UDC 621.577 (07)
МРНТИ 87

DOI: https://doi.org/10.37788/2021-1/ 111-116

A.P. Plevako
Innovative University of Eurasia, Kazakhstan
(e-mail: plada78@mail.ru)

Methods for reducing nitrogen oxide emissions in steam generators of thermal power plants

Abstract

Main problem: Ensuring environmental safety of thermal power plants by reducing emissions of harmful substances, in particular nitrogen oxides. When all types of fossil fuel, including solid fuel, are burned, nitrogen oxides are formed in the boilers of TPPs. The sources of their formation are air nitrogen and nitrogen-containing components of the organic matter of the fuel. As you know, they adversely affect the health of humans, plants and animals. Therefore, it became necessary to consider and analyze methods to reduce these emissions.

Purpose: To review and analyze various ways to reduce nitrogen oxide emissions and propose a new scheme for reducing these emissions by recirculating flue gases.

Methods: This is achieved due to the fact that in the known method for purifying the flue gases of steam generators from nitrogen oxides by lowering the temperature in the furnace of the steam generator by supplying flue gases with a temperature below the temperature in the furnace of the steam generator, it is proposed that the flue gases be fed into the furnace of the steam generator after ash cleaning. At the same time, as a result of the supply of recirculated gas cooled after filtering and passing through the main smoke exhauster into the combustion chamber, having a temperature of 110-170 °C, in comparison with the initial version, a greater decrease in temperature in the furnace of the steam generator occurs, which in turn leads to a decrease in the flue gases of oxides nitrogen, since the chemical reaction of their formation goes with the absorption of heat.

Results and their importance: The technical result at the proposed method of cleaning from nitrogen oxides is to reduce the consumption of electricity by eliminating the collateral wear of the recirculation gas duct, due to the cleaning of time gases from ash (a requirement of the rules of technical operation of PTE).

Keywords: Steam generator, nitrogen oxide, recirculation, pollutant emissions, smoke exhauster, thermal power station, environment.

Introduction

One of the agent modern tasks is to ensure the cleanliness of the air basin. To ensure this, it is necessary to clean the combustion products of the fuel removed from the boilers after their cooling into the atmosphere from harmful substances, including nitrogen oxide.

Materials and methods

The sources of formation of nitrogen oxides during combustion can be nitrogen - consuming air, which is used as an oxidizing agent for combustion. Owing all combustion processes, nitrogen oxides are formed, and most of them are in the form of oxide. Nitric oxide is quickly oxidized to dioxide, which is a red – white gas with an impuissant odor, strong on the human mucous membranes in addition, it is one of the causes for the destruction of the Earth's ozone layer. The higher the combustion temperature, the more intensive is the formation of nitrogen oxides [1; 261].

There are different ways to reduce nitrogen oxide emission:

– limiting the proportion of the oxidizer in the initial section of the flame big choosing the appropriate level of excess air on the burners;

– reduction to the technological possible minimum fraction of primary air;

– input into the primary air of the maximum possible amount of recirculating gases under the conditions of sustainable combustion;

– The maximum possible temperature reduction in the zone and the exit from the active combustion zone, according to the conditions of stage ignition of combustion on and fuel burn out [2].

There is a device for absorption cleaning of temporary gases in order to remove moisture from them. Next is the catalytic nitrogen oxide of nitrogen oxides. In the controlled bed, we use gases by means of a natural gas enhancing sorbent and air duct desorption.

The disadvantage at this method is that its implementation requires high costs, and the process itself and its punctuation is complicated. For this reason, this method final turtle use in heat power engineering.

There is also a way to reduce emission of nitrogen oxides, into the environment by lowering the temperature in the furnace of the steam generator by supporting fine gases with a temperature in the furnace of the steam generator. This is done by reiterating fine gases at a temperature of 300-400 °C and taken from the steam generator.

Despite the fact that the know method of painting nitrogen oxides in the environment from steam generators is simple and cheap, its use leads to premature wear of the heating surface of the steam generator and the recirculation of the due to the fact that together with the fine gases snowing the course of the recirculation, a large amount of ash parties are formed as a result of the combustion of solid fine that enters the furnace. For coals with high ash content, for example, for Ekibastuz coal, such abrasive wear will be the highest. In addition, an additional recirculation smoke exhauster is required, that increases the energy consumption for the implementation of the method [1; 262].

In this regard the task arises to develop a simple method for cleaning the fine gases of the steam generators from nitrogen oxides, excluding the wear of the heating surface of the steam generator and recirculation exhaust fan by the abrasive head.

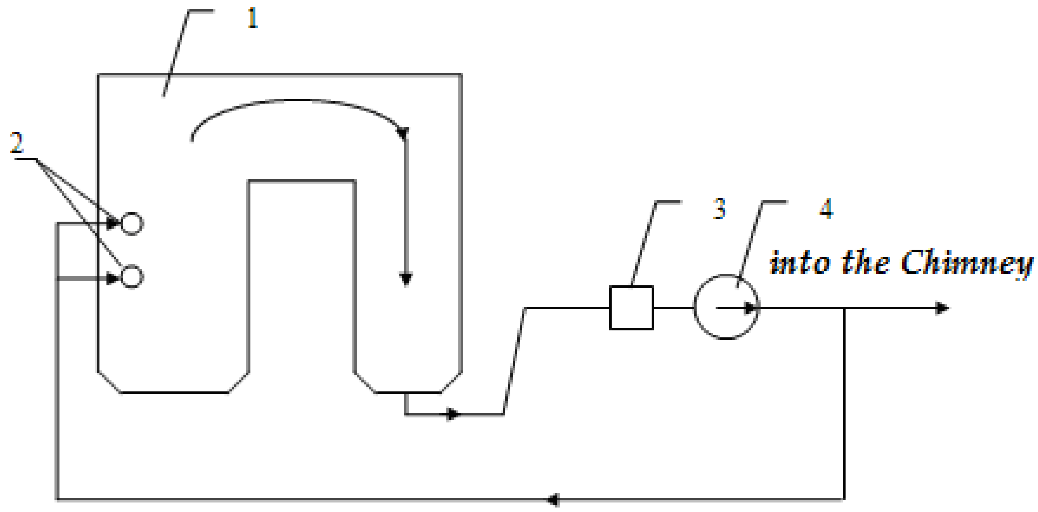

Figure 1 – Scheme of the proposed method for cuaning gases from a steam generator from nitrogen oxides

In this diagram, the steam generator 1, the pulverized coal burners 2, the ash collector 3, the main smoke exhaust 4 and the gas recirculation pipeline 5.

The technical result at the proposed method of cleaning from nitrogen oxides is to reduce the consumption of electricity by eliminating the collateral wear of the recirculation gas duct, due to the cleaning of time gases from ash (a requirement of the rules of technical operation of PTE).

Results

This is achieved are to the fact that the known method of cleaning the gases of steam generators from nitrogen oxides is by lowering the temperature in the furnace by supplying time gases with a temperature below the temperature in the furnace, it is proposed to supply the gases to the furnace at the steam generator after the ash cleaning. At the same time, as a result at supplying a gas cooled after filtration to the combustion chamber and passing through the main exhaust tan of recirculation gas having a temperature between 100-170 ^{0}C, compared to the original version there is a large decrease in temperature in the steam generator, in turn it reads to a decrease in nitrogen oxides in the time gases, since the chemical reaction formation proceeds with the absorption at heat.

Discussion

Recirculation of flue gases into the combustion chamber of a steam generator is widely used today in boiler technology. In this case, the input conditions can be different. The method is carried out in the following way (Figure 1): in the steam generator 1 through the burners 2, Fuel is supphed as the fuel is used for example, coal dust.

As a result of fuel combustion the gases are formed which are directed from the steam generator to the ash catcher corrector 3. After cleaning the fine gases with an ash catcher corrector 3 it is directed by means of smoke exhauster 4 pressure on gas duct 5 into chimney (not shown in the diagram).

From the pressure gas duct 5 fine gases are partially removed an by gas duct 6 the recirculation is directed to the combustion center reduces the combustion temperature, as a result, the formation of nitrogen decreases, since the chemical reaction of their formation goes with the absorption of heat [1; 3].

Conclusion

The proposed method can be implemented at thermal power plants of Pavlodar. Let us consider as an example for assessing the impact of the environment the boiler shop one of the power plants of Pavlodar. It is equipped with power boilers of the Barnaul Boiler Plant (BBP) that generate superheated high-pressure steam (live steam) using the chemical energy of the fuel. Steam is directed to turbines and Reduction and cooling unit. TPP has 6 boilers BKZ-420-140 with a steam capacity of 420 t/h, with a design heating capacity of 249,9 Gcal

/h. Ekibastuz coal is used as the main fuel, and M-100 fuel oil is used as a starting fuel. The share of fuel oil in the total fuel consumption is less than 5 % [3].

The boilers are equipped with auxiliary equipment: raw coal feeders, mills, draft equipment, electric feed pumps, etc., as well as ash collectors. At TPP steam boilers BKZ-420-140 No. 1, 2, 3, 4, 5, 6 are equipped with 2nd generation battery emulsifiers. According to the measurements in 2013, the cleaning efficiency was 99,55 % for boiler unit TPP No. 1, 99,3 % for No. 2, 99,5 % for No. 3, 99,39 % for No. 4, No. 5 – 99,5 %, No. 6 – 99,3 % [3].

Every year the company carries out current and major repairs to improve the reliability of the ash collection plants. The main fuel for the boilers is Ekibastuz coal, the starting fuel is M-100 fuel oil. Characteristics of the fuel used at the station [3]:

For Ekibastuz coal:
ash content Ap – 40,4 %;
sulfur content Sp – 0,41 %;
the lowest heat of combustion Q - 3972 kcal/kg;
The annual consumption of coal is 2 404 071 tons.
For M-100 fuel oil:
ash content Ap – 0,04 %
sulfur content Sp – 2,2 %;
lower calorific value Q - 9 668 kcal/kg;
Annual fuel oil consumption is 3 324 tons.

The share of fuel oil in the structure of the fuel balance is less than 5 %, therefore, the maximum one-time emissions from BKZ-420-140 boilers are determined only when burning coal.

Table 1 – Characteristics of boilers TPP

Stationary boiler number	Boiler type	Steam generator rate, t/h	Main fuel	Reserve fuel	Fuel consumption at nominal load when converted to equivalent fuel
01	BKZ-420-140, steam	420	Ekibastuz coal	Fuel oil	42
02	BKZ-420-140, steam	420	Ekibastuz coal	Fuel oil	42
03	BKZ-420-140, steam	420	Ekibastuz coal	Fuel oil	42
04	BKZ-420-140, steam	420	Ekibastuz coal	Fuel oil	42
05	BKZ-420-140, steam	420	Ekibastuz coal	Fuel oil	42
06	BKZ-420-140, steam	420	Ekibastuz coal	Fuel oil	42

Table 2 – Operating mode of boilers TPP

Operating mode	Boiler number	Indicators			
		Excess air ratio in flue gases after the smoke exhauster	Flue gas temperature after the exhauster	Heat losses with mechanical unburning	Content of combustible in the entrainment
		a	*t*, ^{0}C	q_4,%	*G un, %*
Winter maximum	1	1,16	74	5,68	7,00
	2	1,2	76	4,15	5,20
	3	1,42	80	4,32	5,4
	4	1,29	68	4,74	5,90
	5	1,2	73	6,17	7,55
	6	1,22	76	5,35	6,60
Summer maximum	1	1,16	74	3,66	4,65
	2	1,11	70	4,54	5,70
	3	1,33	77	3,61	4,60
	4	1,36	74	4,83	6,00
	5	1,2	74	4,62	5,80
	6	1,33	75	3,95	5,00

Table 3 – Operating mode of boilers TPP

Operating mode	Boiler number	Indicators			
		Steam capacity	Boiler efficiency	Maximum one-time fuel consumption (coal)	Degree of ash collection
		D_0, т/ч	$\eta_к$,%	B, g / s	η,%
Winter maximum	1	423	85,13	22254	99,55
	2	431	83,66	21169	99,3
	3	427	86,94	21991	99,55
	4	431	85,94	21632	99,52
	5	423	84,4	19572	99,49
	6	400	81,49	20093	99,32
Summer maximum	1	433	87,68	18905	99,55
	2	437	85,71	18529	99,3
	3	354	85,28	16516	99,55
	4	423	87,00	18153	99,52
	5	426	85,54	18264	99,49
	6	403	85,03	16516	99,32
Medium-operational	1	428	86,4	18778	99,55
	2	434	84,69	18416	99,3
	3	391	86,11	17468	99,55
	4	427	85,94	17540	99,52
	5	425	84,97	18429	99,49
	6	402	83,26	17710	99,32

As can be seen from tables 3, the collection rate in all boilers exceeds 99 %.

Table 4 – List of pollutants emitted into the atmosphere [3]

Pollutant code	Name of the pollutant	MPCmr, mg / m^3	MPCss, mg / m^3	Hazard class	Substance emission including treatment, g / s	Substance emission including treatment, t / year (M)
0301	Nitrogen (IV) dioxide (4)	0,2	0,04	2	348,9509	12258,6141
0304	Nitrogen (II) oxide (6)	0,4	0,06	3	56,7046	1991,952
0330	Sulfur dioxide (526)		0,125	3	872,9652	19287,399
0337	Carbon Oxide (594)	5	3	4	81,432	1943,1039
2904	Fuel oil ash from TPP in terms of vanadium (331)		0,002	2		0,0022
2908	Inorganic dust: 70-20 % silicon (503)	0,3	0,1	3	288,9033	6904,4202
Total					1648,956	42385,49

As you can see, most of the emissions of medium substances are sulfur dioxide and nitrogen dioxide.

Table 5 – Parameters of emissions of pollutants into the atmosphere [3]

Production	Source of emission of pollutants		Number of hours of operation per year	Height of the source of emissions, m	Diameter of the pipe mouth, m	Parameters of the gas-air mixture at the outlet from the pipe at the maximum one-time load		
	Name	Quantity, pcs				Speed, m/s	Mix volume, m^3/s	Mix temperature, ^0C
001	Chimney	1	8760	180	7,2	29,76	1211,68245	74,5

End of the table 5.

Name of gas cleaning units, type and measures to reduce emissions	Substance for which gas cleaning is performed	Gas cleaning ratio,%	Maximum degree of purification, %	Substance name	Pollutant emissions		
					g/s	MgN/m^3	t/year
Battery emulsifiers	Inorganic dust: 70-20 % silicon dioxide	94	94	Nitrogen dioxide (4)	348,9509	366,579	12258,6141
				Nitrogen oxide (6)	56,7046	59,569	1991,952
				Sulfur dioxide (526)	872,9652	916,051	19287,399
				Carbon Oxide (594)	81,432	85,546	1943,1039
				Fuel oil ash from TPP in terms of vanadium (331)			0,0022
				Inorganic dust: 70-20 % silicon (503)	288,9033	303,496	6904,4202

According to the Environmental Code of the Republic of Kazakhstan, in accordance with clause 1 of article 40, CHPP-3 belongs to category I. The actual (and calculated) size of the sanitary protection zone of the CHPP-3 industrial site is 1000 m in accordance with clause 13, clause 4 of the Sanitary Rules "Sanitary and Epidemiological Requirements for Establishing a Sanitary Protection Zone of Production Facilities" approved by the Government of the Republic of Kazakhstan. No. 93 dated January 17, 2012. TPP belongs to the I hazard class. The size of the sanitary protection zone of CHPP-3 -1000 m is approved by the Sanitary and Epidemiological Conclusion of the State Institution UGSEN for Pavlodar. Within the boundaries of the regulatory sanitary protection zone, there is no housing, arable land, forest plantations and recreation areas. The performed calculation of dispersion for the period of operation showed that the surface concentrations for all pollutants at the border of the sanitary protection zone, in summer cottages and in the residential area, taking into account the background pollution, do not exceed 1 MPC, except for dust concentrations, due to the already existing excess in the atmospheric air, according to the issued certificate issued by KAZHYDROMET [3]. We assume that the introduction of flue gas recirculation at this station will reduce the emissions of nitrogen oxides, which will have a beneficial effect on environmental protection.

THE LIST OF SOURCES

1 Плевако А.П. Снижение выбросов оксидов азота при сжигании топлива в парогенераторах// Теплофизические основы энергетических технологий: Материалы II Всероссийской научно-практической конференции (6-8 октября 2011 года)/ НИТПУ. – Томск: НИТПУ, 2011. – С. 261-263.
2 Пугач Л.И. Энергетика и экология: учебник. – Новосибирск: Изд-во НГТУ, 2003. – 504 с.
3 Сайт АО «Павлодарэнерго» [Электронный ресурс]. – Режим доступа: https://pavlodarenergo.kz/ assets/files/OVOS_K3_TEC3_PE_2015.pdf.

REFERENCES

1 Plevako A.P. (2011). Snizhenie vybrosov oksidov azota pri szhiganii topliva v parogeneratorah [Methods for reducing nitrogen oxide emissions in steam generators of thermal power plants]. Proceedings from Thermophysical foundations of energy technologies '11: II Vserossijskaia nauchno-prakticheskaia konferentsiia (06–08 oktyabrya 2011 hoda). – 2nd All-Russian Scientific and Practical Conference. (pp. 261-263). Tomsk: Nacional'nyj issledovatel'skij Tomskij politekhnicheskij universitet [in Russian].
2 Pugach L.I. (2003). Energetika i ekologiya [Energy and ecology]. Novosibirsk: NGTU [in Russian].
3 Sait «PAVLODARENERGO» [Site of «PAVLODARENERGO»]. pavlodarenergo.kz. Retrieved from https://pavlodarenergo.kz/assets/files/OVOS_K3_TEC3_PE_2015.pdf [in Russian].

А.П. Плевако
Инновациялық Еуразия университеті, Қазақстан

Бу генераторларында отын жанған кезінде азот оксидтерінің шығарындыларын төмендету

Зиянды заттардың, атап айтқанда азот оксидтерінің шығарындыларын азайту арқылы жылу электр станцияларының экологиялық қауіпсіздігін қамтамасыз ету. Отынның барлық түрлері, соның ішінде қатты отын жағылған кезде, ЖЭС бу генераторларында азот оксидтері түзіледі. Олардың пайда болу көздері - ауадағы азот және отынның органикалық заттарының құрамында азот бар компоненттер. Өздеріңіз білетіндей, олар адамдар, өсімдіктер мен жануарлардың денсаулығына кері әсер етеді. Сондықтан осы шығарындыларды азайту әдістерін қарастыру және талдау қажет болды.

Мақсат - азот оксиді шығарындыларын азайтудың әртүрлі әдістерін қарастыру және талдау мен түтін газдарын айналымға жіберу арқылы осы шығарындыларды азайтудың жаңа схемасын ұсыну. Бұған бу генераторының пешіндегі температураны төмен температура арқылы түтін газдарын беру арқылы бу генераторының пешіндегі температураны төмендету арқылы бу генераторларының түтін газдарын азот оксидтерінен тазартудың белгілі әдісінде түтін газдарын бу генераторының пешіне күлді тазалағаннан кейін ұсынылады. Сонымен қатар, негізгі түтін шығарғыштан жану камерасына өткеннен кейін салқындатылған, циркуляцияланған газдың жану камерасына 110-170 °C температурасы бар, бастапқы нұсқамен салыстырғанда, бу генераторының пешіндегі температураның көбірек төмендеуі орын алады, бұл өз кезегінде оксидтердің түтін газдарының азаюына әкеледі. Азот, өйткені олардың пайда болуының химиялық реакциясы жылуды сіңірумен жүреді. Азот оксидтерінен тазартудың ұсынылған әдісінің техникалық нәтижесі - электр энергиясын тұтынудың төмендеуі, түтін газдарын күлден тазарту есебінен рециркуляциялық газ каналының күл тозуын жою (ПЕТ техникалық пайдалану ережелерінің талабы).

Түйін сөздер: бу генераторы, азот оксиді, рециркуляция, ластаушы заттар шығарындылары, түтін шығарғыш, жылу электр станциясы, қоршаған орта.

А.П. Плевако
Инновационный Евразийский университет, Казахстан

Снижение выбросов оксидов азота при сжигании топлива в парогенераторах

Статья посвящена проблеме обеспечения экологической безопасности тепловых электрических станций за счет снижения выбросов вредных веществ, в частности, оксидов азота. При сжигании всех видов органического топлива, в том числе и твердого, в парогенераторах тепловых энергетических системах образуются оксиды азота. Источниками их образования являются азот, который входит в состав воздуха, идущего на окисление топлива, а также компоненты органической массы топлива, в состав которых входит азот. Как известно, они неблагоприятно воздействуют на здоровье человека, растения и животных. Поэтому возникла необходимость рассмотрения и анализа методов для уменьшения данных выбросов.

Цель - рассмотрение и анализ различных способов уменьшения выбросов оксидов азота, а также предложение новой схемы уменьшения данных выбросов за счет частичного возврата дымовых газов в топку парогенератора. В связи с этим авторами предлагается возвращать в топку парогенератора часть образовавшихся в процессе горения дымовых газов, чтобы снизить температуру в самой топке. В топочную камеру подаются охлажденные газы, прошедшие фильтрование, температура основного дымососа устанавливается на уровне 110-170 ^{0}С, происходит эндотермическая реакция, которая приводит к снижению температуры в топке и уменьшению содержания оксидов азота. Предлагаемый способ очистки дымовых газов от оксидов азота приводит к снижению потребления электроэнергии, исключается износа за счет золы газохода рециркуляции за счет очистки дымовых газов от золы.

Ключевые слова: парогенератор, оксид азота, рециркуляция, выбросы загрязняющих веществ, дымосос, тепловая электрическая станция, окружающая среда.

Date of receipt of the manuscript to the editor: 2021/02/16