On the basis of the results of experimental research we have built the nomogram (fig. 2) of dependency of azimuthal angle of turning of the solar collector α, angle of rotation of the solar collector β, the intensity of the heat flow $I_в$ and the efficiency coefficient $K_{еф}$.

From the nomogram (fig. 2) we see that the efficiency of combined solar collector at the change of the fall angle α and β from 90^o to 30^o falls on 43%.

An insignificant fall of the solar collector efficiency will be at the change of the fall angle of solar radiation.

Conclusion

The research showed the high efficiency of the combined solar collector, that allows to talk about its wide use in the systems of solar heat supply. The efficiency coefficient $K_{еф}$ at the intensity of the heat flow of $I_в$ = 300 W/m^2 changes from 0,96 to 0,53, which means the ability to catch radiation efficiently at different deviations of fall angles of the heat flow from 90^o.

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Y.S. Yurkevich, N.A. Spodyniuk
Lviv Polytechnic National University,
Heat and Gas Supply and Ventilation Department

ENVIRONMENTAL ASPECTS OF USING SOLID FUEL IN URBAN HEATING SYSTEMS

The article presents recommendations for technical solutions and safe volumes transfer applicable boiler houses to solid fuel.

Key words: solid fuel, environmental air, pollutants.

Наведено рекомендації щодо технічних рішень та безпечних обсягів переведення діючих котелень на тверде паливо.

Ключові слова: тверде паливо, навколишнє повітря, забруднюючі речовини.

Raising the question

Recently, Ukraine puts a lot of efforts on economy natural gas. One such event is the transfer of municipal boiler houses from natural gas to solid fuel.

However, the impact of such an event on environment requires research and careful analysis. Thus the aim of the article is to outline the main issues that arise from the translation of the existing gas boiler houses for solid fuels.

The reason for this question was the fact that in February 2012, at a session of the Zolochiv Town Council was approved “The program of modernization of the existing boiler houses MUK “Zolochivteploenerho”, which provided their transfer to solid fuel. This program has been successfully implemented - five municipal boiler houses were modernized before the heating season 2012/2013 and two - for the heating season 2013/2014.

The reason for this decision was very high, as for the district town receivable for gas. In addition, as of 2012 only 12% of the population was used from district heating, and the actual heat losses in MUK "Zolochivteploenerho" constituted 22.7%.

Thus the town Zolochiv the first among the other towns of Halychyna completely translated their boiler houses from natural gas to wood material. To implement this project involved 7.0 million UAN investments. It is assumed that the use of solid fuel boilers will enable to reduce the cost of heat to consumers in the budget sphere from 1176 UAN by 1 GCal to 830 UAN, and this, in its turn, will allow for the heating season to save about 3.37 million UAN.

Since Ukraine in recent years is making significant efforts to reduce the consumption of natural gas in the communal sphere, it is necessary to examine comprehensively the experience of such cities, where a long time coal, wood material, peat are used for heating, in order to avoid or at least minimize the influence of use of solid fuels on the environment.

In this context, the experience of Krakow is especially valuable because in the city was conducted a thorough and lengthy monitoring of air that is caused by highly polluted air in the city, which is one of the highest in Europe. The main source of pollution in the city is the heating system of private houses and apartments, in which using solid fuel boilers.

The main material

Analyzing the results of monitoring the state of the air environment of cities in Western Europe, particularly Polish Krakow, Lyehnits and others we draw attention to the fact that the emission of exploring the entire spectrum of pollutants - CO, SO_2, NO_x, VOC_s (volatile organic compounds), TSP (total suspended particulates - all hovering dust or all spray, even those who have an average diameter of 10 microns), special attention is paid the emission of dust RM10 and emissions of benzo (a) pyrene.

By European standards RM10 - is a fraction of the dust of the average particle size of 10 microns, permissible average concentration RM10 is 50 mkh/m^3 and must not be exceeded more than 35 times in a year. The permissible average concentration is 40 mkh/m^3 and average dangerous concentration for RM10 is 200 to mkh/m^3. In the analysis of air dust national standards view undifferentiated the composition of inorganic dust, which is analogous dust TSP. In this case, the average daily value of the MPC is 0.15 mg/m^3, and the maximum time is 0.5 mg/m^3.

Benzo (a) pyrene is polycyclic aromatic hydrocarbon, which formed by the combustion of solid and liquid fuel (to a much lesser extent - gas). This substance is one of the most dangerous hydrocarbons, it is a very strong mutagen and carcinogen, is harmful even at low concentrations. According to the list of "maximum permissible concentration (MPC) of pollutants in ambient air of places" average daily value of the MPC benzo (a) pyrene in ambient air is 0.1 mg per 100 m^3 (10 -9 g/m^3).

In domestic practice, without sufficient attention is emission of benzo (a) pyrene. In normative methodology of calculation of pollutant emissions from power installations [4] emissions of benzo (a) pyrene in general are not considered. At the same time in the same Russian method [6] are given calculations of emission of benzo (a) pyrene as industrial heat and power from small power boilers and on hot water boilers.

In the conducted analysis of airquality in Lviv concentration of benzo (a) pyrene were measured only 12 times a year (compared to nitrogen oxides - over 1000 measurements, carbon monoxide - more than 2000, and formaldehyde - 4000 [3]).

It should be borne in mind that the 2015 ban on coal heating comes into force in major cities of China, and in Dublin and London such a ban already in force.

It should be noted that the Polish researchers analyzing the entire spectrum of emission of pollutants (CO, SO_2, NOx, VOCs *, TSP **, RM10***, benzo (a) pyrene), pay special attention to the emission of dust RM10 and emissions of benzo (a) pyrene

In MPC 34. 02. 305-2002 "Emissions of pollutants into the atmosphere from power plants. Method of determining" the emissions that occur during combustion of wood biomass generally not considered. It also lacks the calculated dependences for determination of emissions of benzo (a) pyrene.

Therefore, the statutory method [4] can produce only the calculation of emissions of particulate matter. It is held for the Lviv-Volyn coal basin of Gr, HSSH and ZHR. For coals of GH and HSSH Q_i^r = 21,44 MJ/kg, and A^r = 19,8%. For coal ZHR Q_i^r = 19,38 MJ/kg, A^r = 32,2%. Share ash is removed from the power plant in the form of fly ash, a_{vyn} depends on the technology and fuel combustion furnace fixed bed taken a_{vyn} = 0.15 [4].

With such initial data rate of emission of particulate matter (k_{tv}) for coals GR HSSH is 1406 g/GJ and for coal ZHR - 2530 g/GJ.

Polish sources [7] suggest a slightly lower value of the emission of particulate matter.

Table 1

Emissions of pollutants (g/GJ) during combustion of solid fuels [7]

Fuel Type	Dust RM 10	Benzo (a) pyrene
Lignite and hard coal	404	0.27
Wood material	695.3	0.21

This is explained by high ash content of coal Lviv-Volyn basin (19.8 - 32.2%) in coal, which is used in Kraków ash content (A^r) is in the range of 3 - 12% [7].

Results of calculation of emissions of particulate matter and benzo (a) pyrene formed during combustion of coal Lviv-Volyn basin and wood material, conducted by the method of serving in the Russian Federation [2] given in Table 1.

The emission of particulate matter (inorganic dust) in the air without purification system (tonnes per 1 thousand tons of fuel) can also be taken for aggregated indices [8]:

- Coal - 65.32;
- Peat briquettes - 13.02;
- Firewood - 4.3;
- Wood waste and sawdust - 5.1;
- Wood pellets - 4.11.

In terms of these values in 1Hkal produced heat energy to get of the brown coal Q_i^r = 22 MJ/kg value of dust emission 2970 g/GJ, which is close to the values obtained by the method of [4], and of the firewood Q_i^r = 10,21 MJ/kg - 420 g/GJ, which is close to the value given in [7].

In European countries, the typical level of particulate emissions when burning wood biomass was 300 mg/m^3 after cleaning in Multicyclones and 40 mg/m^3 using condensation of combustion products [8]. By Danish standards for boiler houses of farms in which burned wood biomass content of solid particles in the products of combustion must not exceed 600 mg/m^3. Here, in order to achieve acceptable concentrations of particulate matter is mainly used Multicyclones, and for a fine filter - ESP and fabric.

The magnitude of emissions of particulate matter and benzo (a) pyrene, which are released by burning coal and wood material, determined by native, Russian, Polish and German methods, are presented in Table 2.

Table 2

Magnitude of emissions of particulate matter and benzo (a) pyrene

Emission of polluting agent	Fuel Type								
	Lignite				Firewood				Gaz
	By the method N1 [3]	By the method N2 [1]	By the method N3 [2]	By the method N4 [4]	By the method N1 [3]	By the method N2 [1]	By the method N3 [2]	By the method N4 [4]	-
Solidparts, g/GJ	404	1400-2530	2215	2970	695.3	-	-	420	0.5
Benzo (a) pyrene, g/GJ	0.27	-	0.475	-	0.21	-	0.194	-	0.00002

In most cities of Western Ukraine environmental problems caused by the use of solid fuel in heating systems does not exist today. Thus, according to [1] As of 2009, in Lviv consumed only 4.46 tons of coal and 7.76 thousand m^3 of firewood, whereby coal use commercial and government organizations, and wood - almost exclusively public.

In this case, [1] is predicted that in the near future in consumption of wood is close to 5.0 thousand tons, and coal almost completely stopped.

However, the small consumption of solid fuel in heating systems, the condition of air pollution in the city is not very favorable.

According to [3] the average concentration of substances in the form of particulate matter exceeding the MCL by 19% (however, average values are only 0.15 MAC, and the maximum daily - 0.5 MAC). It is also worth noting that this is the average value in the city, and the values for some of the most contaminated areas are not given.

If we take into account the prediction [1], according to which the reconstruction heating plant “Northern” coal share in the balance of heat supply enterprises will be 21% (in the energy balance of the municipality it will be almost 9%), it could significantly affect the environmental situation in the city . In 2009 the production of thermal energy for district heating "Northern" was 187.6 thousand Gcal and now approaching of 200 thousand Gcal.

This corresponds to the consumption of 25.3 thousand m^3 of natural gas. To produce the same amount of heat it is necessary 42.75 thousand tons of coal. Thus the emissions of pollutants will increase significantly. Calculation of emissions of major pollutants was performed by the method [4], the results presented in Table 3.

Table 3

Calculation of emissions of major pollutants

N	Pollutant	Emission of pollutants, tons/year		
		Fuel - natural gas	Fuel - Coal	Increase in emissions
1	Sulphur dioxide (SO_2)	–	2318.90	2318.90
2	Nitric oxide (NO_x)	57.00	101.66	44.66
3	Carbon monoxide (CO)	14.23	9.98	4.25
4	Carbon dioxide (CO_2)	49145.29	81861.10	32715.81
5	Solid particles	–	131.45	131.45

Shown in Table 3 the results are approximate as not fully known parameters a heating plant "Northern" after renovation, including installation specifications gas - dust trapping and composition of solid fuels (considered the possibility of using a mixture of local and Donetsk coal).

This significant increase in the emission of pollutants, of course, lead to a deterioration of the environment in Lviv, especially in its northeastern regions, and adjacent to a heating plant "Northern" villages - Malekhov, Dubliany, Murovane, and others.

Operating in Ukraine SNIP II-35-76 "Boiler installations" requires that the boiler house designed for use on solid fuel, equipped with facilities for cleaning flue gases from the ashes when perfomed condition:

$$AP \cdot B > 5000, \quad (1)$$

where AR - ash content in the working mass of fuel, %

B - the maximum hourly fuel consumption, kg/hr.

Based on this relationship we can calculate the maximum power the boiler house in which the establishment of ash catching equipment is not required for several typical in the Western region, types of hard fuel (Table 4).

Table 4

Maximum power the boiler house

N	Fuel type	The lower estimated heat of combustion; (MJ/kg)	Ash content of fuel A^R; (%)	The maximum hourly fuel consumption, B; (kg/h)	Permissible thermal power the boiler house at η = 0,85; (MW)
1	Coal grade GH and RSSH (Lviv-Volyn)	21.44	19.8	252.5	1.27
2	Coal grade ZHR (Lviv-Volyn)	19.38	32.2	155.3	0.71
3	Wood material	10.21	1.0	5000	12.00
4	Fuel briquettes, pellets	17.5	0.5	10000	41.15

It should be noted that in the Russian Federation since 2012 came into force on REDD rules JV 89.13330.2012 “Boiler installations” in which there are no additional conditions for the establishment of the ash trapping equipment, and states that the the boiler house at work on solid fuels (coal, peat, shale, wood waste, etc.) must be equipped with facilities for cleaning flue gases from the ashes.

But in project DBN “Boiler installations”, developed by PJSC "Design and Research Institute on gas, heating and comprehensive improvement of cities and towns of Ukraine" paragraph 9.4.1 concerning plant the ash trapping are offered in the old edition.

Since in Zolochiv the boiler house has translated into solid fuel - firewood, it is appropriate to carefully examine the implications of this measure to monitor the state of air quality to the experience gained could be used in other places. Because such work is not available, calculate the magnitude of emissions of particulate matter and benzo (a) pyrene, which are formed during production of 55,000 GJ of heat during the heating period (corresponding to 9000 m^3 firewood).

Table 5

Comparison of emissions of pollutants into Zoluchiv and individual stations Krakow

N	Location	Area, ha	Number of inhabitants	Emission of harmful substances, tons/year	
				MR 10	Benzo (a) pyrene
1	Zolochiv	900	24 000	38.24*	0.0116*
				23.1**	-
2	Krakow, section II Grzegorzki	583	30660	52.97	0.0198
3	Krakow, section IIIGzyzyny	1079	25010	4.62	0.0017

* by the method [7]

** by the method [6]

Zolochiv is not the only city in the region, which provides for the use of solid fuels for heating. In particular, "The modernization program of heat supply in the Lviv region for 2012-2016" provides for the replacement of gas boilers for solid fuel in a number of objects with the total capacity of 8.7 Gcal/h, so the expected consumption of natural gas in the region 5436.6 thousand m^3 per year.

The Institute of Engineering Thermophysics, NAS of Ukraine developed the concept of national bioenergy development for the next 10 years. According to this concept, it is expedient implementation of the following technologies:

- Heating boiler houses on wood (1 - 10 MW) - 250 boiler houses;
- Industrial wood-fired boilers (0.1-5 MW) - 360 boilers;
- Domestic wood-fired boilers (10 - 50 kW) - 53 thousand boilers.

With the implementation of these ambitious plans will take the environmental aspects of particular relevance. Effective, safe and environmental work on wood biomass boiler houses depends on the proper organization of procurement, storage, preparation for burning fuel, and measures to protect the environment.

Conclusion

Summarizing the above material we can see that by using the solid fuel to produce heat energy in heating systems have serious environmental problems. Transfer boiler houses in Zolochiv on firewood make it possible to objectively assess the level of risk. This requires monitoring of the air in Zolochiv during the whole heating season. Based on the monitoring results develop recommendations for technical solutions and safe volumes transfer applicable boiler houses to solid fuel.

It is necessary to develop a domestic method for determining the emissions of pollutants into the atmosphere by burning firewood, and review and refine the regulatory framework for equipment boilers by dust trapping gas that run on solid fuel.

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