

# Technological scheme of the combined geothermal-hydrocarbon system for the production and storage of energy resources

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**Abstract.** The complex researches of schemes of extraction and storage of hydrocarbons and geothermal energy are executed in the work. In particular, according to the location, logistics and nature of the processes of generation, transportation, evacuation, injection and local utilization of hydrocarbon and geothermal energy sources, the scheme is divided into subspecies of consumer regional order of electricity, hydrocarbon and chemical energy and hydrogen. It is shown that the tasks of extraction of natural or synthesized hydrocarbons, geothermal energy and subsequent transformation into the required form of commodity resource can be unified with the organization of circuit-combined technologies. At the same time, the developed technological scheme implements the concept of storage of the required amount of energy resources on the one hand and regulation of production capacity for consumption – on the other. The reduction of current energy costs for the implementation and operation of systems with updated functional systems for a total of 20–45%. It is proved that the selection of the scheme of unified extraction and storage energy systems in accordance with the projected order of energy and energy resources, due to the capabilities of productive reservoirs, leads to minimization of capital costs for their construction on a modular basis. Research of application of combined technologies of dual extraction-storage of heat carriers-hydrocarbons is a perspective direction of researches.

## 1 Introduction

There is no doubt that there are geothermal resources available in the existing oil and gas sediments of Ukraine and other countries [1–2]. Recently, oil and gas companies, such as Chevron and Shell, have been working to production and exploit geothermal resources using a variety of advanced technologies. In this case, the conceptual and circuit approaches are determined by the choice of coolants and circuit organization of production [2]. The article analyzes the improvement and attempts to unify circuitry to improve the overall logistics of hydrocarbon and geothermal energy resources.

## 2 Review of the literature

Today, three main types of technological implementation of well geothermal systems (WGTS) and well geoenergy systems (WGS) are used [1–3]:

1. Power plants with a binary (double-loop scheme) cycle, as a working fluid for which not thermal water or steam is used, but another liquid with a low boiling point.

2. Instantaneous or flash steam evaporators, which receive hot water under high pressure and transport it to surface tanks with reduced pressure, where the water is converted into steam to power the turbine.

3) Dry steam power plants that receive steam to rotate turbines directly from a geothermal reservoir.

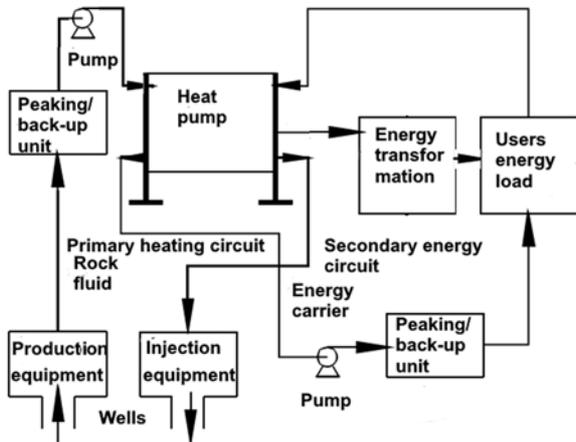
For oil and gas fields, which after depletion were converted into underground gas storage facilities (UGS), usually implement the first type of technological implementation based on binary schemes (a second circuit with low boiling point of the coolant is added) and thermodynamic Rankine cycle or Kalina cycle [2].

The geothermal system of the first type on the basis of objects of development of oil and gas fields can be realized according to the scheme of open combined WGTS with binary or simpler structure. The diagram in Figure 1 shows the real circuitry of operating systems with heat generation in Germany, Austria, Canada and others. countries where the temperature of geothermal sources reaches 100° C [3–4].

Figure 1 shows that the WGS circuit integrates the units of removal and chemical synthesis of various substances required as inhibitors or catalysts of processes, and additional heating of the working coolant before utilization

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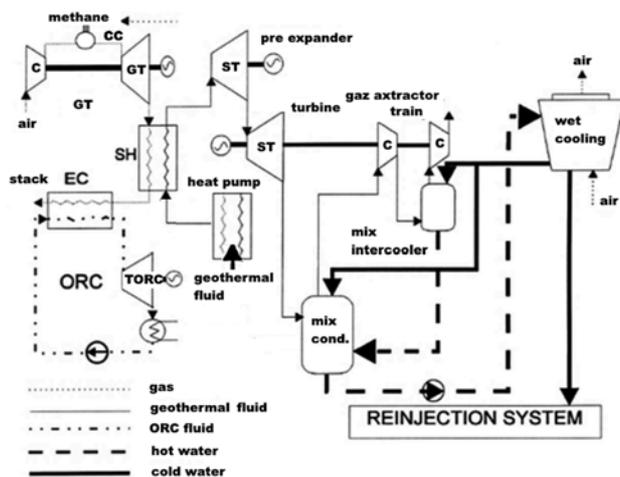
in the consumption units (turbines and heat exchangers) is advantageously realized in parallel hydrocarbon coolant production. The authors of [2–3] did not show the technology unit (technology block) of accumulation and heating in the initial circuit of the formation geothermal fluid (in particular, to simplify understanding), but usually such a unit is used. Therefore, in Fig.1 this block-unit is shown.



**Fig. 1.** System of direct use of extracted geothermal energy and formation water / fluid with heating in the peak boiler-accumulator and extraction of useful chemicals (fuel, metals, salt, etc.) near the wellhead.

If it need to generate and local utilize not only heat but also electricity, use combined WGS circuits (Fig. 2), in which the system shown above in Fig. 1 is one of the basic units (is a WGS subsystem). The essence is the multi-stage utilization of extracted geothermal energy in the following stages (as the circuit build-up development, circuit complication) [4]:

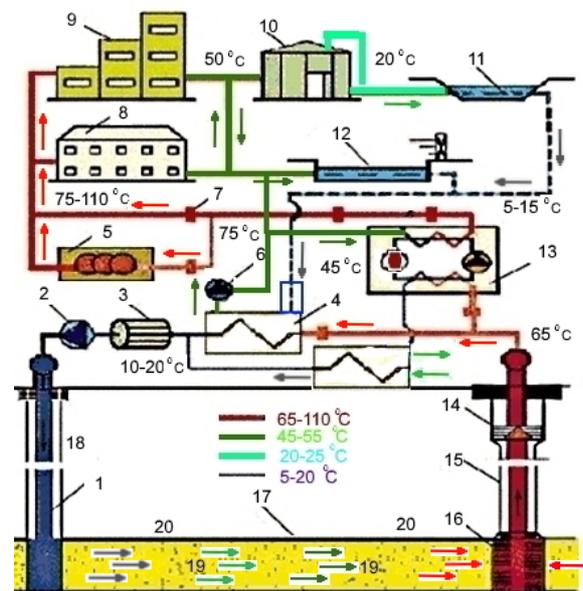
- utilization without heat pumps, absorption systems and turbines;
- utilization without turbines and absorption systems;
- utilization without absorption systems;
- complete utilization (using heat pumps, turbines, absorption systems, cogeneration heat exchangers).



**Fig. 2.** Technological scheme of GeoPP of open combined type with heat pump and heat utilization of turbines operating on geothermal energy and extracted hydrocarbons (in terms of electricity generation and partial heat utilization) [4].

The scheme shown in Fig. 2 is typical for implemented projects in the USA, Italy, Russia, Iceland and others. countries where the temperature of the local geothermal source significantly exceeds 100 °C [1–4]. But this scheme actually reveals a typical solution for the generation of power stations of the well-known company ENEL (stage of utilization at the level – without absorption systems), it is only half of the overall scheme in terms of utilization of thermal energy [4]. The turbine circuit often uses prepared water directly from the production well, which is not possible at downhole source temperatures below 100 °C., especially without the use of a methane fuel turbine or boiler. But the scheme is suitable for working with all the above three types of technological implementation, provided the organization of the binary principle. That is, it can be considered universal after some circuit upgrating, in particular the introduction of several circuits with a cycle of Rankine (or Kalina) and cogeneration heat exchangers.

The second half of the general functional scheme is well understood from Figure 3, which is explained in detail in [5] on the cascade principle of thermal energy utilization by a local consumers. Thus, the scheme in Fig. 3 complements the scheme of geothermal power plant (GeoPP) in Fig. 2 and gives a complete scheme picture of the double generation and utilization of electricity and heat in the case when actively extracting both local hydrocarbons and available local geothermal energy. Thermal energy in large quantities can be used as an auxiliary energy of technological processes in the extraction and transportation of natural gas and oil [6–7]. Unquestionably produced electricity can be used for the synthesis of useful fuels (hydrogen, methanol, gasoline) and synthesized methane on site. About the latter problems and the necessary circuit solutions will be discussed below.



**Fig. 3.** Technological scheme of WGS of open combined type with heat pump and heat utilization of turbines operating on geothermal energy and extracted hydrocarbons (supplement of the scheme in Fig. 2 in part of full cascade local heat utilization of geothermal sources and emissions of GeoPP) [5].

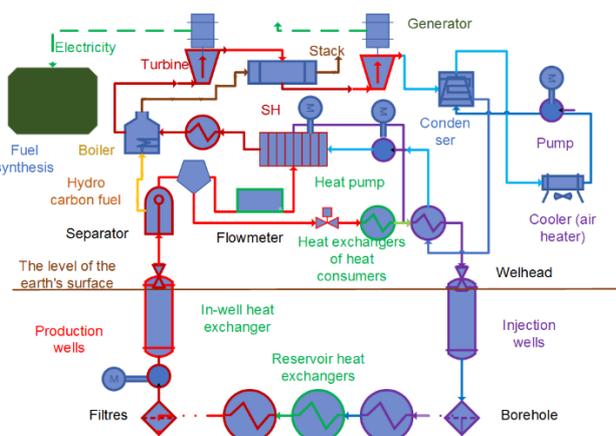
In Figure 2, which generally repeats the circuit solutions from [4], one heat pump is added, which



hybridized system is made with the traditional WGS without underground storage, which schematically includes a binary GeoPP and uses only formation water as a heat carrier.

#### 4.1.1 First stage of research

The developed unified technological scheme of modern WGS of open combined type with binary GeoPP is shown in Fig. 5. The first type of circuit-technological implementation is taken as a basis, with two series-connected turbines and one ORC circuit. For simplicity, the diagram does not show multistage turbines (shown in more detail in Fig. 2), multistage heat pumps (which can operate at the indicated positions of consumer heat exchangers, as shown in Fig. 3), heat recovery units with absorbent heat pump, but clearly three heat exchangers of municipal or technological heat consumers (marked on the diagram – heat exchangers of heat consumers).



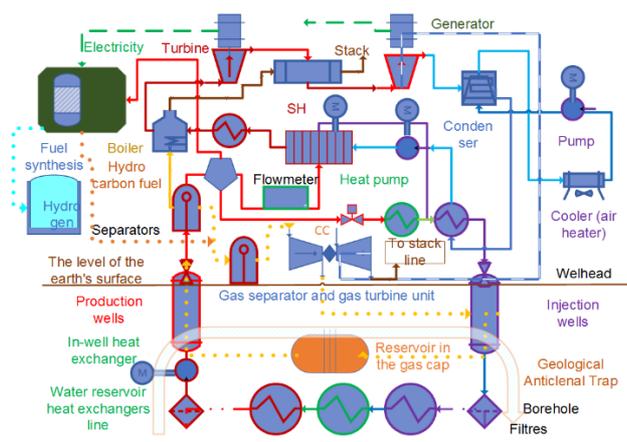
**Fig. 5.** Unified universal technological scheme of modern WGS of open combined type with binary GeoPP.

The diagram in Fig. 5 does not show (schematically not allocated for simplification) units of heat and electricity storage, as well as chillers – devices for cooling liquid coolant and supplying it by a pumping station through a system of pipelines to end users. In modern UGS and WGS systems, chillers are beginning to be widely used to regulate the main energy production and energy transformation processes and simultaneously equalize the uneven consumption of extracted/stored (taking into account the rate of extraction) heat and hydrocarbons.

Note that Fig. 5 is also, at first glance, not universal in the need to organize the thermodynamic cycle of Kalina in one of the circuits instead of the Rankine cycle. But according to [1], the Kalina cycle begins to be realized when only one gas-liquid separator and cogeneration heat exchanger are added inside the circuit. That is, the developed scheme (Fig. 5) is still unified but with a reduced set of technological components and unit, which in turn are implemented in terms of circuitry according to technical solutions [1, 4, 7, 8, 11, 12].

Scheme at Fig. 5 can be modified to a functional hybrid for simultaneous production and storage of natural gas in the gas cap of the reservoir of a partially depleted oil and gas field and extraction of geothermal energy with

conversion into synthesized gas (methane or hydrogen) through the groundwater line (Fig. 6).



**Fig. 6.** Unified technological scheme of hybrid WGS of open combined type with binary GeoPP and UGS of water-pressure / gas mode of cyclic operation.

#### 4.1.2 Second stage of research

The developed combined technological scheme of hybrid WGS can be realized under the condition of the available water pressure mode of development of oil and gas field or at artificial flooding and maintenance of pressure of a gas cap of an oil and gas deposit at technologically necessary level.

It is envisaged that wells, separators, as well as a line with a pump for the preparation and injection of separated formation water are used in combination. Electric generators and turbines, as well as other WGS units, also work to synthesize additional volumes of methane and fuel, which may be in high demand during the UGS filling season and peak consumption periods. Thus, for the use of a unified scheme for simultaneous storage of natural gas (methane), extraction of oil residues from the reservoir (flooding technology) and gas condensate (cycling process) added only two technological units: finishing preparation by gas separator and gas compressor with gas turbine drive (gas turbine unit – GTU).

The aircooling device (ACD) present in the classic UGS schemes does not make sense (absent) in the developed scheme because all excess heat is removed by the scheme for electricity generation and synthesis of artificial gases. In addition, when implementing the circuit-technological solution shown in Fig. 6, the geothermal field with UGS acquires a new economic meaning – it can add volumes of synthesized methane (other fuels by gas-to-liquids (GTL) and mini-refineries) or hydrogen. The scheme works smoothly during the gas injection season for storage or in the mode of regulating consumer demand for energy types at the place of their using.

At the end of the second stage of the study, one feature of the case was found – to obtain synthetic oil or LNG, you need to change the average carbon / hydrogen ratio in the hydrocarbon feedstock (mini-refinery by hydrocarbon-hydrogen conversion), and the necessary hydrogen is easiest to take from reservoir water. In this case, the combination of "water" geothermal energy and "hydrocarbon" energy production / storage according to the

hybrid scheme (Fig. 6) becomes even more profitable on a regional scale. To do this, the scheme (Fig. 6) shows the supply of prepared water to the methane (and others. fuel) synthesis unit .

According to the obtained circuit technical results, for the developed hybrid scheme the number of modules of the whole WGS decreased by four units: 1) separation module for mechanical impurities, water and oil; 2) GTU; 3) gas heating unit during reduction in the sampling/production mode; 4) ACD. To implement the storage of gas / energy resources and control the production of hydrocarbons / energy resources, we add only one gas separator. Minimization of modular units in capital construction and a corresponding reduction in the cost of the entire technical complex of WGS and increase its manufacturability are obvious.

#### 4.1.3 Third stage of research

When using cogeneration units that produce both electricity and heat, the efficiency can reach 60–80% (achievable efficiency at both ends “power–power”). This became possible with the implementation of reversible solid oxide fuel cells under pressure [13]. When converting in the scheme of Fig. 6 electricity–gas–heat / electricity (with a pressure of up to 50–80 atm. Under the standard main natural gas pipeline) work [14–17] more pragmatically announce the average efficiency of 43–68%. In the diagram in Fig. 6, one power energy unit is added – a turbine for pumping gas for its storage and maintaining the required level of pressure in the reservoir. The efficiency of gas–tube compressors averages 23–28% [19]. But important for the future of combined hydrocarbon–geothermal energy system may be the fact that turbines in GeoPP schemes are enough, they are also multi–stage. That is, in the technological scheme of the hybrid type the compressor is added only schematically, and mechanically it will rotate on the existing shafts. Let's analyze this circuit solution in more detail. The diagram in Fig. 2 separately shows a gas turbine unit running on methane (top left in the diagram), which is used to increase the efficiency of GeoPP in normal mode. Undoubtedly, in general, the WGS will have additional losses on the compression of hydrocarbons for injection to well (2–3% – fuel gas) of the GTU [19], but this is incomparably less than acquired. That is, for traditional incompatible operation in the GeoPP + UGS pair, the turbines will operate with double energy loss according to the efficiency, and during the operation of the unified developed scheme, the efficiency losses in the WGS will be reduced by an average of 23%. This ratio of energy losses is performed as accurately as possible in the conditions of the Proletarsky UGS (Dnipropetrovsk region, Ukraine), where the potential power of geothermal energy is close to the power in the hybrid circuitry involved GTU. Therefore, the current energy consumption of combined systems of extraction / storage of hydrocarbon–geothermal resources according to the developed hybrid scheme in comparison with similar volumes of individual (non–combined) extraction / storage of hydrocarbon and geothermal resources will be reduced by 20–45%. Since the ranges of energy consumption by technological units individually have significant differences according to data

from different sources, it is not possible to estimate the energy positive more accurately.

## 5 Conclusions

1. The developed unified scheme of combination of GeoPP and UGS on the basis of oil and gas partially-depleted deposit with residual water characteristics is characterized by the minimum number of additional technological units to GeoPP for realization of simultaneous extraction and storage of hydrocarbons and evacuation / transformation of geothermal energy.

2. For maximum efficiency of hybrid WGS of open combined type with binary GeoPP and UGS of water-pressure / gas mode of cyclic operation in the circuit solution it is important to use the synthesis gas unit and the compressor of gas injection into the gas cap of the oil and gas development object. Production of synthetic gasoline and LPG, and not only compressed natural gas (CNG) for local internal combustion engines is realized by schemes of mini–refineries and GTL–technology.

3. The forecast of reduction of current energy costs of combined systems of extraction / storage of hydrocarbon–geothermal resources in comparison with similar volumes of individual (not combined) extraction / storage of hydrocarbon and geothermal resources showed 20–45%.

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