Complex for the production of compressed carbon dioxide based on an industrial furnace for food production

K V Osintsev, M M Dudkin and S I Kuskarbekova

South Ural State University, 76, Lenina Ave., Chelyabinsk, 454080, Russia

E-mail: pte2017pte@mail.ru

Abstract. Today, the problem of the use of energy is the most common. In order to increase energy efficiency could be used at food enterprises. A new scheme of combined main production and auxiliary production has been developed. In particular, on the basis of industrial furnaces for the production of compressed carbon dioxide. In this system, the coolant is supplied from an industrial furnace. In addition, it is shown that the coolant may be a rotary kiln or an industrial steam generator. The developed scheme is universal and can be used at the enterprise for various purposes.

1. Introduction
In the food industry, various technological processes are used. These processes include heating, cooling, evaporation and many others [1, 2]. These processes proceed with the supply and removal of heat. Heat exchangers are classified into devices of mixing type and surface type. Another type of heat exchange devices should include industrial furnaces.

Industrial bakery ovens are used to produce a wide range of bakery and confectionery products. The furnace has a baking chamber, a conveyor belt for feeding the blanks of the final product. The furnace technology includes a radiator and a steam humidification system [3, 4]. The conveyor movement is intermittent, with a certain time interval, which is necessary according to the production process. The furnace is equipped to burn either solid fuel or natural gas [5, 6].

2. Scientific novelty. The principle of operation of the technological scheme of industrial furnace and compressed carbon dioxide complex
The scientific novelty of the work consists in integrated approach to solving issues of technological combination of production related to the integration of the principles of using renewable energy sources and standard heat engineering facilities, such as industrial food-grade furnaces [7, 8]. Scientific results include analysis of theoretical studies of the process of absorption of water vapor and carbon dioxide from flue gases and recommendations for further development of research. In the study, a thermodynamic analysis method was used, based on the balance of the amount of energy when using the heat of condensation of water vapor at a constant partial pressure of the exhaust flue gases [9, 10]. In addition, it is proposed for the first time to use the resulting compressed carbon dioxide directly for the main production, in this case, the food industry [11, 12]. Figure 1 shows combination scheme of carbon dioxide production and the main production of the food industry.
Figure 1. Combination scheme of carbon dioxide production and the main production of the food industry (explanations are provided hereinafter)

The authors propose a combined installation in which the method of flue gas absorption in a contact heat exchanger with subsequent heating is implemented. The combination scheme is shown in Figure 1. The flue gas 1 leaving the industrial furnace for food production enters a vertical channel with convective heating surfaces, such as an economizer and an air heater [13, 14]. Feed water is heated in the economizer and water heat exchanger of an industrial furnace [15, 16]. The feed water of the industrial furnace enters the industrial furnace after the treatment system from excesses of hardness salts dissolved in it [17, 18]. Heated feed water 2 enters the heat exchanger of an industrial furnace. Atmospheric air 3 enters the air heater 4 using a fan. Heated air 4 is sent to the fuel supply system. Fuel for an industrial furnace can be any type of fossil fuel, including coal dust and natural gas. Air enters the burner device or directly into the furnace, depending on the type of fuel burned and the fuel preparation system. After an industrial furnace on convective surfaces, the flue gases are cooled to a temperature of just over 100 degrees Celsius [19, 20]. The gases cooled to this temperature are directed to a convective heat exchanger. In the heat exchanger, the exhaust gases pass through a special grill into which chilled water is sprayed from nozzles 5 connected to the piping system from the top of the heat exchanger. Water sprayed by nozzles 5 reacts with flue gas components. The part of gases, primarily CO$_2$, except NO$_x$ and SO$_x$, is adsorbed by water and enters the lower part of the heat exchanger [21, 22]. Gas-saturated water is sent through a pipeline system to the Li-Br 6 absorption chiller. A distinctive feature of the Li-Br 6 absorption chiller is the presence of a heating unit that uses solar radiation. The heating elements 7 of the Li-Br absorption chiller 6 are combined into one unit 8. Gaseous water is heated in the compartment 9. The element 7 is installed in the compartment 10 for water heating. Compartment 10 is heated by solar radiation. The upper part of the compartment 25 may be made convex or concave parabolic in shape [23, 24].

The compartments 9 and 10 are separated by a partition 11. Heat-treated feed water circulates in the heating unit 8. Water heated in compartments 10 is sent to heat exchangers 12 of a chemical water
treatment unit. Initial water is pumped through the chemical preparation unit using a pump 13 and sent to the thermal preparation unit 14. Unit 14 includes a main deaerator and heat exchangers. From block 14, feed water is sent to the economizer of the boiler. Recycled water, cooled in block 8, is sent to the auxiliary deaerator 15, consisting of a deaeration column 30 and a tank. A solution of monoethanolamine is injected into the deaerator 15 by the metering pump 16 from the reservoir 17 for better desorption of CO$_2$. Vapor from the deaerator 15 is sent to a reservoir 17 into which a calcium chloride solution is injected, which is necessary for the separation of NO$_x$ and SO$_x$. Gases are removed from the tank 17 and sent to the separation unit 19.

A mixture of the resulting materials 20 is removed from the processing tank 17. Thermally purified water from the tank is divided into two streams. The flow is directed to the heat exchangers 21 of the raw water treatment unit, pumped by the pump 22. After the heat exchangers 21, the water must be cooled in the evaporator of the Li-Br absorption chiller 6. The source water is mixed with water after the heat exchangers 21. The mixture of flows is sent to the Li-Br absorber of the absorption chiller 6. Heated in Li-Br absorption refrigeration machine 6, the water is sent to the heat pump.

3. Practical part. Another application of new scheme

We consider the new heat exchanger for drying food material in figure 2. This is one type of industrial furnaces.

![Figure 2](image)

The resulting oven-dried product is used further in the production cycle of the enterprise. The flue gases behind this industrial furnace [25, 26], which is classified as rotating, can also be used in the heat treatment process according to Figure 1. In addition, the application of the scheme in Figure 1 does not apply only to industrial furnaces, industrial steam generators and other fuel-burning can also be used. Devices [27, 28].

4. Conclusion

Thus, the general range of increasing of steam generator efficiency is possible in case energy and. The analysis is prepared the method of increasing energy efficiency in the use of energy resources at the enterprises of the food industry. This problem was solved on the basis of models and technological schemes developed by the authors and describing the thermal regime of an industrial furnace. It is advisable to use intermittent heating in industrial ovens for food production. A scheme of using secondary resources to produce compressed carbon dioxide is developed. Compressed carbon dioxide is proposed to be used mainly in the food industry.

Acknowledgments

The work was supported by Act 211 Government of the Russian Federation, contract №02.A03.21.0011.

References

[1] Rudig W 1986 Combined heat and power for district heating Physics in Technology 17 125
[2] Hammond G 1977 Combining district heating and power generation Physics in Technology 8 163
[3] Panferov V I and Anisimova E Y 2008 The analysis of a possibility of economy of thermal energy at the faltering mode of heating Bulletin of the SUSU 112 (12) 30-37
[4] Kiyanets A V 2017 Improving Energy Efficiency of Buildings in the Urals IOP Conf. Ser.: Mater. Sci. Eng. 262 012068
[5] Panferov V I and Anisimova E Y 2009 About economy of energy at optimum control of the mode of faltering heating ABOK NORTHWEST 5(44) 32-35
[6] Hrvoje K and Mihaela T 2017 IOP Conf. Ser.: Mater. Sci. Eng. 245 042049
[7] Sharovarova E, Alekhin V and Shcheklein S 2018 IOP Conf. Ser.: Mater. Sci. Eng. 451 012045
[8] Danilov O L, Garyaev A B and Yakovlev I V 2011 Energy Saving in Heat Power Engineering and Heat Technologies (Moscow: MPEI Publishing house)
[9] Panferov V I and Anisimova E Y 2011 Effective operation of heating systems Conf. Heat and gas supply: state, problem and prospects (Orenburg: LLC Nikos) pp 129-133
[10] Gershkovich V F 2000 About a possibility of implementation of regulation of heat consumption of buildings by method of periodic interruption of a stream of the heat carrier News of heat supplying 02 63-71
[11] Mozgalev K M 2011 Energy Efficiency of Buildings (Chelyabinsk: REKPOL)
[12] Golovnev S G 2010 Modern Construction Technologies: a monograph (Chelyabinsk: South Ural St. Univ.Publ.)
[13] Malayvina Y G 2011 Heat loss of buildings: reference book (Moscow: AVOK-PRESS)
[14] SP 23-101-2004. Design of thermal protection of buildings
[15] SP 50.13330.2012 Thermal performance of the buildings. Revised edition SNiP 23-02-2003
[16] SP 60.13330.2012 Heating, ventilation and conditioning. Revised edition SNiP 41-01-2003
[17] Z Y Li, S B Zhang, Y B Xiao, Q Q Shi, Y Q Zhao and J L Gao 2018 IOP Conf. Ser.: Earth Environ. Sci. 188 012105
[18] Paiho S, Hedman Å, Abdurafikov R, Hoang H, Sepponen M, Kouhia I and Meinander M 2013 Energy saving potentials of Moscow apartment buildings in residential districts Elsevier Energy and buildings 66 706-13
[19] Dimevska L, Cvetkovska M and Gavriloska A T 2019 IOP Conf. Ser.: Earth Environ. Sci. 222 012028
[20] Khayatian F, Sarto L and Dall’O’ G 2016 Application of neural networks for evaluating energy performance certificates of residential buildings Energy and Buildings 2018 Annual Conf. IISE 125 45-54
[21] Osintsev K V, Prikhodko I S and Zavyalova M I 2018 Methods for improving energy efficiency of air handling unit using factor analysis of data Earth and Environmental Science 194 052019 7-12
[22] Osintsev K V, Prikhodko I S and Psenitsyna T A 2018 Choice of Chelyabinsk and Kuznetsk coals as main fuel for steam generator PK-14 using elements of cluster analysis Earth and Environmental Science 194 052018 6-10
[23] Vershinina K Y, Glushkov D O and Strizhak P A 2017 Characteristics of the ignition of the drops of organic coal–water fuels based on waste oils and industrial oils Solid Fuel Chemistry 51(3) 188-194
[24] Nyashina G S, Vershinina K Y, Shlegel N E and Strizhak P A 2019 Effective incineration of fuel-waste slurries from several related industries Environmental Research 176 108559 238-242
[25] Khavanov P, Chulenyov A 2017 Boiler water regime Earth and Environmental Science 90 012199 8-13
[26] Zhang X, Ye Y, Wang H and An X 2018 A new method for boiler combustion calculation Earth and Environmental Science 199 032083 154-157
[27] Batrakov P A, Mikhailov A G and Ignatov V Yu 2018 Fire-tube boiler optimization criteria and efficiency indicators rational values defining Journal of Physics: Conf. Series 944 012009
[28] Bukowska M, Nowak K, Proszak-Miasiak D and Rabczak S 2017 Concept of Heat Recovery from Exhaust Gases Materials Science and Engineering 245 052057 23-25