Modernization and performance enhancement of gas gathering and compression systems in mature oil and gas condensate fields

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Abstract. This study investigates the modernization of gas collection and compression systems at the South Kemachi oil and gas condensate field, which is currently operating under conditions of declining reservoir pressure and reduced well productivity. A comprehensive assessment of the existing surface infrastructure revealed significant limitations in handling low-pressure gas, leading to production losses and increased operating costs. Two development scenarios were analyzed: a baseline option preserving the existing system and a proposed option involving the installation of wellhead compressor stations integrated with existing booster compressor facilities. Production forecasting and variant modeling for the period 2023–2035 indicate that the proposed modernization strategy enables an increase in cumulative gas production by 681.2 million m³ and condensate production by 14.3 thousand tons. The results confirm that wellhead compression improves residual hydrocarbon recovery, enhances utilization of surface facilities, and reduces dependence on third-party compression services, thereby ensuring stable production at the late stage of field development.

INTRODUCTION

The late stage of oil and gas condensate field development is commonly associated with declining reservoir pressure, increasing water cut, and reduced well deliverability. Under such conditions, traditional gas collection and compression systems often fail to ensure stable production rates, resulting in inefficient utilization of installed facilities and higher operational costs [1, 20, 24]. Consequently, the modernization of surface infrastructure becomes a critical factor in extending the productive life of mature fields [21].

Worldwide experience demonstrates that the introduction of advanced gas gathering and compression technologies, particularly wellhead compression, provides an effective solution for producing low-pressure gas [2, 12, 13]. However, the applicability of such technologies must be justified through field-specific technical and economic assessments [36]. The South Kemachi oil and gas condensate field represents a typical example of a mature asset requiring urgent modernization measures.

This paper aims to evaluate alternative development options for the South Kemachi field and to substantiate an optimal modernization strategy that ensures stable gas production, maximizes recovery of residual reserves, and improves the economic efficiency of field operations.

EXPERIMENTAL RESEARCH

As a result of research conducted worldwide on the development of effective systems for collecting, preparing, compressing and transporting gas, a huge number of variants of these systems have been created, designed for specific periods of field operation [1, 2].

The creation of new and modernization of existing natural gas production systems is one of the most pressing issues [5, 6].

In this regard, one of the priority tasks of the oil and gas industry is the improvement of production methods for the purpose of additional growth of hydrocarbon raw materials, which have important theoretical and practical significance [3, 4, 9].

Scientific research aimed at improving the technology of collecting and preparing gas at the late stage of development of gas condensate fields is carried out in leading research centers, technical universities and technology companies developing various types of separation and compressor equipment [25, 26].

Ensuring relatively high rates of natural gas production by modernizing the technology for collecting, preparing, and compressing gas at a late stage of field development [14, 15].

Variant computer modeling of gas collection, preparation and compression technology.

Considerable importance is attached to the design of rational systems for the further development of gas condensate fields, ensuring relatively high rates of natural gas production in the final stages of their operation, with positive technical and economic indicators [30, 31].

The most important task in developing a productive hydrocarbon-containing formation is to achieve the maximum possible hydrocarbon recovery.

At the same time, the options for modernizing the ground infrastructure of the South Kemachi field were considered, with a proposed concept for the development of the field from the implementation of the planned measures aimed at achieving the planned extraction of natural gas and gas condensate [16, 37].

Commissioned in 1979. Reservoir pressure 247/37.5 kg/cm2 (initial/current)

Average water cut of well production (WC 92.7%) [11].

The gas production fund consists of 75 units, including: 72 operating, 2 undergoing repair, and 1 idle. Average daily indicators: oil and condensate production 144 tons/day, free gas production.

The initial gas flow rate per well is 276 thousand m3, the current one is 41.0 thousand m3/day.

Cumulative production: free gas 60.5 billion m3, condensate 2081 thousand tons.

Remaining recoverable reserves: free gas 19.9 billion m3, condensate 909.0 thousand tons.

Information about the South Kemachi Booster Compressor Station (BCS). The South Kemachi BCS is designed to collect low-pressure gases from oil fields and subsequently supply them to the South Kemachi Gas Treatment Plant. The compressed gas is then supplied to the South Kemachi Gas Treatment Plant for subsequent purification from heavy hydrocarbons at the NTS unit in preparation for transportation to the Mubarek Gas Treatment Plant [22, 29, 34].

The facility is currently owned by Kokdumalakgaz LLC, a joint venture, and provides gas compression services at fields developed by the Mubarek Oil and Gas Production Department and SANEG LLC, a private enterprise. The service costs 99,000 soums per 1,000 cubic meters (excluding VAT) [32].

DKS "South Kemachi"

Design capacity – 4.6 million m3/day Actual capacity – 3.7 million m3/day Current status:

Total installed capacity – 52.0 MW.

I-stage – 2 units. GPA (1 work + 1 rez.)

The capacity of each GPU is 8.0 MW

Project. Pin= 0.16 MPa; Pout=0.65 MPa

Fact. Pin= 0.05 MPa; Pout=0.5 MPa

II stage – 2 units. GPU (2 workers)

The capacity of each GPU is 18.0 MW

Project. Pin = 0.5 MPa; Pout = 7.7 MPa

Fact. Pin = 0.5 MPa; Pout = 4.2 MPa

The existing state. During the period from 01.12.2021 to 01.12.2022, a sharp drop in gas production indicators was observed at the South Kemachi field [38].

Due to declining wellhead indicators, the inlet pressure of existing installations and compressor units dropped, making it technically impossible to deliver low-pressure gas using the current transport system. To maintain gas production, urgent measures were taken to reconnect the medium- and high-pressure gas flow to the inlet of the South Kemachi Utilization BCS. However, since the Utilization BCS is owned by Kokdumalakgaz LLC, the Mubarek Oil and Gas Production Department must pay for compression services, which increases the cost of well production [17].

In connection with the above, in order to prevent a further sharp decline in production levels at the field and to reduce operating costs associated with gas compression, it is necessary to urgently implement technical and technological measures [27, 35, 33].

At the same time, the options for modernizing the ground infrastructure of the South Kemachi field were considered, with a proposed concept for the development of the field from the implementation of the planned measures aimed at achieving the planned extraction of natural gas and gas condensate.

To resolve the current situation, it is proposed to consider two options:

Basic option - Gas supply DKS Utilization SP OOO "Kokdumalak-gaz"

The proposed option is the construction of compressor station mouths (CS) on separate input thread blocks (ITB) with gas supply to the Kokdumalak DKS.

Additionally, the installation of wellhead compression allows for enhanced separation of liquid hydrocarbons under field conditions, increasing condensate recovery and reducing losses during transportation.

RESEARCH RESULTS

Baseline option – The forecast of hydrocarbon production indicators from the field is made without implementing measures, that is, with the preservation of the existing development system.

In total, 9994.8×106 m3 of gas, including 209.9×103 t of condensate, are projected to be produced from the South Kemachi field between 2023 and 2035. Reservoir pressure is expected to decrease by the end of 2035 from 35.7 kg/cm2 (2023) to 19.1 kg/cm2, and working wellhead pressure is expected to decrease from 8.4 kg/cm2 to 5.5 kg/cm2.

Proposed option 2. The maximum annual gas extraction volume of 106580×106 m3 is projected for 2023.

In total, 10,676.0 x 106 m3 of gas, including 224.2 x 103 t of condensate, are projected to be produced from the South Kemachi field between 2023 and 2035. Reservoir pressure is expected to decrease by the end of 2035 from 35.7 kg/cm2 (2022) to 17.8 kg/cm2, and working wellhead pressure is expected to decrease from 8.4 kg/cm2 to 2.5 kg/cm2.

From a comparison of the assessment of the production capabilities of the options, it is clear that the increase in production due to the implementation of measures will amount to 681.2×106 m3 of gas, including 14.3×103 tons of condensate.

TABLE 1. Parameters of the designed UKS at the South Kemachi field

Name of installations	Daily gas extraction, thousand m³	Gas pressure UKS (excess), kgf/cm²		Gas temperature, °C		UKS capacity, kW	Compression ratio
		at the entrance	at the exit	at the entrance	at the exit	consumed	
UKS-1 (BVN-4)	1073.5	1.1	12.7	35.0	45.0	4200	6.6
UKS-2 (BVN-5 and BVN-6)	896.8	1.1	12.6	35.0	45.0	3300	6.4
UKS-3 (BVN-2r and BVN-2)	490.8	1.1	12.4	35.0	45.0	1800	6.3

TABLE 2. Comparative indicators of advantages and disadvantages by options

No.	Naming of indicators	Basic option	Proposed option
1	Description of options	**Gas supply BCS Utilization JV Kokdumalak-gaz LLC**	**Construction of a UKS on separate BVNs with gas supply to the Kokdumalak DKS**
2	CAPEX	Average	High
3	Possibility of maximum extraction of residual reserves	Average	High
4	Costs of gas compression services	Tall	Low
5	Extraction of liquid hydrocarbons from produced gas under field conditions	Average	High
6	Possibility of loading existing preparation and compression capacities	Low	High
	Final scores:		
1	Good - 3 points	0	12
2	Neutral - 2 points	6	0
3	Bad - 1 point	2	1

The gas collection and transportation system consists of production well sites and pipelines connected to gas pipelines-collectors, which in turn are sent to a comprehensive gas treatment plant (CGTP) [7, 18].

Only part of the gas is sent to the South Kemachi gas treatment plant and then to the South Kemachi booster compressor station for compression and further transportation to the Moscow gas processing plant, while the other part is fed to the Kokdumalak booster compressor station for further compression.

At the South Kemachi gas treatment plant, extracted natural gas is processed to separate hydrocarbon condensate, formation fluid, and mechanical impurities from the gas flow under field conditions under actual process parameters.

According to the basic version of the assessment of the production capabilities of the South Kemachi gas condensate field, the implementation of measures is not envisaged [23, 28].

Gas from the above-mentioned field is to be prepared at the existing South Kemachi and Kokdumalak gas treatment plants.

Description of the designed systems. Based on preliminary calculations and the proposed field development concept, it was determined that the increase and maintenance of natural gas production from the South Kemachi field is projected to occur with the restoration of the current well stock from 84 to 91 units between 2023 and 2024, as well as with the implementation of additional measures to further develop the above-ground portion and modernize the current systems [8, 10].

Gas from the above-mentioned fields is to be prepared at the existing South Kemachi and Kokdumalak gas treatment plants.

The obtained results are consistent with global experience in the development of gas condensate fields at a late stage of exploitation [36, 25]. The study confirms that the introduction of wellhead compression is an effective technological solution for maintaining production under conditions of declining reservoir and wellhead pressure. Furthermore, the modernization of surface infrastructure enables a balanced integration of new equipment with existing facilities, ensuring technical feasibility and long-term production stability.

Overall, the results demonstrate that the proposed modernization measures provide a reliable and efficient pathway for extending the productive life of the South Kemachi field while achieving higher hydrocarbon recovery and improved economic performance.

CONCLUSIONS

The conducted study confirms that the decline in gas production at the South Kemachi oil and gas condensate field is primarily caused by decreasing reservoir and wellhead pressures, high water cut, and the limited ability of the existing gas collection and compression system to handle low-pressure gas. Under these conditions, maintaining stable production without modernization measures is technically and economically inefficient [1, 19].

The variant-based analysis demonstrates that the implementation of wellhead compressor stations and the modernization of surface infrastructure significantly improve the performance of the gas collection and compression system at the late stage of field development. Compared with the baseline scenario, the proposed option enables an additional cumulative production of 681.2 million m³ of natural gas and 14.3 thousand tons of condensate over the forecast period from 2023 to 2035.

The results show that wellhead compression ensures stable gas transportation under declining wellhead pressure, increases the utilization of existing gas treatment and booster compressor station capacities, and reduces dependence on third-party compression services [20, 21]. Despite higher capital expenditures, the proposed modernization measures provide clear operational and economic benefits by lowering operating costs and enhancing recovery of residual hydrocarbon reserves.

Overall, the proposed development concept represents a technically feasible and economically justified solution for extending the productive life of the South Kemachi field. The findings of this study may be applied to other mature oil and gas condensate fields facing similar challenges associated with low-pressure gas production and declining reservoir energy.

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