Using absorption principles of water-ammonia mixture for energy supply of agricultural enterprises

K V Osintsev
South Ural State University, 76, Lenina Ave., Chelyabinsk, 454080, Russia
E-mail: pte2017pte@mail.ru

Abstract. The most promising developments in the field of energy supply for industrial enterprises are research in the field of alternative energy sources. As experience in the construction of the first geothermal power plants operating along the Kalina cycle shows, the efficiency of heat use increases sharply due to the utilization of the heat of low-potential energy sources. As such, energy sources use ground, in particular, geothermal water. In regions where there are enough geothermal sources, power plants based on the Kalina cycle can be used. The generated heat and electricity can be used for agro-industrial complexes. This is possible, as theoretical studies show, for enterprises in the field of crop production, animal husbandry and processing of agricultural products. In addition, the article describes the principles of using absorption refrigeration machines in agriculture.

1. Introduction
Crop production is a leading branch of agricultural production, the most important source of human food resources. Green plants, binding the energy of sunlight, create in the process of photosynthesis with inorganic low-energy substances, for example, carbon dioxide, air, water and mineral compounds of the soil, as well as various organic substances. The main goal of crop production is the creation of optimal technological and ecological prerequisites for the production of the required amount of high-quality crop products based on intensive photosynthesis in crops of field crops while maintaining or improving soil fertility. The main tasks of the plant growing industry at the present stage of development are the production of high quality, environmentally friendly products with minimal energy and labor costs with a maximum output per unit time per unit area, which requires the widespread introduction of varietal, intensive, energy- and resource-savings environmentally appropriate technologies. Vegetable growing is divided into vegetable growing of open and protected soil. In the first case, crops are cultivated in the fields, in the second case; they are cultivated on a specially designated area or in rooms where the necessary microclimate is artificially created. Growing vegetable seeds is part of the task of seed production. Each branch of vegetable growing is specific and requires deep knowledge of plant biology, based on which agricultural requirements for mechanized work on their cultivation and harvesting are developed. Technical requirements for soil preparation, sowing and care coincide with those presented to previously considered row crops [1]. Currently, there are various ways to use crop waste in agriculture [2, 3].

Agro-industrial complexes need heat supply and electricity supply, which can be ensured by building the first geothermal power plants in our country, operating on the Kalina cycle, the efficiency of heat use increases sharply due to the use of heat from low-potential energy sources.
2. The principle of operation of the technological scheme and scientific novelty

Now, the first geothermal power plants operating on Freon are existed. These power plants are built in the USA and Iceland. The principle of their work is to use low-potential energy sources. The Kalina cycle uses a mixture of ammonia and water.

Figure 1. The heat supply scheme of greenhouses using geothermal water: 1 - a supply pipe for geothermal water, 2 - a return pipe for geothermal water, 3 - a heat exchanger, 4 - a supply pipe for circulation water, 5 - a greenhouse, 6 - a return pipe for circulation water, 7 - an expansion tank, 8 - recirculation pipe, 9 - circulation pump

Figure 2. The application scheme of the Kalina cycle: 1 - hot water pump, 2 - hot water circulation pipe, 3 - evaporator, 4 - ammonia-water mixture circulation pipe, 5 - separator, 6 - intermediate heat exchanger, 7 - ammonia-water mixture recirculation pipeline, 8 - condenser, 9 - ammonia-water mixture recirculation pump, 10 - cold water pump, 11 - cold water circulation pipeline, 12 - turbine, 13 - electric generator, 14 - greenhouse, 15 - heat exchange surfaces

At the same time, methods for heating rooms are known, in particular at agricultural enterprises in which the flow of geothermal water is the heating medium. To heat greenhouses, geothermal water is supplied directly to the greenhouse heating system. If water has a high salt content, that it is necessary to use more complex water treatment systems and additional heat exchangers. The authors' studies were carried out in the field of heat transfer [4, 5]. Three electricity production schemes have been developed. There is a direct scheme that uses water vapor. The scheme is used where there is direct access to
geothermal pairs. An indirect scheme uses not steam, but water. It is fed to the evaporator, converted to steam by the technical method and sent to the turbine. Water requires additional purification, because it contains aggressive compounds that can destroy working mechanisms. Waste but not cooled steam is suitable for heating needs. There is also a binary circuit. In this cycle, water replaces fuel, which heats another liquid with higher heat dissipation and it drives a turbine.

The principle of operation of the circuit in Figure 1 is as follows. Geothermal water flows through the supply pipe 1 to the heat exchanger 3. This water transfers heat to the water located in the annulus of the heat exchanger 3. Then the geothermal water returns through the pipe 2 to the well of the geothermal source. The circulation water heated in the heat exchanger is sent through the supply pipe 4 to the greenhouses 5, where it gives it is heat to heat the agricultural building. After which the circulating water is directed through the return pipe 6 to the expansion tank 7. From the expansion tank, the circulating water through the pipe 8 is pumped by the pump 9 again to the heat exchanger 3.

The principle of operation on the Kalina cycle in Figure 2 is as follows. Heated water is pumped through pipeline 2 by pump 1. Part of the heat is supplied to the heat supply of greenhouses 14 through heat exchange surfaces 15. Next, hot water is sent to the evaporator 3. In the evaporator 3, a mixture of ammonia and water is heated and evaporated. The vapors of the ammonia-water mixture rise into the separator 5. The dry saturated steam is sent to the turbine 12 to generate electricity in the electric generator 13. In the separator, not only dry saturated steam is generated, but also the liquid phase of the mixture of ammonia and water, which is first sent through recirculation line 7 to the intermediate heat exchanger 6. Then the cooled mixture is sent to the condenser 8 along with the condensate after the turbine 12. The cooled mixture in the condenser 12 is additionally cooled with cold water, which is pumped by the pump 10 through cold water pipeline 11.

3. Theoretical part of using absorption machine

The use of geothermal energy is repelled from the initial temperature. The temperature +30 °C and above is suitable for heating without additional transformation. Water, high temperature steam is used to generate electricity. The principle of operation of a thermal power plant is similar to a power plant device. The heat source at standard thermal power stations is a steam generator [6, 7]. The working element in both cases is heated steam [8, 9]. However, the heating methods differ. In thermal power plants, water is converted into steam using coal, fuel oil or natural gas for heating. Thermal installations and coolant are taken ready. The upper layers of the soil warm up or freeze naturally under the influence of solar heat or in its absence. Other external factors play a role. A little deeper the temperature is kept at the same level regardless of solar activity. Geothermal energy is based on an increase in the temperature of the Earth as it dives inside. The temperature increases on average by 2.5 °C every 100 meters. In mining mines, it is hot; the temperature is kept within 300 °C. Sometimes the problem of geothermal energy production is solved by nature itself. Heated water or steam is a natural coolant. They come to the surface or lie at a shallow depth. At the same time, their temperature is at least not much, but higher than the surrounding air.

4. Practical part. Application of the absorption machine in agriculture

Geothermal energy has a direct geographical dependence and is concentrated in zones with tectonic cracks in mountain ranges and seismic activity. There are various methods for analyzing the effectiveness of thermodynamic cycles [10, 11]. Therefore, its share in the total mass of energy is only 1%, and in some regions it rises to 25-30%. Technologically, the production of geothermal energy is much simpler than the generation of wind and solar electricity. Further, it will spread and grow, as it has high indicators of accessibility and environmental friendliness. This despite the fact that alternative sources of traditional energy are steadily becoming more expensive, sooner or later they will be exhausted and there simply will be no other choice. Absorption is the absorption of gas by a liquid. The operation of absorption refrigeration units is because the solubility of gases in a liquid increases with decreasing temperature, and with increasing temperature, the solubility decreases. Binary solutions, that is, solutions consisting of two components with different boiling points at the same pressure, serve as
the working fluid of absorption chillers. One of these two substances, boiling at a lower temperature, is a refrigerant; the other substance with a higher boiling point serves as an absorber, or absorbent. Substances used, as absorbents should not enter into an irreversible chemical reaction with an absorbed substance called a refrigerant. Despite the large number of binary solutions, only a water-ammonia solution and a solution of lithium bromide in water received industrial use. According to its thermodynamic properties, ammonia is one of the best refrigerants actively absorbed by water: at 0 °C, one liter of water absorbs up to 1140 liters of ammonia. Like a compression chiller, an absorption chiller has an evaporator, a condenser and a control valve. During operation, periodically do analyze of the coolant and water for the presence of ammonia in them. To protect the equipment of water-ammonia absorption refrigeration units from corrosion, distilled water is used in the solution, to which potassium dichromate or ammonium dichromate is added in an amount of 0.5% by weight of the solution. Absorption chillers are widely introduced in the chemical, metallurgical and other industries. They allow the use of secondary energy resources: heat of chemical reactions, heat of cooling of molten metal’s, flue gases and products of combustion of chemical wastes, low-pressure steam from waste heat boilers, and so on. The amount of these heat resources is growing from year to year; using them to get cold dramatically increases the efficiency of refrigeration units.

5. Conclusion

Thus, the general range of increasing of heat supply efficiency is possible in case energy and technological combination. Currently, only water-ammonia absorption chillers and continuous bromide lithium absorption chillers of a single-stage type are widely used in industry, using steam, hot and superheated water, hot gases and gas-vapor mixtures as a heat carrier. When describing the design features of individual devices, information is given on the main heat and mass transfer processes that occur in them. In such cases, it is necessary to check the appropriateness of the use of water-ammonia absorption refrigeration machines, in the absorbers of which water can be heated to the required temperature. The disadvantages of absorption machines compared with compressor machines are lower efficiency when using expensive heat sources, high metal consumption, cumbersomeness, increased cooling water consumption. Nevertheless, the experience of using absorption machines at artificial fiber plants for the joint production of cold and heat, as well as at a number of chemical and petrochemical enterprises, confirmed the possibility of their economical use in the above conditions. Other advantages of absorption machines are the ability to place them in open areas, low complexity of equipment and reliable operation. Water-ammonia absorption machines are more often used in the low-temperature range, while lithium bromide is used to produce cold water. Lithium bromide machines in a comparable temperature range have a higher thermal coefficient than water-ammonia ones. Part of the exhaust steam from the steam-powered unit is sent to a water-ammonia absorption refrigeration machine, the rest of it enters the hot water boiler. The water passing through the absorber, condenser and reflux condenser of the absorption chiller is heated. Then it enters the boiler, where it is heated by the exhaust steam to 80°C. However, their low cooling capacity necessitated the installation of several machines at each of the plants. The specific metal consumption for them was much higher, and, in addition, a much larger area was required for the placement of machines, and they could not satisfy the growing demand for artificial cold. The processes of absorption chillers are carried out using working substances, namely solutions, consisting, as a rule, of two components: refrigerant and absorbent. When the machine is operating, the refrigerant is periodically in both liquid and vapor states, and the absorbent is only in the liquid state. In recent years, in order to increase the efficiency of the absorption chiller, a series of studies of cold processes has been carried out using solutions such as choline chloride and water, monomethylamine and glycerin, methanol and lithium bromide, lithium chloride, lithium nitrate and water. It is advisable to check the effectiveness of a particular solution. Since in some cases it is necessary to exclude the rectification of steam of the working substance in the generator (in comparison with a water-ammonia solution), increase the solubility of the binary lithium chloride-water system, and reduce the corrosivity of the aqueous solution of lithium bromide in relation to the structural materials of absorption refrigeration machine or achieve other indicators. In general, the energy efficiency of the investigated
alternative solutions turned out to be approximately the same with the corresponding known solutions, however, according to a number of other indicators and under certain conditions, they can be recommended for use in an absorption refrigeration machine. If a steam generator already exists at an agricultural enterprise, it must be used as an additional source of thermal energy. A water-carbon mixture can be recommended as a fuel [12, 13]. As experience in the construction of the first geothermal power plants operating along the Kalina cycle shows, the efficiency of heat use increases sharply due to the utilization of the heat of low-potential energy sources. As such, energy sources use ground, in particular, geothermal water. In regions where there are enough geothermal sources, power plants based on the Kalina cycle can be used. The generated heat and electricity can be used for agro-industrial complexes.

Acknowledgments

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

References

[1] Miranda T, Román S, Montero I, Nogales-Delgado S, Arranz J, Rojas C and González J 2012 Study of the emissions and kinetic parameters during combustion of grape pomace: Dilution as an effective way to reduce pollution Fuel Processing Technology 103 160-165
[2] Wang Y and Cai J 2017 Renewable energy development in North West China Sustainable Renewable Energy 4(2) 56-62
[3] Sadhu S 2011 Handbook of Mechanical Engineering (S.Chand & Company Ltd) p.2080
[4] Osintsev K V, Tregubova M V, Kuskarbekova S I and Prikhodko I S 2019 Shifting the boiler units of mining enterprises and processing plants to a new scheme of heat supply Earth and Environmental Science 378 012049 1-4
[5] Osintsev K V and Prikhodko I S 2019 Application of mathematical modeling to optimize the operation of a tubular oil heating furnace Earth and Environmental Science 560 012081
[6] Thulukkanam K 2013 Heat exchanger desing handbook 2nd ed. (CRC Press) p. 1245
[7] Bukowska M, Nowak K, Proszak-Miaśik D and Rabczak S 2017 Concept of heat recovery from exhaust gases Materials Science and Engineering 245 052057 23-25
[8] 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 944 012009
[9] Shatskikh Y V, Sharapov A I, Byankin I G 2017 Analysis of deep heat recovery from flue gases Journal of Physics 891 012188 1-5
[10] Pashchenko D I, Semenov B A, Shchelokov A I, Naplekov I S and Mustafin R M 2018 Thermodynamic analysis of thermochemical recuperation of high-temperature flue gas heat Journal of Physics 1111 012009 6-10
[11] 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
[12] 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
[13] 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