significant methane emission level in the first stage of start-up proves insufficient amount of oxygen supplied to the combustion chamber. When the furnace operation slowly stabilizes, the level of CO and CH_4 decreases. From 5:00 p.m. the conditions stabilize and the boiler reached a thermal load of 6.8MW. For almost 2 hours, the conditions stabilize and reach the actual values for a given load. The CO value is around 100mg/Nm^3, which proves the lack of proper optimization of the furnace operation.

The stage of turning off the boiler no. 1 started with connecting the measuring equipment to the flue gas duct after the boiler, upstream of the flue gas cleaning devices. The thermal load reached 6.95MW. The stabilization of the conditions lasted from around 1.30 p.m. to 1.50 p.m..

Then the boiler extinguishing procedure was started, the grate feed was reduced. The boiler WR-10 reacts quickly to set changes. There was an increase in carbon monoxide gaseous emissions both during start-up and during load reduction. The value of the concentration of CO emissions reached a value of over 3250mg/Nm^3, slowly reducing its value, but still maintaining a very high content in the exhaust gases. With the increase in CO, an increase in methane was also noted to the value of approx. 260mg/Nm^3 (at a pressure of 101.325kPa and a temperature of 0°C), Fig. 7. The reason was the formation of the semi-combustion process in the combustion chamber and the formation of CO and CH_4. However, the achieved load values are higher than expected.

c) Object C

The available thermal power of Object C is 174.6MW. Six WR-25-015 water boilers are available for heat production. The individual boilers have a thermal power:

- K1 (WR-25) – 29,1MW;
- K2 (WR-25) – 29,1MW;
- K3 (WR-25) – 29,1MW;
- K4 (WR-25) – 29,1MW;
- K5 (WR-25) – 29,1MW;
- K6 (WR-25) – 29,1MW.

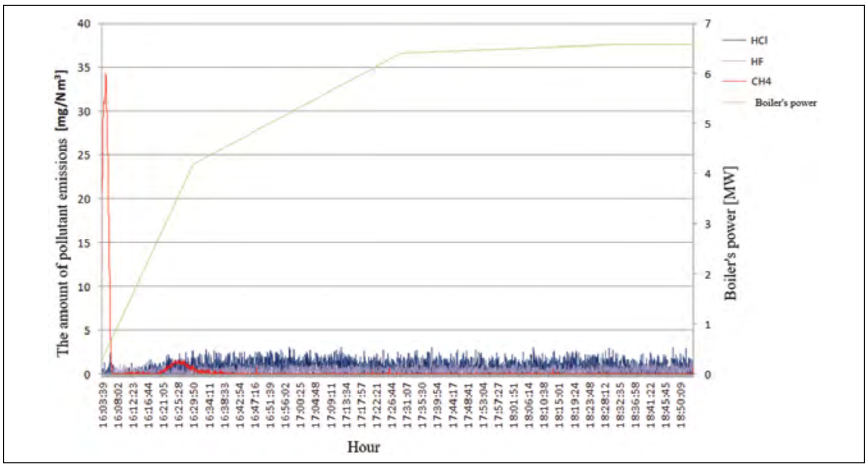


Fig. 5.
Emission load during start-up of the boiler no. 4 in Object B – hydrogen chloride, hydrogen fluoride, methane
Rys. 5. Wielkość emisji zanieczyszczeń powietrza przy rozruchu kotła nr 4 w Obiekt B – chlorowodór, fluorowodór, metan

From 2:00 p.m., the boiler was slowly extinguished from the power of approx. 20MW. The measurements started at 4:37 p.m., the thermal load reached 16.8MW. The thermal power of boiler no. 3 was reduced by changing the feed of the grate and the amount of air supplied to the grate. At 7:00 p.m. the fuel supply was cut off. Carbon monoxide emissions increase significantly immediately. The value of the concentration of CO emissions almost reached the value of 400 mg/Nm^3, slowly decreasing its value. With an increase in CO, an increase in methane concentration was also noted to the value of approx. 1.5mg/Nm^3 (at a pressure of 101.325kPa and a temperature of 0°C, for a 6% oxygen content), Fig. 8. During the shutdown of the boiler, oxygen deficiency in the combustion chamber takes place, which causes the formation of the semi-combustion process and the formation of CO and CH_4. The values of the emissions of hydrogen chloride and hydrogen fluoride did not exceed 1.0mg/Nm^3 (at a pressure of 101.325kPa and a temperature of 0°C, for 6% oxygen content), reaching the acceptable values specified in the Regulation [12].

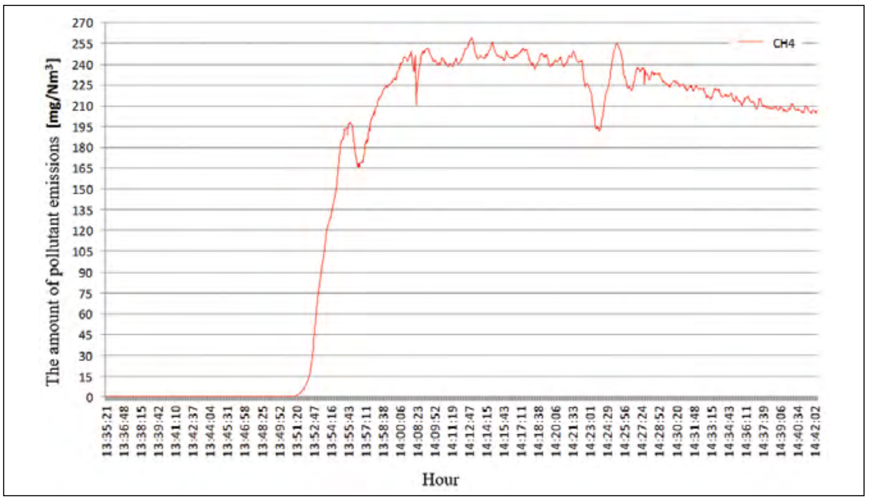


Fig. 7.
Emission load during switching off the boiler no. 1 in Object B – methane
Rys. 7. Wielkość emisji zanieczyszczeń powietrza przy wygaszaniu kotła nr 1 w Obiekt B – metan

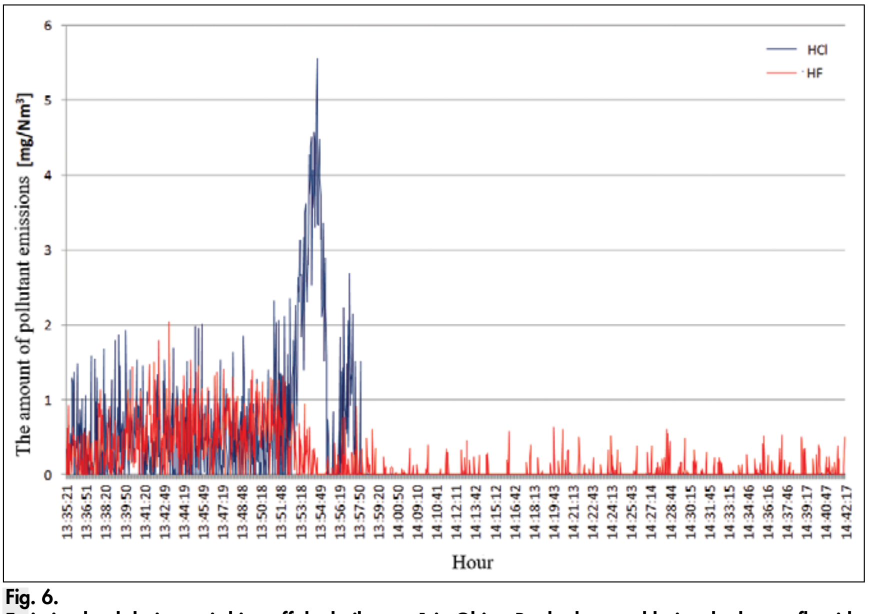


Fig. 6.
Emission load during switching off the boiler no. 1 in Object B – hydrogen chlorine, hydrogen fluoride
Rys. 6. Wielkość emisji zanieczyszczeń powietrza przy wygaszaniu kotła nr 1 w Obiekt B – chlorowodór, fluorowodór

d) Object D

Boiler house is equipped with two WR-5/WR-8M boilers and one WR-5 boiler. The individual boilers have a thermal power:

- K1 (WR-8M) – 10MW;
- K2 (WR-8M) – 10MW;
- K3 (WR-5) – 5,815MW.

At the start of the measurements, the heat load of boiler no. 3 was 1.6MW. (In the case of the WR-8M boiler, the load is much below the permissible level (2.4MW, according to the DTR), in which the boiler works stably. It took 50 minutes to stabilize the conditions, until around 12:40 p.m.. At that time, the average boiler efficiency was approx. 68.4%, the excess air coefficient was =3.2. During the stabilization of the conditions, one can observe the CO content in the exhaust gas at the level of about 400 mg/Nm^3 (at the pressure of 101.325 kPa and the temperature of 0°C, for the oxygen content of 6%).

Then the boiler efficiency was increased to 3.7MW. The feed speed of the grate was increased, the excess air ratio was reduced. During this time, the concentration of carbon monoxide increases, reaching the value of 800÷850mg/Nm^3 (at a pressure of 101.325kPa and a temperature of 0°C, for an oxygen content of 6%). At 01:23 p.m. the assumed efficiency level was reached (average efficiency 65.1%, =2.1). Then the load was changed to 0.9MW by increasing the amount of air in the combustion chamber and

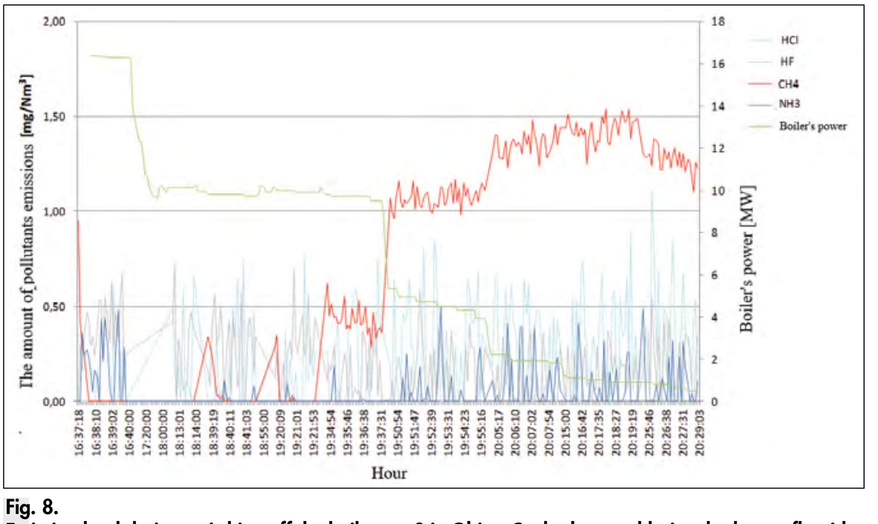


Fig. 8.
Emission load during switching off the boiler no. 3 in Object C – hydrogen chlorine, hydrogen fluoride, methane, ammonia
Rys. 8. Wielkość emisji zanieczyszczeń powietrza przy wygaszaniu kotła nr 3 w Obiekt C – chlorowodór, fluorowodór, metan, amoniak

reducing the grate feed rate. At that time, the average efficiency was 98%. The reaction of such a small boiler unit is basically immediate. During the reduction in efficiency, the concentration of carbon monoxide increases to a maximum value of about 1400mg/Nm^3 (at a pressure of 101.325kPa and a temperature of 0°C, for an oxygen content of 6%). Three large peaks can be observed, which also appear for the concentrations of SO_2 and CH_4, Fig. 9. This phenomenon indicates an unstable combustion process. There is underburning of coal in the combustion chamber. The boiler efficiency at this time is 98%, the excess air coefficient increases from λ=2.2÷5.2, until the efficiency level of 0.9MW is achieved. The concentration of pollutant emissions for CH_4 and HCl increases.

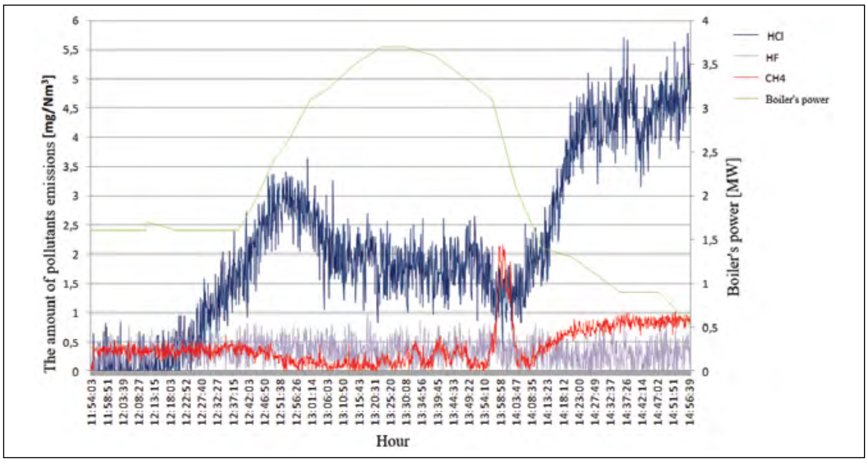


Fig. 9.
Emission load during power changes of the boiler no. 3 in Object D – hydrogen chlorine, hydrogen fluoride, methane
Rys. 9. Wielkość emisji zanieczyszczeń powietrza przy zmianie obciążenia kotła nr 3 w Obiekt D – chlorowodór, fluorowodór, metan

Conclusions

The problem of unstable boiler operation conditions was presented, including mainly the variable load of the entire heating plant and individual boilers during the year.

Summing up, when designing a boiler house, one should take into account the variability of the power load, designing and selecting boiler units so that the operation with the maximum achieved efficiency takes place as long as possible during a year. During operation, the number of boiler units should be selected for cooperation, so that their load is close to the nominal one, i.e. close to the maximum efficiency. Each boiler in the heating plant should be evenly loaded. This is a serious problem, especially in the case of heating plants which only have WR-25 boilers. Here, the problem of low loads occurs especially in the summer, when the heating plant works only for domestic hot water purposes. [15,16] And so in the case of Object "A", in 2012, the WR-25 boiler no. 1 in the heating season worked 59 days with a load below 30% of nominal power, was turned off and on three times, and the entire period outside the heating season was operated with a load below the nominal load. This gives as much as 5166 hours of operation per year with significantly increased specific emissions of pollutants, not including start-ups and shutdowns.

In addition, process of boiler start-up and extinction is also noteworthy. It must be carried out in accordance with the manufacturer's recommendations and indications related to the characteristics of a given boiler as well as the materials and construction used.

A very important aspect is following the appropriate procedures by the boiler operator during operation of the unit. These are the conditions under which the installation operates at partial load – low efficiency, lower dedusting efficiency, increased fuel consumption rate and unstable parameters of the furnace operation. Therefore, in order not to damage the boiler's structural elements, these processes should be carried out very slowly. The brickwork in the combustion chamber cannot be subjected to a rapid temperature increase. It is similar with most of the construction elements. The type and method of feeding fuel to the mechanical grate is also important. The ignition of coal on the grate depends on the effectiveness of heat conduction, so good transport will ignite even coal with worse parameters. It will also move the flame away from the vault and burn coal on a larger grate surface, which will reduce NO_x emissions caused by too hot vault [17].

The start-up time is strictly dependent on the size of the boiler unit.

During experimental measurements, the emission of substances not covered by emission limits so far was measured. These compounds are HCl, CH_4, HF, NH_3. Hydrogen chloride and hydrogen fluoride are monitored in waste incineration plants. This allows us to believe that the concentration of these substances in the air above the permissible level is harmful to humans and the environment. This is the basis for an in-depth analysis of the impact of measured substances on human health and life, as well as for the necessary introduction of emission limits for these substances.

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