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Methods of Using Secondary Energy Resources in Industry

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Abstract: *The purpose of this study is to study the use of secondary energy resources (SER) as a tool to reduce the energy component of production costs. The paper discusses ways to reduce energy costs, one of which is the use of SER. The definition of SER has been clarified sources and directions of using SER have been identified. A technology is proposed for generating electricity from secondary energy resources of metallurgy. The method of generating electricity from the secondary energy resources of metallurgy consists in the use of elemental sulfur and sulfide materials in the process of converting thermal energy into electricity.*

Keywords— *secondary energy resources, metallurgy, furnace, electricity production, sulfur.*

1. INTRODUCTION

Secondary energy resources (SER) are energy of various types that leaves a technological process or installation, the use of which is not mandatory for the implementation of the main technological process. Economically, it is a by-product that, with an appropriate level of technological development, can be partially or fully used for the needs of new technology or the power supply of other units (processes) at the enterprise itself or outside [1].

Domestic energy resources of industry are divided into three main groups:

1. Combustible. 2. Thermal. 3. Overpressure.

1. Combustible (fuel) SER - the chemical energy of the waste from technological processes of chemical and thermochemical processing of raw materials, namely [2]:

- by-product combustible gases of melting furnaces (blast furnace gas, blast furnace gas, shaft furnaces and cupola furnaces, converter, etc.),

- combustible waste from the processes of chemical and thermochemical processing of carbon raw materials (synthesis, waste from electrode production, combustible gases in the preparation of feedstock for plastics, rubber, etc.),

- solid and liquid fuel wastes not used (not suitable) for further technological processing,

- waste wood, liquor pulp and paper production.

2. Thermal SER - this is the heat of the exhaust gases during fuel combustion, the heat of water or air used to cool technological units and plants, heat production waste, for example, hot metallurgical slag.

One of the very promising areas of using heat from slightly heated water is the use of so-called heat pumps, operating on the same principle as the compressor unit in a home refrigerator. A heat pump draws heat from the waste water and accumulates thermal energy at a temperature of about 90 ° C, in other words, this energy becomes suitable for use in heating and ventilation systems [3].

3. SER of excess pressure (pressure) is the potential energy of gases, liquids and bulk solids leaving process units with excess pressure (pressure), which must be reduced before the next stage of use of these liquids, gases, bulk solids or when they are released into the atmosphere, reservoirs, tanks and other receivers [4].

An example of the application of these resources is the use of blast furnace gas overpressure in recycling compressorless turbines to generate electrical energy.

As a result of the energy service of one or another process, spent energy carriers turn into thermal waste, which can be used for energy purposes. Such thermal waste is called secondary energy resources. Industrial enterprises have especially significant secondary energy resources.

Secondary energy resources in a number of industries reach 30-60% or more of the corresponding total fuel consumption (ferrous and non-ferrous metallurgy, chemical production, etc.).

The use of secondary energy resources reduces the overall fuel consumption and reduces the size of the energy consumption, which is covered by a centralized way from the energy supply system. Therefore, the rational, that is, techno-economically justified, use of the internal resources of industrial enterprises should be carried out, possibly more fully.

2. MATERIALS AND METHODS

Characteristics, quality parameters of varieties of energy resources [5-10]:

- Solid liquid, gaseous fuel or electricity for servicing high-temperature technological processes (industrial furnaces) and cooling input.

- Gas and liquid fuel for servicing technological power processes (with internal combustion engines of blowers, compressors and other units) and cooling water.

- Fuel and technological raw materials (in enterprises of metallurgical, woodworking, textile, food and other industries).

- Steam for maintenance of technological power (in hammer, press and stamping units) and heating processes.

- Hot water for domestic heat consumption

- Electricity serving power, thermal and lighting processes.

- SER are also available at power plants and represent thermal waste or heat loss obtained in the process of energy production.

In hydropower plants, such heat wastes are only the heat in the hydrogenerators of the stations.

From those listed in table. 1 secondary energy resources are the main ones:

1) waste combustible gases from metallurgical furnaces and refineries;

2) waste hot gases of industrial furnaces;

3) spent and secondary production steam;

4) heated cooling water and evaporative cooling steam of industrial furnaces.

In this case, combustible gases, in view of their significant heat of combustion and transportability, should be considered as types of fuel used for technological and energy purposes.

The rest of the types of secondary energy resources have only partial, still far from insufficient, use or are completely lost, as, for example, the heat of molten metals and industrial furnace slags [20].

Waste combustible gases from metallurgical furnaces and refineries. These flammable gases include:

1) coke oven gas, obtained in coke ovens and giving on average 14.5% of the heat from the total heat of the fuel supplied to coke ovens;

2) blast furnace gas leaving blast furnaces and containing about 49% of all heat entering the blast furnaces;

3) petroleum gas obtained in oil refining units of cracking units and containing on average about 8% of the heat of the processed liquid fuel.

Currently, the listed combustible gases are primarily used as process fuel for production units, and partially (coke oven and oil gases) as chemical raw materials. Only to a small extent are these gases used as energy fuel in local power plants.

It should be borne in mind that with modern technology of metallurgical production, some gas losses (about 5% for blast furnace and 1% for coke oven gases) are practically inevitable. Losses in excess of these values in most cases can be eliminated [50].

Waste hot gases from industrial furnaces. The industrial use of fuel to date is associated with huge losses, reaching 70–80% of the thermal energy contained in it.

The thermal efficiency, understood as the ratio of the heat used for the technological process to the heat of the fuel consumed, for most industrial furnaces does not exceed 20-30% (in particular, for smelting and heating furnaces of metallurgical, machine-building, cement, ceramic and other industries). At the same time, heat losses with exhaust gases are especially high, amounting to an average of 30-50% and decreasing only for certain types of industrial furnaces to 20%.

For one and the same industrial furnace, the amount of waste gases in normal operating conditions is more or less constant.

The temperature of the exhaust gases in front of the heat recovery unit depends on the following factors: the purpose and general thermal scheme of the production unit, cooling and dilution of exhaust gases with sucked air, as well as the presence and parameters of upstream production heaters that are elements of industrial furnaces.

The average possible values of the temperature of the flue gases (before the heat recovery unit) are shown in table. one.

When determining the value of the available secondary energy resources in the form of hot waste gases, it is also necessary to take into account their possible dustiness by low-melting entrainment, especially in shaft and other furnaces of non-ferrous metallurgy enterprises.

The use of oxygen blast for industrial furnaces by enriching the air blown into them with oxygen up to 30% or more will make production heaters of blast furnaces, steel-making and other furnaces unnecessary. In this case, the temperature of the exhaust furnace gases will increase significantly.

Spent and secondary production steam. Spent production steam is obtained in production units serving mainly for the plastic processing of metals, i.e. hammers, presses, forging machines.

The pressure of the spent industrial steam is on average 1.2–1.5 atm. Its temperature depends on the initial parameters of the steam in front of the units (hammers, presses, etc.) and on the relative internal efficiency of the latter, constituting about 150–160 ° C for heat supply of production units from the CHPP.

The total amount of spent industrial steam is on average 80–90% of the amount supplied to the workshop of industrial steam and is a significant secondary energy resource of metalworking and machine-building enterprises.

Until now, the spent production steam is still far from being used to supply power to consumers.

Many production processes associated with heating or evaporation of one or another product produce secondary steam with a pressure close to atmospheric. Such thermal waste occurs, for example, in the enterprises of sugar, alcohol, soda, sulphate cellulose and other industries and represent quite significant secondary energy resources.

Heated cooling water and evaporative cooling steam of industrial furnaces and hot waste water for industrial and domestic heat consumption. The most significant heat wastes in the heated cooling water are produced by steel-smelting (open-hearth) furnaces, in which heat losses in the cooling water make up from 16 to 25% of the consumed fuel. However, until recently, these secondary energy resources were of limited use due to the low temperature, heated cooling water (below 100 ° C) and the possibility of servicing it only for low-temperature processes, mainly of a seasonal nature.

On average, per 1m of steel smelted in an open-hearth furnace, heat loss in cooling water heated to 90–95 ° C is about 180,000 kcal.

Recently, evaporative cooling of metallurgical furnaces has been increasingly used to replace cold cooling water with boiling water and use the latent heat of vaporization when removing heat from the cooled parts of the furnace.

The advantages of evaporative cooling over water cooling are: increased reliability of the furnace; lengthening the service life of the cooled parts; a sharp reduction in water consumption (by 35-50 times) and the absence of cooling devices, pumping stations and large-diameter water pipelines; utilization of heat lost with cooling water through the use of the resulting steam.

A number of steel-making (open-hearth) furnaces have already been transferred to evaporative cooling. The steam output from the evaporative cooling of open-hearth furnaces is 0.22 tons per 1 ton of cast iron (in terms of cast iron) at a pressure of 1.6–4 atm.

Evaporative cooling of blast furnaces and heating furnaces is also being introduced. Heat losses in blast furnaces with cooling water range from 3 to 5% and range from 4 to 6 Mkcal / h per furnace. Heat losses from heating furnaces with cooling water range from 15 to 25% and range from 1.5 to 2.5 Mkcal / h.

Hot waste water for industrial and household heat consumption at a temperature of the order of 30 ° C and higher has no practical use to date.

Combustible waste from technological production. Combustible waste from technological production is subdivided into the following:

a) combustible solid waste obtained in the form of crushed solid metallurgical fuel - coke (coke nut) with a heat of combustion Qpn = 7000 kcal / kg and coke breeze (Qpn = 6500 kcal / kg), as well as in the form of other solid combustible waste technological production;

b) combustible liquid waste obtained in oil refineries and other enterprises in the form of cracked fuel oil (Qpn = 10,000 kcal / kg), etc.

Other secondary energy resources of industrial enterprises. Other secondary industrial energy resources include:

a) heat released by radiation from industrial furnaces and their products (quenched by coke, liquid and cooling metals and their slags, etc.);

b) heat generated in production facilities when electricity is consumed.

From modern coke ovens, together with 1 ton of incandescent coke, about 300,000 kcal of heat are removed, which is 45-50% of the total heat of the fuel spent on its burning. With the huge scale of coke production, the efficient use of heat lost with hot coke is of great importance, but this heat is still practically not used.

The use of the heat of slags becomes difficult due to their transition from a liquid to a solid state with a decrease in temperature to 900-1000 ° C and below.

3. Analysis of the way to solve the problem

Such energy resources can be used to meet the needs for fuel and energy either directly (without changing the type of energy carrier), or by generating heat, electricity, cold and mechanical energy in recycling plants. Most combustible fuel and energy resources are used directly in the form of fuel however some of them require special utilization facilities. Some thermal SERs are also directly applicable (for example, hot water from cooling systems for heating).

1. Sources and ways of using SER in the steel industry.

Combustible gases - waste of the main production: Blast furnace and coke oven gases are almost completely used. The use of ferroalloy gas is possible for technological (heating materials, partial preliminary recovery of raw materials) and cogeneration purposes, burning in a boiler room. Converter gas is partially used in coolers, but its full use has not yet been decided [11].

Heat of cooling water: In evaporative cooling installations, the steam output is 0.1 t / t of pig iron and 0.2 t / t of open-hearth steel. All technological issues of evaporative cooling of furnaces are solved and the widest possible implementation of the method in production is required. It is necessary to improve technical solutions for the unification of cooled elements, increase steam pressure, improve control over the density of cooling circuits, and improve the automation of disposal plants. It is necessary to disseminate the experience of ferrous metallurgy in the chemical industry, mechanical engineering, etc [12].

2. Sources and ways of using SER in non-ferrous metallurgy.

Large reserves for the efficient use of SER are also available at non-ferrous metallurgy enterprises.

Effective in non-ferrous metallurgy is the use of flue gas heat to heat the air entering the furnace for burning fuel. This saves fuel, improves the combustion process and, in addition, increases the productivity of the furnace. However, a significant amount of thermal energy that can be used in waste heat boilers to generate steam is also carried away with flue gases [13].

As the costs of fuel extraction and energy production increase, the need for their more complete use when converting in the form of combustible gases, heat of heated air and water increases. Although utilization of SER is often associated with additional capital investments and an increase in the number of staff, the experience of leading enterprises confirms that the use of SER is economically very profitable [14].

4. Proposed technical solution to the problem

Today, the demand for electricity in all areas is increasing and as a result, demand for raw materials used in the generation of electricity, such as natural gas, coal and fuel oil, is also increasing. Year after year, prices for such minerals are becoming more expensive. This is due to the fact that these resources are not renewable. This fact, of course, cannot but affect the cost of electric energy. In addition, there are a huge number of thermal power plants that, as a result of using the above resources, emit a very large amount of carbon dioxide (CO_2) into the atmosphere, which is the root cause of global warming. Given all these

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circumstances, it becomes clear that it is necessary to come up with a cheaper, safer and more modern method of generating electrical energy.

The aim of the proposed study is to generate electricity in a more affordable and gentle way, minimizing damage to the environment.

In the process of generating electrical energy, we propose using elemental sulfur instead of traditional fuel. This process is carried out in thermal power plants, as follows:

In the fuel preparation workshop on special equipment, Sulfur is cleaned of unnecessary impurities and rubbed into powder, ensuring its complete combustion. Finished fuel is delivered to the steam generator through special pipes. When powdered sulfur and air are sprayed into a furnace heated to 280-360 ^oC, sulfur begins to oxidize (burn), generating heat:

$$S + O_2 = SO_2 + 297\ KJ\ (71.05\ kcal)$$

When burning 1 m^3 of natural gas, 8500-8600 kcal of thermal energy is released, while from 1 kg of sulfur 2200-2220 kcal of energy can be obtained. Judging by the calculations, 4 kg of powdered sulfur will be required to compensate for the energy released during the combustion of 1 m^3 of natural gas.

The heat generated by the combustion of fuel is used to evaporate water from the boiler and heat the generated steam. The resulting pressure reaches 240 atmospheres, and the temperature is 560 ° C. The water vapor formed in this way enters the steam turbine. The turbine shaft is attached to the rotor of the induction generator. A steam turbine and a generator consisting of a generator are called a turbogenerator. The resulting high-pressure water vapor rotates this turbogenerator and, as a result, electricity is generated. The generated electricity is sent to the auxiliary power station. From there it is served to consumers.

It is known that thermal power plants using natural gas and coal directly release carbonate anhydride and dust into the atmosphere. And this leads to environmental pollution and becomes the cause of the increasing global warming problem.

In contrast to the prototype, in the new proposed method, SO_2 and SO_3 gases are formed as a result of sulfur combustion. Emitting these gases into the atmosphere is very dangerous. However, these gases are considered the main raw material for the production of sulfuric acid (H_2SO_4). It is for this purpose that they are sent to the sulfuric acid production workshop (therefore, it is imperative that the TPPs and the workshop producing H_2SO_4 be located at close distances to each other). Here, SO_2 and SO_3 gases sent to the sulfuric acid production plant, with the participation of oxygen using a catalyst (V_2O_5), are completely converted into SO_3 gas, which, when it reacts with water, forms H_2SO_4 (sulfuric acid):

$$2SO_2 + O_2 \rightarrow 2SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

The only drawback of this method is that the SO_2 and SO_3 gases formed as a result of burning sulfur in the furnace, due to their strong acidic properties, can destroy the walls of the furnace and the walls of the steam boiler. In order to prevent this, it is required to fabricate the walls of the furnace and steam boiler from acid-resistant (i.e., acid-resistant) materials or to cover their surface with such materials.

In addition, a common drawback for all Heat Power Stations (HPS) is their low coefficient of performance (COP), which is 36 percent. This is due to losses arising from the formation of the main steam and when using exhaust steam. For example, 47 percent of the energy is released together with the exhausted steam, 8 percent - with the flue gases, and 2 percent is spent on the plant’s own production needs.

In the proposed method, due to directing the resulting gases SO_2 and SO_3 to the production of sulfuric acid, 8% of energy is saved. Thus, the efficiency will reach 44%.

At this time (according to information from January 2018), the cost of 1 m^3 of natural gas in Uzbekistan is 1000 sums. The cost of 1 kg of sulfur is 50 sums. If we take into account the use of 4 kg of sulfur to replace 1 m^3 of natural gas, a total of 4 * 50 = 200 sums of capital will be spent. From this it is clear that the consumption of sulfur instead of natural gas reduces the cost of electricity production by 5 times.

5. Conclusion

Direct use of the study gives a number of technical results, such as:

- As a result of the combustion of sulfur, the composition of the gases leaving the furnace contains a large amount of SO_2 gas, which is considered the most high-quality and effective raw material for the production of sulfuric acid;
- Due to the fact that the formed gas SO_2 is free, it can produce very cheap but high-quality sulfuric acid (H_2SO_4);
- As a result of directing the exhaust gases to the production of H2SO4, it becomes possible to completely utilize toxic gases released into the atmosphere;
- If this method is applied at the global level, the problem of global warming will significantly decrease and environmental protection will increase significantly.

The solution of this research to technological, environmental and social problems, as well as the use of sulfur in it, fully meets the criteria of inventions such as “novelty”.

Thus, increasing the level of utilization of secondary energy resources provides not only significant fuel savings, capital investments and the prevention of environmental pollution, but also a significant reduction in the cost of production of oil refineries, metallurgical and petrochemical enterprises.

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