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ENHANCED ENERGY EFFICIENCY OF CERAMICS MANUFACTURING DUE TO HEAT RECOVERY FROM SECONDARY ENERGY SOURCES

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ABSTRACT

The article describes a method for increasing the energy efficiency of ceramics manufacturers by renewable energy via recovery of heat from kilns used for firing ceramic products. For ceramics manufacturings, there is a heat recovery scheme that has been developed to use heat released during the cooling of kilns, which makes it possible to reduce energy consumption for heating the air entering an air-drying plant, the specific energy effect from this scheme has been calculated.

Disciplinary: Sustainable Energy Technologies, Renewable Energy.

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1. INTRODUCTION

Most ceramics factories use electricity for the firing process in kilns and heating the air used for drying. Saving electricity purchased by the Company from outside will reduce the cost of manufacturing the finished product.

One of the ways to reduce electricity consumption at such enterprises is to use secondary energy resources of the enterprise (SER). SER is understood as the energy potential of used heat transfer media, finished products, by-products, and intermediate products generated in process units, which can be used to supply power to other units [1].

In energy-intensive industries, the most representative group, which accounts for more than 60% of the energy-saving potential, is secondary thermal energy resources, which are the sensible heat of waste gases from process units, sensible heat of main and by-products, heat from fluids of cooling systems of process units and installations.

Ceramic factories have the potential for thermal energy generated during heating and cooling of process heaters. This heat can be used to reduce energy consumption for heating a drying agent in the air heater.

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2. CERAMICS MANUFACTURING PROCESS

Figure 1, ceramics manufacturing takes place in several stages. At the initial stage, the raw material is subjected to crushing, grinding, settling, and stirring, passing through a forming die, which gives the clay its final shape. After that, the clay workpiece is placed in a convective dryer with intermediate air heating. In the drying unit, products are losing moisture contained in them due to its evaporation. This process takes place when the heat is supplied to the clay by convection from the heated air. Then dried products are sent to electric resistance furnaces of indirect heating, where heat is transferred to the heated product from heating elements located on the furnace walls, roof, and bottom. During firing, hydrated moisture is being removed from products, and complex silicates are being formed. The time of firing products in the furnace is 18-24 hours, of which 10 hours are taken by heating, and the remaining time is used for holding at constant temperature (about 1120°C). Further, the cooling process begins, it lasts 8-15 hours and consists of several stages, during each of which, when a certain temperature in the furnace is reached, the door will be partially and slightly opening until fully opened. After cooling, the finished product leaves the furnace and goes to the cutting and packaging unit.

Figure 1: A general ceramic factory.

The drying plant with intermediate heating of the air consists of several zones, in either of each the air participates in the drying process [2], warms up on intermediate heating surfaces 2, 3, 4 to the required temperatures, then it comes into contact with the wet material due to which it is being cooled and humidified at the same time (Figure 2).

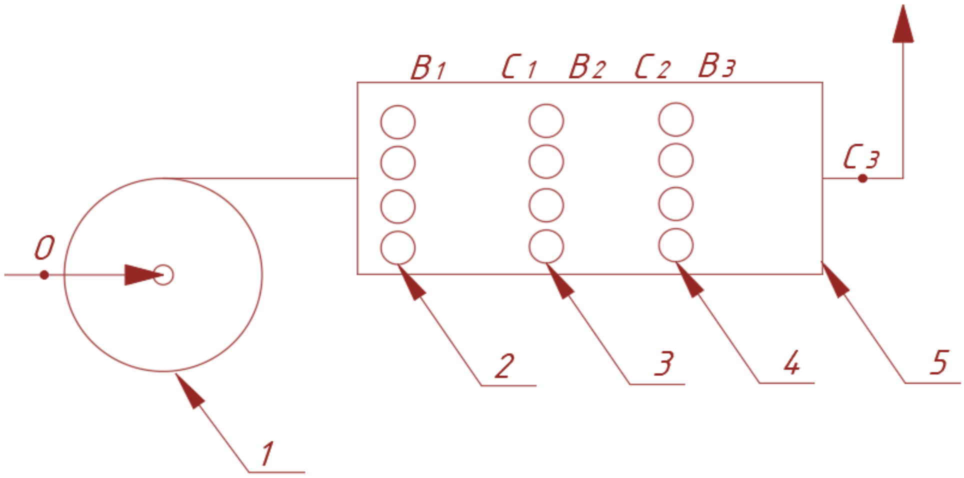

Figure 2: Schematic diagram of a drying unit with staged heat supply: 1-fan; 2-1st stage heater; 3-2nd stage heater; 4-3rd stage heater; 5-drying unit.

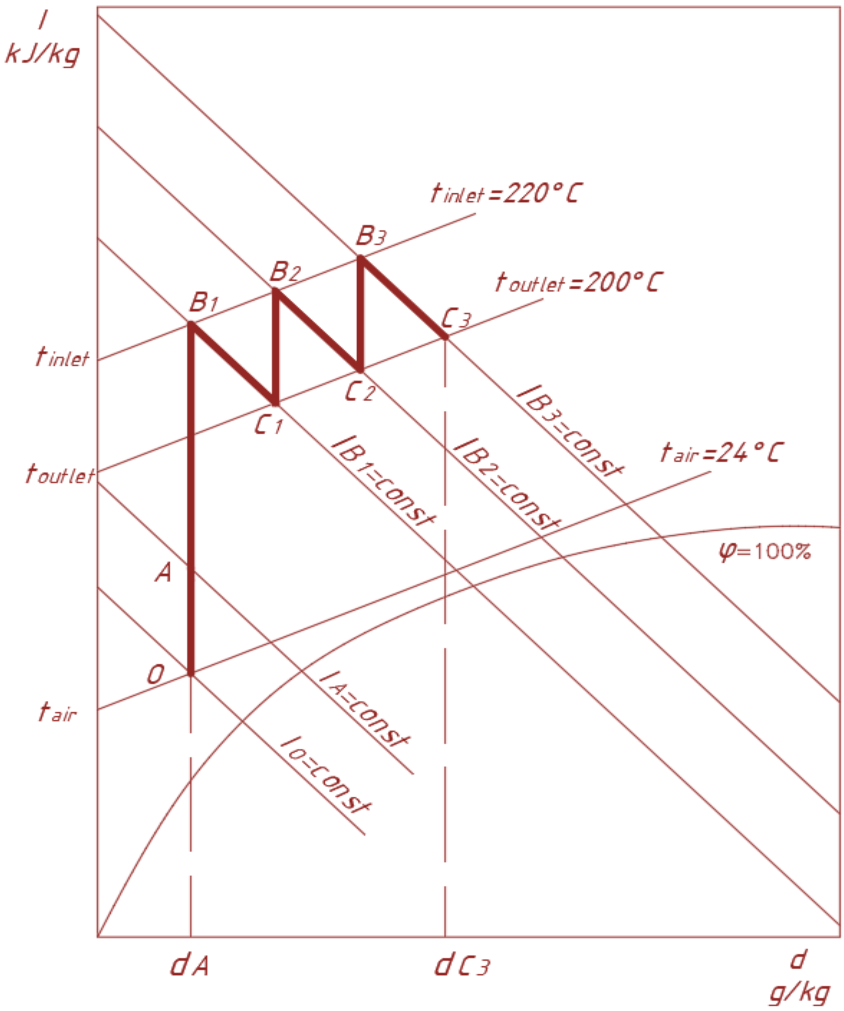

Figure 3: Calculation of the theoretical drying process with staged heat supply.

Drying is carried out with the air taken from the workshop with t_{air} = 24°C. Before each stage of drying, the air is heated in the corresponding heaters with heating elements and enters the stage with the temperature of t_{inlet} = 220°C, during the drying process at each stage outlet the air has the temperature of t_{outlet} = 200°C [3, 4]. After the last 3rd stage, the exhaust system removes humid air

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with a temperature of 200°C. With this scheme, the greatest energy consumption falls on the 1st stage heater, in which the air needs to be heated from 24 to 220°C. In the heaters of the 2nd and 3rd stages, energy consumption will be significantly lower, since in these heaters the air is heated from 200 to 220°C.

The drying process on the I-d diagram is shown with broken line $OB_1C_1B_2C_2B_3C_3$ (Figure 3).

OB_1-heating of the air taken from the shop in the first stage heater; AB_1-additional heating of the air coming from the zone above the furnace in the first stage heater; B_1C_1-cooling and humidification of the air after the first stage; C_1B_2-heating the air in the second stage heater; B_2C_2-cooling and humidification of the air after the second stage; C_2B_3-heating of the air in the third stage heater; B_3C_3-cooling and humidification of the air after the third stage.

According to the technical data, when opening the furnace, the temperature under the crown is about 100°C. Energy costs for drying can be reduced by taking the air directly from the zone above the furnace, which accumulates the air escaping from furnaces during the cooling period. This diagram is shown in Figure 4.

Heat for recovery is taken directly from the furnaces using exhaust hoods. An exhaust hood is located above each furnace, considering the unhindered opening of sliding gates and a door. Air valves are provided for all sections of the air intake from the furnace to automatically control the air intake during the furnace cooling. The air heated from cooling furnaces to a temperature of 100°C enters the air heater through the air duct system for additional heating to the temperature of 220°C and then goes to drying. In the I-d diagram (Figure 3.), the air condition after heating is determined by point A. The process of additional heating of the air by heating elements in the 1st stage heater up to t_{inlet} = 220°C goes along the AB_1 line [5-8].

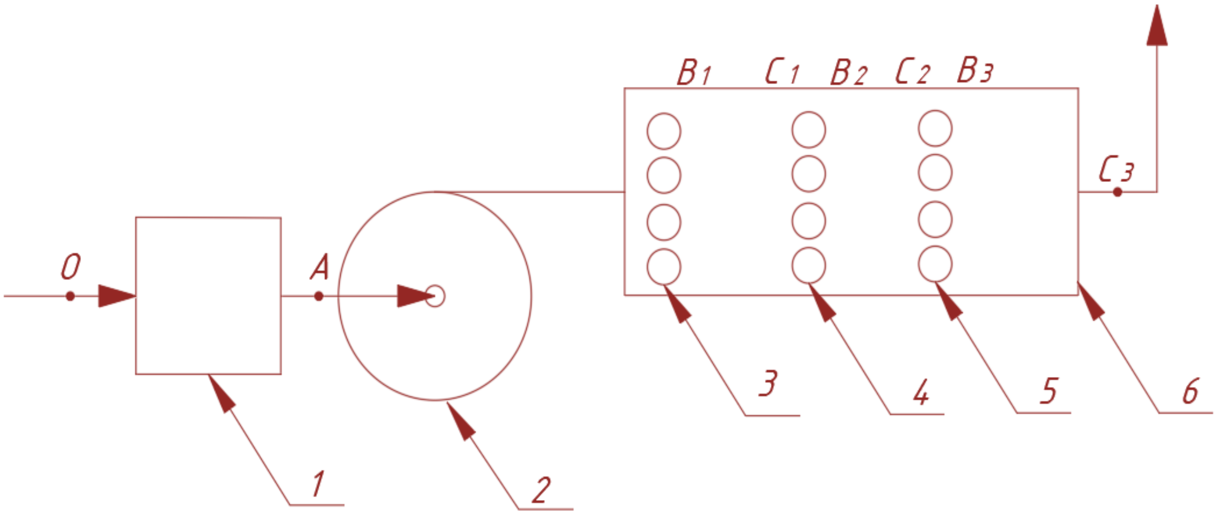

Figure 4: Schematic diagram of a drying plant using heat from kilns: 1-zone above the furnace; 2-fan; 3-1st stage heater; 4-2nd stage heater; 5-3rd stage heater; 6-drying unit.

For the scheme using the air taken from the workshop, the specific energy consumption in the 1st stage heater was

$$q_{el} = (h_{B_1} - h_O)/3600, \text{ kWh/kg of air},$$

where h_{B_1}, h_O - for this scheme of air enthalpy in the 1st stage heater at the inlet and outlet, respectively, kJ/kg of air.

According to I-d diagram, we determine h_{B_1} = 258.51 kJ / kg of air, h_O = 54.43 kJ/kg of air, h_A = 135.4 kJ/kg of air

$$q_{el} = (258.51 - 54.43)/3600 = 0.0567 \text{ kWh/kg of air}$$

For the scheme using the air from the zone above the ovens, the specific electricity consumption in the 1st stage heater was

$$q_{el} = (h_{B_1} - h_A)/3600, \text{ kWh/kg of air,}$$

where h_{B_1}, h_A - for this scheme of the air enthalpy in the 1st stage heater at the inlet and outlet, respectively, kJ / kg of air

$$q_{el} = (258.51 - 135.4)/3600 = 0.0341 \text{ kWh / kg of air}$$

Analyzing the energy efficiency of the proposed scheme with a constant airflow rate, we conclude that electricity costs in the 1st stage heater are reduced by 40%.

3. CONCLUSION

From the results of this work, we can say that the air heat from ceramic kilns is a valuable secondary energy resource. The use of this heat makes it possible to reduce the cost of electricity for heating the air entering the drying unit in the 1st stage heater by 40% and thereby reduce the economic costs per unit of final output production.

4. AVAILABILITY OF DATA AND MATERIAL

Information can be made available by contacting the corresponding author.

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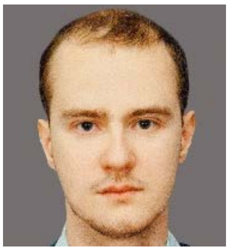

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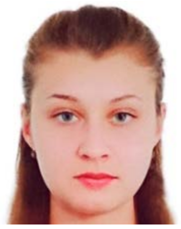

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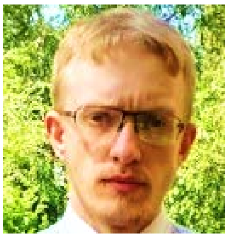

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