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Reducing heat losses in air-cooled units with fuel gas heating using finned tubes in a design used at thermal power plants with a combined cycle gas device

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Abstract. The article is devoted to the reduction of heat losses in air-cooled units with fuel gas heating using water collectors with finned tubes to increase the thermal conductivity of the collector used in thermal power plants with a combined cycle device. The article provides information about the types and materials of fins, tips for reducing heat loss and air coolers. You can get information about the design of the air cooler, which includes: the type and materials of finned tubes that can be used to improve the design, thermal, hydraulic calculations to reduce heat loss and this design, technological schemes, block diagrams of the main elements of the air cooler.

1 Analysis of the state of the problem

The energy sector is currently the fastest growing sector,one of them is fuel and thermal energy. Energy plays a big role in the prosperity of the state and is one of the highly valued shockers in all fears, from the main roots of the development of the state is to achieve independence in the energy industry, it will give us a great opportunity to enter the international trade market. Therefore, the need for energy is growing day by day due to the increase in the demand for electricity, the need for fuel resources is also growing.At present, most of the production of electrical energy is produced in thermal power plants. Thus, most of the fuel is used in thermal power plants. These stations mainly use three types of fuel:
1) Natural gas;
2) Coal;
3) Fuel oil

The main large-scale fuel used in power plants is “natural gas” and the combustion of this fuel provides much more kilocalories of energy and is environmentally friendly than other fuels. Large-scale use of fuel reduces its reserves and forces geologists to find new resources of natural gas and other natural resources for use in the thermal power industry Thermal power plants with large capacities use more than one hundred thousand cubic meters per hour of natural gas to produce electricity. The main unit in thermal power plants is heat exchangers, with the help of these devices heat exchange is created between several liquid or

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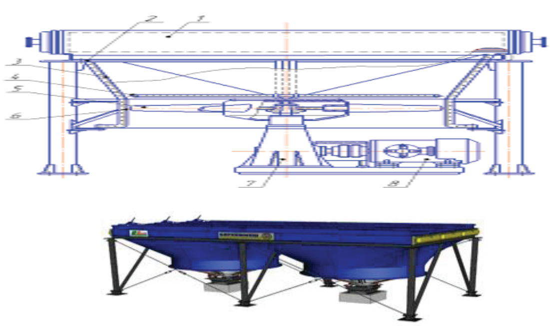
gaseous bodies. The main problem of these devices is heat loss and a large mass. In connection with such problems in heat exchangers, thermal engineers are tasked with working to improve, improve and reduce heat loss in these units.

At present, many production companies are working on these, one of such companies is the French company “KELVION”, this company has a great reputation in the industry for the production of various types of heat exchangers and exports to all over the world. One of these products of this company is “Air coolers with heating of fuel gas” used in thermal power plants using “combined-cycle plants”.

To reduce heat loss in air coolers, various materials with high thermal conductivity are used to minimize heat loss in combined cycle plants. This horizontal type air cooler (AHV) is used to cool the air of the cooling rotor of the gas turbine, which is taken from the selection of the seventeenth stage of the air compressor lying in one shaft of the gas turbine. To cool the air of the gas turbine cooling rotor, atmospheric air is used with the help of exhaust fans. [1, p.152]

Depending on the principal purpose in the technological scheme, AGBs can be designed for cooling or for heating working media. According to the principal purpose of the AVG heat exchange section for liquid coolers, air coolers, vapor mixture coolers, condensers or gas heating and coolers. Structurally, the equipment consists of a heat exchange section, in a frame, sewn on both sides with tube sheets, and with spacers of tube sheets between them, in case of a large length (more than two meters). To improve heat transfer in the heat exchanger headers, finned copper tubes (or aluminum and stainless steel tubes) can be used. The design is closed with a metal case, with mounting supports (legs). The fans direct the air flow to the heat exchange section, accelerating the process of heat exchange between the working media due to the effect of forced convection.



1 – heat exchange section; 2 - welded frame; 3 - diffuser; 4 - water nozzles; 5 - fan; 6 - collector; 7 - reducer; 8 - electric motor.

Fig. 1. Drawing design of the air cooler

Air coolers have a number of advantages over other types of heat exchangers, for example, they do not require preliminary preparation of heat carriers, have small dimensions of the apparatus and a large cooling surface, are highly efficient, reliable in operation, environmentally friendly, have simple connection schemes, and can be operated in different climates. A common disadvantage of all known air coolers is their high power consumption, which makes them expensive to operate. According to the principle of operation, air coolers are classified as surface devices, and according to the method of heat transfer, they are recuperative. Air coolers can be attributed to surface-type devices, where atmospheric air is used as the working substance of the refrigeration machine. The device is designed to operate in a different range of operating pressures. The apparatus pressure is determined by the cooled medium and its temperature. The air cooler consists of several heat exchange sections, an air supply system and supporting metal structures, between which a frame with a grid is installed, while on the inside of the grids there are curtain-valves made of air-tight material.

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EFFECT: invention makes it possible to increase heat transfer due to the use of surface movement of air masses. Air cooler sections consist of pipes with fins. The finning is done by rolling or winding. At Russian refineries, rolling ribs are more often used, which are obtained by extruding ribs from an aluminum pipe put on a steel one. Such pipes have an increased heat transfer coefficient compared to smooth pipes, which makes it possible to compensate for the low heat transfer of air. [2, p.1024]

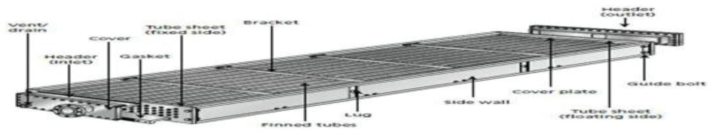

Fig. 2. The design of the air cooler with fins

The air supply system includes:
1) fan impeller
2) electric motor
3) electric fan diffuser
4) safety net

Sections of the apparatus are installed on supporting metal structures,the air supply system is attached from below.

Additionally, the device can be equipped with:
1) pneumatic blinds
2) positioner to the blinds pneumatic actuator
3) humidifier
4) air heater

Operating principle Air is forced by the blades of the impeller of the fan into the annulus [4, p.625]. The blades of the fan impeller are located in a cylindrical manifold, which is designed to direct the air flow.

The diffuser of the fan manifold is attached to the frame. The heat exchange sections are attached to the same frame. The fan with the motor is located on a special frame. The air passing through the section is heated, and the product in the pipes is cooled or condensed. To regulate the air flow on the section of the air cooler, a blade speed controller or a frequency converter is installed directly on the fan. Additionally, the volume of supplied air can be regulated by changing the angle of rotation of the fan blades, or by installing special devices - shutters. They are located after the heat exchange sections and are regulated either manually or by means of an electromechanical drive. Air cooler designs and the number of heat exchange sections may be different, but the principle of operation always remains the same.

In thermal power plants, this type of heat exchanger is used to cool the cooling air of the gas turbine rotor, which is taken from the air of the clamping compressor lying in one shaft of the gas turbine (the cooler uses atmospheric air). The inlet temperature of the cooled air is approximately 450°C, and the outlet temperature is cooling, the cooling air is heated and preheats the fuel gas to 220°C which is located at the top of the cooling air manifold. After heating the gas, the temperature of the heating air is about 100~110°C and goes into the atmosphere, which is the main reason for such heat loss in the air cooler.

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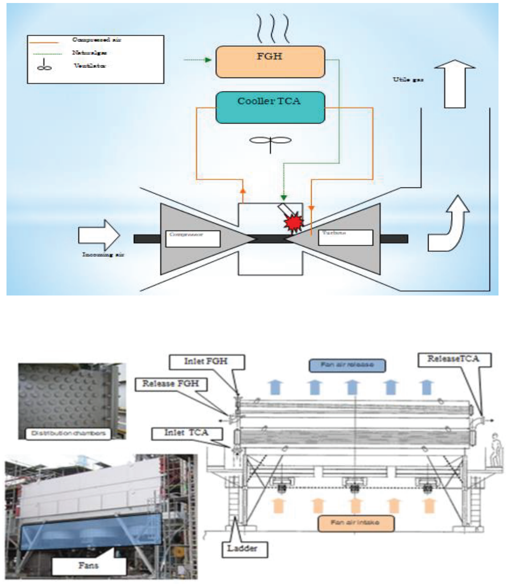


Fig. 3. Principal drawings of the air cooler for CCGT (steam gas installation)

When the fan is turned on, the cooling of the cooling air of the turbine is intensified and the natural gas is heated to improve the combustion of fuel in the combustion chamber of the gas turbine transported through the pipes due to the air flow around them, which has a lower temperature than the cooling air of the rotor.

To improve the thermal conductivity of this apparatus, the new methods of finned tubes of the heat exchange section can be used, which enables the apparatus to absorb more heat energy due to the good thermal conductivity of the fins and increase the heat exchange area.

Pipes with metal fins can be used to increase the outer surface area. This design allows you to increase heat transfer by 1.5 times. These products are used in applications where rapid heat exchange between the liquid in the pipe and the environment is required. Efficiency depends on the correct choice of design and raw materials in relation to specific conditions. [3, p.235]

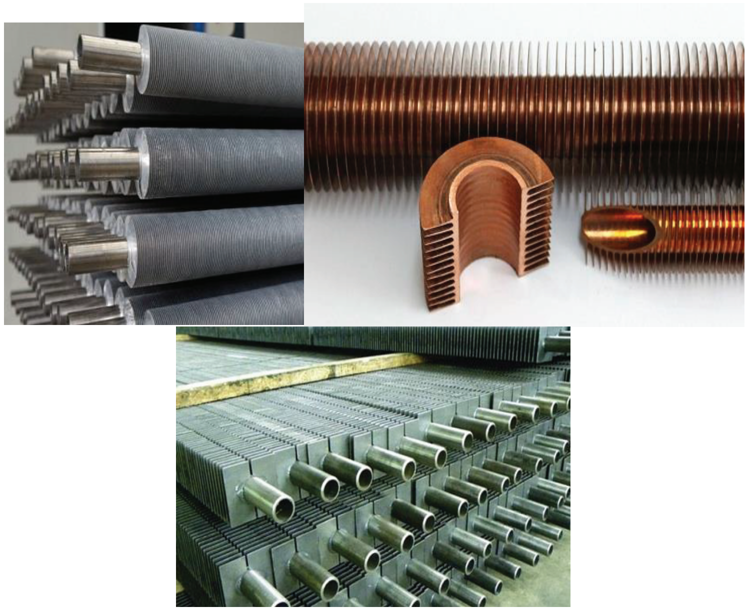


Fig. 4. Types of pipe finning (aluminum, bimetallic, stainless steel)

Regardless of the material, products of this type are the same in terms of device. They differ only in details - the shape of the petals and the coefficient of finning. "Construction" is assembled from two components

1) The base is a pipe made of a material with anti-corrosion properties. Its task is to withstand pressure and temperature differences. Use steel, cast iron and non-ferrous metal pipes. Depending on the tasks to be solved, cool or heat carrier flows through them.
2) Ribs fixed on the base. Since heating is carried out over the entire surface of the petals, its efficiency remains at the same level regardless of the carrier temperature.

The finning coefficient is the value obtained by dividing the area of the protrusions and the areas between them by the unfinned surface. The larger it is, the higher the efficiency.

Cast iron pipes are cast immediately with ribs. For the manufacture of products from other materials used:

1) high-frequency welding of elements;
2) crimp washers;
3) transverse helical knurling;
4) electric arc and resistance welding;
5) winding with tension of the metal tape on the.

Some manufacturers make slotted fins to improve heat transfer efficiency. Aluminum rolled tubes can be used at temperatures up to 350 ^{0}C. Structures made using steel tape winding technology are able to withstand more severe conditions.

To create a heat-resistant layer, the surfaces are coated with magnesium oxide. After annealing, they get:

1) increase in heat transfer coefficient; high resistance to corrosion;
2) long service life;
3) increased resistance to temperature differences;
4) no need for special care, they can work in any conditions;
5) the possibility of application in aggressive environments.

Due to the acquired advantages, finned heat-resistant types have the following advantages:

1) High manufacturability. The contact welding used consumes little energy, it does not require special consumables and expensive equipment.
2) In the gaps between the fins, turbulent air turbulences occur, which increases the intensity of heat transfer in all areas.
3) Through the use of resistance welding, a connection is created between the petals and the base with low temperature resistance.
4) Reducing the thickness of the condensate film. This is due to the use of a heat-resistant coating. As a result, the level of condensation of carrier vapors decreases.

Two types of finned products are produced: monometallic and bimetallic. The former are made from the same material, the latter from different alloys. Characteristics are normalized by GOST:
1) wall thickness - 2-12 mm;
2) outer diameter - 20-219 mm;
3) the height of the ribs - 8-28 mm;
4) pitch of turns - 3.6-25 mm;
5) protrusion thickness - 0.8-2.5 mm; length - 1.5-24 m.

1.1 Aluminum fins

Due to the high resistance to chemically active substances, these pipes are widely used in industry. Among the advantages it should be noted:
1) Non-corrosiveness of products made of material with an aluminum content above 95%. Pipes made of alloys with a large amount of additives rust, so they must be protected from moisture.
2) Light weight - does not create problems during transportation and installation.
3) Possibility of application in aggressive environments.
4) Low roughness of the inner walls compared to steel and cast iron counterparts - provides good throughput.
5) Ease of machining.

High-purity aluminum has carcinogenic properties, so pipes made from it cannot be used for domestic needs. When choosing, it should be borne in mind that products that have not been processed by annealing, hardening or work hardening are easily deformed in the cold.

1.2 Stainless fins

These pipes are considered the best for mounting radiator heating systems of any type. They have the following benefits:
1) A small coefficient of thermal expansion, so even a long pipe will not warp with strong heating;
2)high strength;
3) durability;
4) good resistance to corrosion and chemically active substances;
5) heat resistance, which allows the use of stainless pipes even in high-temperature furnaces; strong thermal conductivity.

1.3 Bimetallic fins

The combination of dissimilar alloys makes it possible to obtain products with unique properties. For example, aluminum finned steel pipe has high strength and excellent heat dissipation, which can expand the scope of application. Since they began to be produced relatively recently, the study of the properties of various combinations is still ongoing.

In the manufacture of bimetallic products for heat exchangers, the following combinations of materials are used (pipe + fins):
1) steel with aluminum;
2) stainless steel with copper;
3) brass with aluminum;
4) stainless steel with aluminum.

The combination of different metals allows you to get the following advantages:
1)Excellent heat dissipation;
2) great mechanical strength;
3)Long service life;
4)low cost;
5) the possibility of using in systems with high pressure of the coolant.

The heat exchange section of the air cooler consists of four, six or eight rows of tubes in tube sheets. Pipes are fixed by flaring or flaring with welding. Sections can be single-pass and multi-pass. In multi-pass sections of the air cooling, where the volume of the cooled medium decreases as it moves through the pipes, the number of pipes also decreases sequentially along the passages. To ensure the rigidity of the tube bundle, the section is reinforced with a metal frame. However, during operation, the nuts on the studs connecting the grate to the frame must be unscrewed to a distance exceeding the possible thermal elongation of the pipes. In a tube bundle, each tube can have an individual deflection. To prevent contact between the ribs of the upper row of tubes and the ribs of the tubes of the lower row, spacers about 15 mm wide from 2 mm thick aluminum tape are placed between adjacent rows in several places along the length of the tube. Covers are attached to the tube sheets of heat exchange sections at high pressure permanently or on studs. If the section of the apparatus is multi-pass, the covers are provided with partitions that divide the tube bundle into passages. Removable covers are usually made of cast steel. As indicated, the pipes in air coolers have fins along the outer surface, since the heat transfer coefficient on the outer surface of the pipes is an order of magnitude less than the coefficient for the inner surface. [5, p.852]

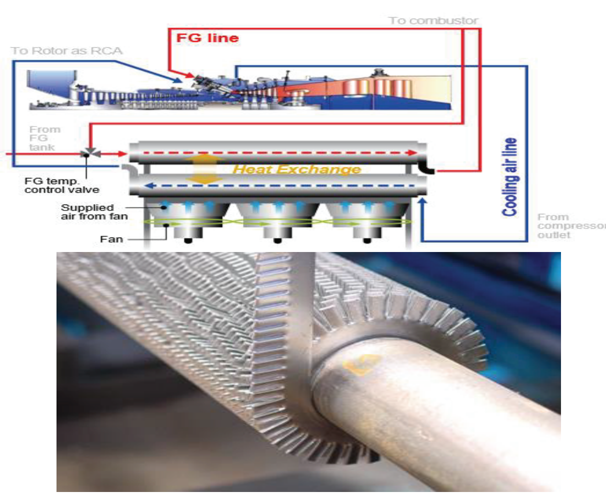


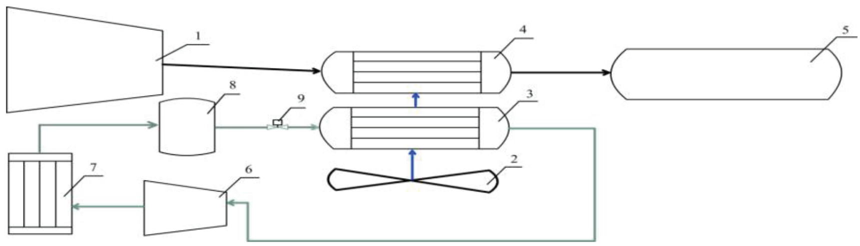
Fig. 5. Structural details of the air cooler for CCGT.

With the help of this device, the air is cooled, which cools the rotor part of the turbine gas. The cooling air of the gas turbine rotor exits from a 17-stage air clamp compressor which is attached to one shaft of the gas turbine.

The temperature of the air entering the air cooler is about 450°C and after leaving the air temperature is about 230°C

Cooling of the air of the gas turbine cooling rotor is carried out with the help of atmospheric air with the use of fans that create forced convection attached to the lower body of the apparatus.The temperature of the cooling air rises to 210-220°C and heats up the fuel gas which enters the manifold located at the top of the air manifold.

The fuel gas inlet temperature is about 120°C, after heating, the gas outlet temperature rises to 220°C and is fed into the gas turbine. The rest of the temperature goes into the atmosphere which is about 100°C, this is the heat loss of the air heat exchanger apparatus.



1 - gas compressor; 2 - fan; 3 - part exchanging heat with the cooler; 4 - heat exchange part with APG; 5 - separator; 6 - refrigerator compressor; 7 - capacitor; 8 - receiver (receiver); 9 - screw.

Fig. 6. Schematic diagram of an air heat exchanger

Our main task is to find a way to reduce the heat loss of this device. In order to reduce the heat loss of this apparatus, it can be recommended to install water collectors with finned tubes in the upper part of the apparatus to absorb the outgoing air temperature by supplying water to the water collector and heating several tons of water per hour. To do this, we can take the extraction from the incoming water line to the waste heat boiler and the heated water can be returned back to the inlet of the low pressure economizer in order to increase the efficiency of the waste heat boiler. [6, p.157]

Water consumption can be determined using the heat balance formula.

To determine the flow of water between the pipes in the water manifold, we need the following parameters:

The approximate temperature of the heat dissipated in the device is $T_1 = 110^0C$,

$T_2 = 40^0C$ outlet temperature after device modification.

We can determine the amount of heat of the device at this temperature

$$Q_1 = Cp \times M \times (T_1 - T_2) \tag{1}$$

Depending on the amount of heat detected, we can determine the amount of water needed to heat the water supplied to the device from $t_1 = 35^0C \; to \; t_2 = 80^0C$

$$G = Q_1 / (Cp \times (t_2 - t_1)) \tag{2}$$

Based on the results, if we add $t^2 = 80^0C, G^2 = 46.3635 \; t/h$ of water to the boiler system $t_1 = 35^0C, G_2 = 354 \; t/h$, we can determine how much the total water flow can withstand.

$$T = (G_1 \times t_1 + G_2 \times t_2) / (G_1 + G_2) \tag{3}$$

we can wait

This makes it possible to heat 400 tons of water per hour up to 5ºC.

2 Main results and conclusions

Today, in the energy and industrial sectors, heat exchange devices are becoming one of the integral parts of these systems. Therefore, the need for heat exchangers is increasing day by day. Before buying such a device, every user pays attention to the device's reliability, low cost, easy to find spare parts and low cost, and most importantly, low heat loss in the heat exchanger, which requires the device manufacturer to do more research on device improvement. requires.

In some cases, depending on the conditions of use of the device, we can use the result obtained by reducing the heat loss in it for many purposes, depending on the local conditions.

For example, by improving the equipment to reduce the heat loss in the air cooling and gas heating device coming out of the last stage of the air compression compressor in the steam-gas equipment workshop of the thermal power station, we can increase the supply water of the boiler utilizator to 5^{0}C. allows. This leads to an increase in the FIK of the boiler user in the recirculation system, which reduces the amount of heat required in the recirculation system to catch the "dew point" of the main chimney, which is absorbed by the supply water. we will be able to increase.

If we use the high-temperature distillate obtained by improving the device to heat the recycled water in the chemical workshop, it can lead to better mixing of the reagents mixed with the recycled water and the consumption of the used reagents.

What advantages will give us the improvement of the air cooling device:

1. In the waste heat boiler, it will provide an opportunity to improve the “Recirculation” system, which is part of the waste heat boiler, and reduce depreciation costs;
2. Possibility to refuse the tubular heat exchanger used for gas heating with the help of boiler water;
3. Possibility to abandon the tubular heat exchanger used to cool the air from the 17th stage of the compressor, to cool the gas turbine rotor;
4. Ability to start the gas turbine in a simple cycle in case of a problem with the steam turbine;
5. Reducing the risk of sulphurous acid in the tubes of the waste heat boiler by increasing the temperature of the flue gas.

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