Cogeneration scheme of using SER of gas-processing plant

UDC 662.99

A.I. Kompan

"Regional Natural gas Company" LLC

A.O. Redko

Doctor of Engineering Science of KHNUCA

S.B. Shelest

Kachanivskiy GPP

This article describes the thermal protection schemes application of the secondary resources to generate electricity, as well as the technological plan for energy disposal plant is given. The analyses of numerous research works in the sphere of thermodynamic effectiveness of power plant cycles with different working substances were presented. It is shown that the application of secondary resources provides a considerable volume of electricity for balance-of-plant needs.

Important problem of oil production industry is use of old powerful and economically deficient technologies which require modernization. Significant expenditures energy resources in operating plants doubly-trebly exceed foreign counterparts. As for today notable growth tendencies as for substantial consumption of energy by 2,5–3,0 %, heating energy by 8,5– 9,0 %, herewith use of utilized heating decreases by [1–6].

Analysis of activity related to increase of energy efficiency of gas-processing enterprises showed applicability and necessity of integrated problem solution. Technical solutions were substantiated as for creating the source of heating energy saving based on GTCC-TPP [6].

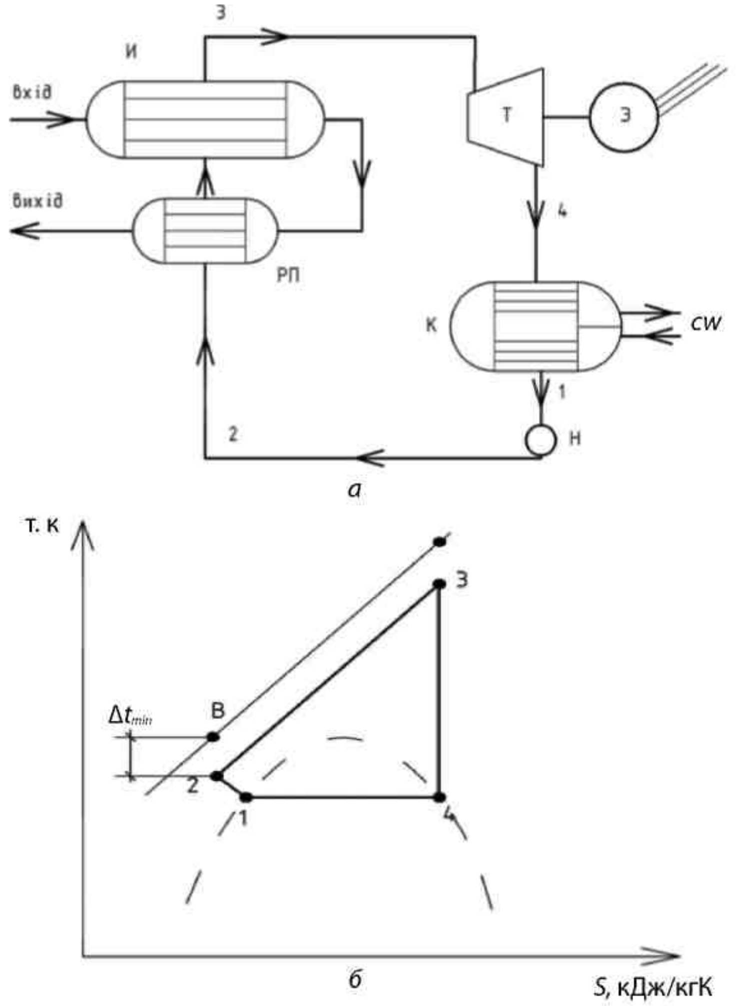
Setting up of system for energy and technological combination gives the possibility to produce technological and energy product within one production. Priority area for development of power utilities enterprises within oil and gas complex is a transition of closed-evaporation systems of energy supply.

Modern oil and gas production provides its needs in heating energy by 50 % in cost of own sources herewith delivery of electricity supply has been insufficiently processed. Temperature potential of high-temperature production areas of organic synthesis compiles for about 800 °C which admits the possibility of using gas-vapor technologies.

In oil and gas-processing plant technological equipments are used actually radioactive-convective furnaces for heating up the oil, natural gas and other liquids in oil-gas gathering systems. Thermal effectiveness of such furnaces is not high enough, thermal power efficiency compiles for about 0,5–0,6. Replacement of burners with more efficient ones gives the possibility to increase power efficiency of modern furnaces up to 0,7–0,8. However, the temperature of reject natural gases reaches about 400–500 °C and it gives the possibility to apply secondary energy resources (SER) for heating and energy supply of enterprises. The use of SER in the systems of heating supply is complicated by restriction of the heat power during the year. Other area of using SER is cogeneration production of heating and energy for own needs of enterprises.

The purpose of activity is increase of energy efficiency of carbon usage equipment for gas-processing enterprise through integration transformation of the heating of reject gases into energy.

Use of energy equipment with low-temperature cycle of Rankine (the Organic Rankine Cycle – ORC) provides deep cooling of combustion materials and steam condensation. Equipments are widespread in industry either new technologies for utilization of waste heat of difference processes. Power efficiency of energy utilization equipments compiles 0,13–0,17 and the number of power which is additionally produced compules for about 130–150 kW for MW of established heating power of carbon usage equipment which provides production and consumption of energy for own needs. Reconstruction of heating boiler stations in mini TPP with the use of gas-turbine or gas piston equipments provides production per 1 MW of established electric power of 1.5-2 MW heat. Herewith the expenses for electric consumption decrease, the reliability of heating supply systems increases including alarm station during network electricity supply. However there are problems in placement of gas-turbine additional structures in boiler facilities. In case of using other fuel (carbon, residual oil) application of vapor turbines or reciprocating engines is also possible for production of electricity but their power efficiency is significantly lower than in gas-turbine ones [6–13].



Pic. Heat balance of using the heat of reject gases *(a)* and the cycle of utilization energy facility *(b)*

In low-temperature ORC of different purposes (geothermal, cogeneration and utilization and others) different working substances are used – organic substance and ozone-safe refrigerants because selection of cycle working substance (given efficiency of heat exchanging facility, power efficiency of turbines and pump) in large measure defines efficiency of utilization facility in whole [7, 14–17].

New ozone-safe substances find an application – freons which don't contain chloride and bromine. Natural refrigerants are preferred (carbon dioxide (R 744), ammonia (R 717), carbohydrates –propane (R 290), isobutane (R 600a), pentan (R 601) and their mixtures). Efficient in cooling refrigerants are mixtures of carbohydrates with ammonia and dioxide of carbon [16].

The results of studies for precritical (Renkin cycle) and overcritical cycles are presented in the articles as for single-stage energy facilities. Working substances R 600, R 600a, R 601a, R

602, R 13в, R 134a, R 142в, R 143a, R 404a, R 407a, R 410a, R 503в, R 600a/R 161, R 600a/R 141, R 600a/R 601, NH_3/R 170, were studied as working heating agent as well as other organic substance and other mixtures.

Thermodynamic activity of cycles is defined by thermal power efficiency of cycles or coefficient of thermodynamic transformation (COP - Coefficient of Performance), as well as energy power efficiency (utilization coefficient). Thermal power efficiency (or COP) is defined in accordance with formula:

$$\eta_t = \frac{W_{кор}}{Q_{2\text{-}3}} = \frac{l_{3,4} - l_{1,2}}{Q_{2\text{-}3}}, \qquad (1)$$

where $W_{кор}$ is effective work of cycle; $l_{1,2}$ and $l_{3,}4$ are accordingly the work of adiabatic compression and enlargement in the pump and turbine in the recycle process; $Q_{2\text{-}}3$ is added heat.

Pressure build-up activity which is used by pump, equals:

$$l_{1,2} = m(i_2 - i_1) = m(i_{2s} - i_1)/\eta_н, \qquad (2)$$

where m is consumption of working substance; condition 2 and 2S respond to real process and isoentropy $\eta_н$ which is real power efficiency of pump.

Steam expansion in turbine is defined by formula:

$$l_{3,4} = m(i_3 - i_4) = \eta_T m(i_3 - i_{4s}), \qquad (3)$$

where η_T is a real power efficiency of turbine; condition of 4 and 4S respond to real and isotropic processes. Exergy power efficiency or utilization coefficient is defined as ratio of real working power of facility to maximum theoretical power which could be obtained from refrigeration of combustion products;

Table 1 Flue gases volumes depending on power of furnace

Indicator, m^3/hour	Heating power of furnace	
	12 kc/hour	14 kc/hour
Flue gases volumes upon normal conditions	19 762,0	23 016,9
Flue gases volumes upon t=300 C	43 287, 5	49 063,4
Flue gases volumes upon t=400 C	46 721, 8	52 955,9

Table 2 Powers produced in utilization facilities

Working substance	N_T, kW(kg/s)	ηc, %	m, kg/s
H_2O	17, 7 8	10,4	0,057
C_7H_{16} (heptane)	106,5	18,4	0,53
C_8H_{18} (octane)	109,6	18,9	0,54
$C_{10}H_{22}$ (decane)	114 ,7	19,4	0,59
C_7H_{16}(80 %)+H_2O(20 %)	138,9	24,3	0,38

$$\eta_e = \frac{W_{кор}}{m_{пр\ зг}\left[(i - i_0) - T_0(S - S_0)\right]}, \qquad (4)$$

where *mpr zg* is consumption of combustion products of heat generator; i, i_0, S, S_0 is accordingly entalpy and entropy of combustion products under temperature at the entrance of facility and under environment temperature; T0 is environment temperature.

Thermal power efficiency of cycle (or COP) is changed in short range 0,13–0,16 which insufficiently completely characterizes efficiency of cycles therefore more indicative criterion of the working substance selection is an activity obtained due to steam expansion in the turbine.

Calculations were made based on the following assumptions: temperature difference between combustion products and working substance Δt_{min}=3; 5 C; power efficiency of turbine – 0,7–0,8; power efficiency of pump 0,75–0,80; steam expansion process in the turbine is completed in the single-face area; steam condensation after turbine is carried out in air condenser; the atmosphere air temperature 15 C (288,15 K).

Due to the study and optimization of cycles by the number of working substance either in precritical or in overcritical cycles in the single-stage energy facility was established where maximum electricity production is provided in overcritical cycle.

As the source of SER preheater of stable condensate is considered in desorber K-230 within oil-absorption facility.

In Kachanivskiy GPP the furnace with heating power of 12,0 MW is under operation. Type of heaters is GBP; DLPBS (radiation) or ECO-FLAME, gas consumption - 40 m^3/ hour (burner); excess air ratio is 1,05; heating power of burner is 395 kW.

Consumption of fuel gas for furnace is 2640 m^3/ hour. Volume of combustion products (a_e=1,05) are 27 m^3/ hour; mass consumption of combustion products ($t_{пр}$=400 C) is 4 kg/s.

Measurement data of heating parameters of furnace show that the temperature of reject gases reaches about 400hours500 C and thermal power efficiency of furnace reaches about 0,45hour0,5 (modern ones up to 0,8).

Heating agent-absorbent with a temperature of 210 C falls within convectional section of furnace where heats up to 250 C and then to radiation camera where heats up to 310hour330 C.

As fuel of furnace P-201 fuel gas of high pressure is used, previously separated and heated.

The oxygen content in flue gases is defined with the help of gas analyzers A I72, A I73, portable TESTO-350. Consumption of fuel gas for furnace is 0,38–0,44 kg/s (1360c1584 kg/hour). Number of flue gases which depends upon operating mode of furnace and their temperature is presented in the table 1 (power efficiency 0,8).

Heat balance of cogeneration equipment includes additional placement of heat-exchange unit-evaporator in the gas pipe of furnace. Scheme of energy equipment for heat utilization is presented in the picture.

Meaning of energy equipment parameters is presented in the table 2.

Analyzing number of results we may see that the power which is produced in the turbine with vapor is less by several times than in the turbine with organic working substances.

Comparing different organic substances we may say that the production of specific electricity power in the turbine with decane compiles 114,7 kW/(kg/s). Herewith, mixture of C_7H_{16} (80 %)+H_2O (20 %) gives the possibility to increase specific electricity power up to 138,9 kW/(kg/s) actually by 17,2%.

Comparison results of specific difference of steam enthalpy in turbines with different working substances under t_h=347 C show that for heptanes turbine the specific difference of steam enthalpy compiles 208,6 kJ/kg and for heptane mixture (80 %)+H_2O (20 %) – 375,7 kJ/kg. In [7] the difference of enthalpy is presented in n-pentane turbine for about 200 kJ/kg under steam temperature of about 350 °C.

Therefore, the specificities of the working substance significantly impact the efficiency of energy facilities cycles.

The use of energy facility in utilization technological scheme of SER of the gas-processing plant under combustion products in the furnace by 6,7–7,7 kg/s (with increase of furnace power up to 11,9–14,7 kg/s) provides production of electricity in the volume of 904–1070 kW and more which may be used for own needs of enterprise (pumps drive, ventilators, compressor sets) and heat of water-cooled condenser in the volume (2,5–3) 10^3 MJ/hour which may be used in the heating system or in the hot water supply of the enterprise.

The results of numerous studies show the possibility of applying utilization energy units with organic working substance which use the heat of reject gases of fuel usage aggregates for production of electricity and heat.

References

1. **Лейтес Н.Л.** Теория и практика химической энерготехнологии / Н.Л. Лейтес, М.Х. Сосна, В.П. Семенов. – М.: Химия, 1998. – 280 с.

2.**Писаренко Б.И.** Использование вторичных энергоресурсов на НПЗ / Б.И. Писаренко. – МЦНИИТЭнефтехим, 1982. – 47 с.

3.**Лисицын Н.В.** Оптимизация нефтеперерабатывающего производства / Н.В. Лисицын. – СПб: Химиздат, 2003. – 184 с.

Конь М.Я. Нефтеперерабатывающая и нефтехимическая промышленность за рубежом / М.Я. Конь, Е.М. Зелькинд, В.Г. Шершун. - М.: Химия, 1996. - 184 с.

5. **Нормы** технологического проектирования газоперерабатывающих заводов. - РД 51-1-95.

6. **Долотовский И.В.** Энергетический комплекс газоперерабатывающих предприятий. Системный анализ, моделирование, нормирование / Е.А. Ларин, И.В. Долотовский, Н.В. Долотовская. - М.: Энергоатомиздат, 2008. - 440 с.

7. **Пятничко В.А.** Утилизация низкопотенциального тепла в энергетических установках с органическими теплоносителями / В.А. Пятничко // Экотехнологии и ресурсосбережение. - 2002. - № 5. - С. 10-14.

8. **Утилизационные** энергетические установки с органическими теплоносителями / Г.В. Шварц, СВ. Голубев, Б.П. Левыкин [и др.] // Газовая промышленность. - 2000. - № 6. - С. 14-18.

9. **Басок Б.И.** Анализ когенерационных установок. Ч. 1. Классификация и основные показатели / Б.И. Басок, Е.Г. Базеев, В.М. Диденко, Д.А. Коломейко // Промышленная теплотехника. -2006. - Т. 28. - № 3. - С. 83-89.

10.**Басок Б.И.** Анализ когенерационных установок Ч. 2. Анализ энергетической эффективности / Б.И. Басок, Д.А. Коломейко // Промышленная теплотехника. - 2006. - Т. 28. - № 4. - С. 79-83.

11.**Степаненко В.** Реконструкция промышленной энергетики Украины в 21 веке / В. Степаненко // ЭСКО. - 2005. - № 7.

12. **Долинский А.А.** Эффективность когенерационных тепловых схем / А.А. Долинский, Б.И. Басок, Д.А. Коломейко. - К.: ИТТФ, 2008. - Т. 61. - Вып. 4в. - С. 30-38.

13. **Барков В.М.** Когенераторные технологии: возможности и перспективы / В.М. Барков // ЭСКО - электронный журнал энергосервисной компании «Экологические системы». -2004. - № 7.

14. **DiPippo r.** Geotermal Power Plants: Principles, Application and Case Studies. - Oxford OX51GB, UK. - 2005. - 450 p.

15.**Алхасов А.Б.** Геотермальная энергетика: проблемы, ресурсы, технологии / А.Б. Алхасов. - М.: ФИЗМАТЛИТ, 2008. - 376 с.

16.**Редько А.А.** Методы повышения эффективности сис тем геотермального теплоснабжения. - Макеевка: ДонНАСА, 2010. - 302 с.

17. **Артеменко С.В.** Выбор рабочих тел для низкотемпературных циклов Ренкина на органических веществах. Ч. II. Фторированные эфиры / С.В. Артеменко, Д.Н. Никитин // Холодильна техніка і технологія. – 2010. – № 1 (9123). – С. 6–1

Contributors

Kompan Artem Igorevych

Ph.D. student of heat and gas supplying academic department, ventilation and use of the heating secondary energy resources of Kharkov National University of Construction and Architecture (KHNUCA). He has graduated from Yu. Kondratyuk Poltava National Technical University, the specialty – equipment of oil and gas industry. Scientific interests: accounting and rational use of the natural gas, energy saving in industry

Redko Andriy Oleksandrovych

Doctor of Engineering Science, professor of heat and gas supplying ventilation and use of heat secondary energy resources academic department of Kharkov National University of Construction and Architecture (KHNUCA). Scientific interests: low-potential power system, alternative energy sources, thermodynamics of energy transformation processes.

Shelest Serhiy Borysovych

Head of technical department of Kachanivskiy gas-processing plant of PJSC "Ukrnafta". He has graduated from Ukrainian correspondence polytechnic institute, the city of Kharkiv. By occupation he is mechanic engineer. Production interests are connected with energy saving.

NEWS

Argentina is going to mine oil and gas from non-traditional collectors

Shevron Company has signed an agreement with Argentinean company YPF as for investment of 1,24 billion USD dollars in exploration of slate oil and gas in the largest in the South America area of Vaca Muerta in Argentina. Therefore this country would like to grow extraction of oil and gas which during the long period of time keeps on decreasing.

At the initial phase the companies are going to bore 100 holes in the area of Loma La Lata Norte and Loma Campana with an area of 2 thousand ha. At the second stage it is planned to bore 1500 holes. Based on evaluations of American Energy Department the margin of gas in plates in Argentina mainly in the area of Vaca Muerta compile 21,9 trillion m^3 which is more than: in Europe in general.

Pipeline & Gas Journal/August 2013, p. 16